TCRP

SYNTHESIS 50

TRANSIT
COOPERATIVE
RESEARCH
PROGRAM

Sponsored by
the Federal
Transit Administration

Use of Rear-Facing Position for Common Wheelchairs on Transit Buses

A Synthesis of Transit Practice

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SUBJECT AREAS

Public Transit

Research Sponsored by the Federal Transit Administration in Cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

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TRANSIT COOPERATIVE RESEARCH PROGRAM

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

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

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB), and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

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

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FOREWORD

By Staff
Transportation
Research Board

Transit administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the transit industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire transit community, the Transit Cooperative Research Program Oversight and Project Selection (TOPS) Committee authorized the Transportation Research Board to undertake a continuing study. This study, TCRP Project J-7, "Synthesis of Information Related to Transit Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute a TCRP report series, *Synthesis of Transit Practice*.

The synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

This synthesis will be of interest to transit agency staff and those who work with them in dealing with common wheelchair securement on transit buses. It offers information on existing programs in many countries and documents transit agency experiences for the benefit of others considering similar deployments, in particular with respect to the Americans with Disability Act (ADA) and to its use in U.S. Bus Rapid Transit (BRT) systems. The report describes the state of the practice with respect to the use of rear-facing position for accommodating "common wheelchairs" (as defined by the ADA) on large transit buses (more than 30,000 lb) and identifies pertinent issues related to its transferability to the U.S. context.

This report from the Transportation Research Board integrates the information obtained from a literature review, gathered from many sources and countries. Agency surveys of all Canadian transit systems that have adopted the rear-facing position, case studies, and interviews with key experts in several other countries (the United Kingdom, France, Germany, and Sweden, as well as communications with Australian experts) were conducted to obtain information and to offer better insights. Case studies were conducted at British Columbia Rapid Transit (BC Transit), Victoria, BC, Canada, and Mississauga Transit, Mississauga, Ontario, Canada. Additionally, extensive discussions were held with Alameda–Contra Costa Transit (AC Transit) staff, Oakland, California—the first U.S. transit agency to design a rear-facing position in their 2002 order of transit buses to be used in a planned BRT deployment.

A panel of experts in the subject area guided the work of organizing and evaluating the collected data and reviewed the final synthesis report. A consultant was engaged to collect and synthesize the information and to write the report. Both the consultant and the members of the oversight panel are acknowledged on the title page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

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Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting Joseph A. Calabrese, Chief Executive Officer, Greater Cleveland Regional Transportation Authority; Dennis Cannon, Trans/Accessibility Specialist, U.S. Access Board; Kimberly Fisher, Senior Program Officer, Transportation Research Board; Katherine Hunter-Zaworski, Civil, Construction, and Environmental Engineering Department, Oregon State University; Allan Little, Transolutions Consulting, Victoria, British Columbia; Jerry L. Trotter, Senior Project Manager, Bus Programs, American Public Transportation Association; Terrance Turner, ADAPT, Denver; Richard Wong, Attorney–Advisor, Office of the Chief Council, Federal Transit Administration; and Park Woodworth, Manager, Paratransit/Rideshare Operations, King County Metro Transit.

This study was managed by Donna L. Vlasak, Senior Program Officer, who worked with the consultant, the Topic Panel, and the J-7 project committee in the development and review of the report. Assistance in project scope development was provided by Stephen F. Maher, P.E., and Jon Williams, Managers, Synthesis Studies and Amelia Mathis. Don Tippman was responsible for editing and production. Cheryl Keith assisted in meeting logistics and distribution of the questionnaire and draft reports.

Christopher W. Jenks, Manager, Transit Cooperative Research Program, assisted TCRP staff in project review.

Information on current practice was provided by many transit agencies. Their cooperation and assistance was most helpful.

USE OF REAR-FACING POSITION FOR COMMON WHEELCHAIRS ON TRANSIT BUSES

SUMMARY

The Americans with Disabilities Act (ADA) of 1990 introduced a new era for enhancing the lives of persons with disabilities, in particular by facilitating improved integration and access to facilities and services, including public transportation. To enact provisions mandated by the ADA, the Architectural and Transportation Barrier Compliance Board has issued guidelines, which have been implemented through U.S.DOT regulations. One of the issues covered by these guidelines and regulations concerns the securement of wheelchairs on board transit buses.

The ADA securement standard was developed based on experience with smaller vehicles (e.g., van conversions) and school buses, and has resulted in a complex system typically involving four separate securement straps plus occupant restraint belts. Although secure in design when properly used, this system has raised a number of practical challenges for transit systems, as well as for wheelchair users on board transit buses.

- Assistance is required to secure the wheelchair and, if requested, to fasten the occupant restraint. The wheelchair passenger is the only passenger who may be wearing a seat or shoulder belt.
- Operator–passenger physical contact is also a sensitive issue, which can result in discomfort for both parties and that is sometimes perceived as a degrading experience by wheelchair passengers.
- The system is not readily adaptable to the wide range of wheelchairs in use, in particular scooters. Extra straps are required, thus increasing the complexity of the securement process, and a growing number of wheelchairs cannot be accommodated at all because of the lack of designated attachment points and/or risk of damage to the mobility aid.
- The straps are difficult to keep clean and properly store; they can soil clothes and, in some cases, cannot be found for use, thus decreasing the integrity of the system. Because they hang loose, the straps can also be a hazard to other passengers.
- Securing a wheelchair is time consuming, disrupting schedules and sometimes causing embarrassment to the wheelchair passenger because the other passengers must wait.
- Securement is often physically demanding for the bus operator and can involve the risk of employee injury.
- Finally, in conventional transit systems, the infrequent use of strap systems and the wide range of wheelchair designs may result in incorrect securement practices. Safety could be compromised if the securement system is not actually, or is improperly, used.

To address some of these challenges, efforts have been undertaken over the last decade to develop universal securement systems. These designs, however, sometimes introduce new concerns. Therefore, solutions remain generally elusive given the number of wheelchair design types and stakeholders, the diversity of interests, the lack of standards for wheelchairs and docking securement systems, and the need to modify the wheelchairs or scooters to adapt to the securement systems.

An alternative approach, using a rear-facing position, was initially deployed in Germany and the United Kingdom in the early 1990s, and now has been widely deployed across Europe, in several transit systems in Canada, and most recently in Australia. The rear-facing position concept enables persons using mobility aids to position themselves independently within an accessible urban transit bus, with their back and head near a load-bearing panel. This approach uses the vehicle's mass and operating dynamics to protect passengers who use wheelchairs in cases of severe braking or collisions. It provides independence to the wheelchair passenger, adapts to most wheelchair and scooter sizes and types, does not generally require the assistance of the operator, and requires shorter dwell times.

The objective of this synthesis of transit practice is therefore to survey current practice with respect to the use of the rear-facing position for wheelchairs on transit buses and to identify pertinent issues related to its transferability to the U.S. context, in particular with respect to the ADA and to its use in Bus Rapid Transit systems. The synthesis includes a review of literature from many sources and countries, a survey of each of the Canadian transit systems that have adopted the rear-facing system, case studies, and interviews with experts in several countries.

The synthesis found that during the last decade, the rear-facing approach to accommodating wheelchairs on large transit buses has progressed from its use in a few leader transit systems to widespread adoption by an ever-growing number of transit systems around the world, including Germany, the United Kingdom, France, Poland, Austria, Spain, the Czech Republic, Sweden, Belgium, Canada, and Australia. Such adoption is being accompanied, or in some cases spurred on, by the inclusion and definition of this approach in legislation, regulations, and standards.

The following design elements have been observed among Canadian and European transit systems that have adopted the rear-facing position:

- An accessible path from the service door to the wheelchair position;
- For rear-facing positions accessed through the front door, enough floor space to allow for backing into the position and doing a 180˚ turn when exiting (including floor space under seats overlapping the mobility aid's maneuvering space);
- For rear-facing positions accessed through mid doors, enough floor space to allow for turning 90˚ and backing into the position, and then doing a 90˚ turn when exiting (including floor space under seats overlapping the mobility aid's maneuvering space);
- A designated floor space (although dimensions vary);
- A load-bearing back panel that allows the passenger's back to be near the back panel, which requires that wheelchair wheels and handlebars be able to straddle the backrest (although dimensions and design characteristics with respect to deceleration forces vary);
- A vertical aisle stanchion, wall-mounted lateral straps, or other means to prevent the wheelchair scooter from sliding or tipping into the aisle;
- A horizontal handrail along the bus wall;
- A stop request button with a separate signal displayed at the operator's workstation;
- A visual stop display that can be seen by the wheelchair passenger; and
- A process for consulting with users, through advisory committee or focus groups, before adoption of this approach.

These consultations have helped to identify a number of benefits derived from the rear-facing position, as expressed by transit systems using this approach. Benefits for the wheelchair passenger include:

- Independent and dignified use of the system, without, for most wheelchair passengers, the need for assistance by others;
- Faster boarding and alighting;
- Reduced need for physical contact with other persons;
- Adaptation to the most commonly used wheelchairs and scooters, and even some less common types of wheelchairs, without the need for attachment points; and
- Less damage to the mobility aid from the securement system.

Benefits for the transit system include

- Reduced dwell times at stops;
- No or limited involvement of bus operators and, correspondingly, a lesser likelihood that bus operators will be injured or be placed in awkward working positions; and
- Reduced maintenance costs.

A preliminary review of ADA requirements indicates that the rear-facing position can be used by U.S. transit systems, provided that certain conditions are met. However, further study should be conducted concerning the specific system design based on transit system experience and accounting for future research concerning dynamic forces, appropriate design requirements, and effective system designs.

The identified benefits associated with the rear-facing position clearly make this approach particularly attractive to transit systems implementing Bus Rapid Transit systems, given their requirements for short dwell times; high-frequency, large-capacity vehicles operating in tight corridors; and expectations of high levels of service reliability.

CHAPTER ONE

INTRODUCTION

BACKGROUND

The Americans with Disabilities Act (ADA) of 1990 ushered in a new era for enhancing the lives of persons with disabilities, in particular by facilitating improved integration and access to facilities and services, including public transportation. To enact provisions mandated by the ADA, the Architectural and Transportation Barrier Compliance Board has issued guidelines, which have been implemented through U.S.DOT regulations (*1*). One of the provisions covered by these guidelines and regulations concerns the securement of wheelchairs on board transit buses.

The ADA securement standard was developed based on experience with smaller vehicles (e.g., van conversions) and school buses, and has resulted in a complex system involving typically four separate securement straps plus occupant restraint belts. Although secure in design when properly used, this system has raised a number of challenges for transit systems, as well as for wheelchair passengers riding transit buses, including the need for assistance; adaptability to the wide variety of wheelchairs in use; the demands, both in time and physically, on the operator; and safety issues involving either improper use or the total lack of securement (*2*,*3*).

During the last decade, efforts have been undertaken to address some of the challenges encountered when developing universal securement systems (*4–6*). However, these designs can introduce new concerns; therefore, solutions remain largely elusive given the number of wheelchair design types and stakeholders, the diversity of interests, the lack of standards for wheelchairs and docking securement systems (*7*), and the need to modify the wheelchairs or scooters to adapt to these systems.

An alternative approach, using a rear-facing position, was initially deployed in the early 1990s in Germany and the United Kingdom. It is currently widely deployed across Europe, in several transit systems in Canada, and most recently in Australia. The rear-facing approach enables persons using mobility aids to independently position themselves within an accessible urban transit bus, with their back and head near a load-bearing panel. This approach uses the vehicle's mass and operating dynamics to protect passengers who use wheelchairs in instances of severe braking or collisions. In addition, it provides a high degree of independence to the wheelchair passenger, adapts to most wheelchair and scooter sizes and types, does not generally require the assistance of the operator, and requires shorter dwell times.

In the United States, a rear-facing position for wheelchairs had not until recently been deployed in any transit bus, as a result of the historical development in bus designs and past interpretations of the ADA, although rear-facing positions are common in rail transit. The ADA does allow a rear-facing position for wheelchairs on buses under certain conditions [see Title 49 of the Code of Federal Regulation (CFR), Part 38.23, "Mobility and Accessibility"], although this is not in current practice on buses, nor widely recognized.

The need to address the issues raised by current wheelchair securement practice in transit buses has become all the more important as a result of the widespread development of Bus Rapid Transit (BRT) systems in a number of regions in the United States. The FTA has been actively encouraging transit systems to consider implementation of BRT systems as an alternative to light rail. However, BRT systems involve high-frequency, large-capacity vehicles operating in tight corridors; expectations of high levels of service reliability; and short dwell times. Current securement practice using the complex four-strap system is likely to be a source of disruption to BRT systems. In a recent survey of transit systems in Florida about wheelchair securement issues (*2*), 56% of respondents indicated that securement of wheelchairs requires more than 3 min. The rear-facing position may offer an attractive alternative that may be well suited for BRT systems.

The objectives of this synthesis were to

- Survey current practice with respect to the use of the rear-facing position for wheelchairs on transit buses and
- Identify pertinent issues related to the transferability to the U.S. context, particularly with respect to the ADA and to its use in BRT systems.

SCOPE

This study synthesizes experience and research related to the use of the rear-facing position for accommodating "common wheelchairs" on urban transit buses that are more than 13 636 kg (30,000 lb) GVWR (gross vehicle weight rating).

- The limitation to buses of more than 13 636 kg (30,000 lb) GVWR corresponds to the distinction made in the ADA (49 CFR Part 38). This scope encompasses most buses that are 18 m (60 ft), 12 m (40 ft), 10.8 m (35 ft), and 9 m (30 ft) in length, where the rear-facing position has been primarily used.
- Under the ADA, a common wheelchair is defined as a mobility aid belonging to any class of three- or four-wheeled devices, usable indoors, designed for and used by persons with mobility impairments, which do not exceed 0.75 m (30 in.) in width and 1.2 m (48 in.) in length, measured (2 in.) above the ground, and which do not weigh more than 270 kg (600 lb) when occupied.

APPROACH

The approach used for this synthesis includes the following elements:

- Literature review—A search was undertaken for pertinent literature in the form of research, reports, and legislation in Europe, Australia, Canada, and the United States.
- Survey—A survey questionnaire was developed and distributed to Canadian transit operators that use the rear-facing approach. The questionnaire was translated into French for the benefit of those transit systems in Québec (see Appendix A). The survey explored various aspects of transit experience including rear-facing system design planning, operations, customer acceptance, and safety.
- Supplier contacts—Discussions were held with the three Canadian bus manufacturers whose vehicles have been used to deploy the rear-facing position, as well as with a seat supplier that now provides a kit for a rear-facing position. These discussions sought the manufacturers' perspectives on this design and the issues it raises.
- Case studies—Case studies, based on on-site visits, were conducted at BC Transit in Victoria, British Columbia, and at Mississauga Transit in Mississauga, Ontario. In addition, extensive discussions were conducted with AC Transit in Oakland, California, the first U.S. transit system to design a rear-facing position in its 2002 order of transit buses to be used in a planned BRT deployment.
- Expert contacts—In addition, interviews were conducted with key experts in the United Kingdom, France, Germany, and Sweden, and communication was undertaken with Australian experts. Those experts represent a range of perspectives: transit systems, transit system associations, wheelchair user groups, government agencies, and research organizations. The contacts have been extremely useful toward gaining a better insight into the experience, legislative framework, and issues related to the rear-facing approach.

As a whole, these activities have helped to provide a broad picture of the experience and issues related to the rear-facing design in large transit buses. The report contains four additional chapters and two appendixes. Chapter two describes the rear-facing position design and discusses the important steps that have led to its development and deployment, first in Europe, and then in Canada. Chapter three describes current practice based on the results of a survey of Canadian transit systems, a presentation of some important new developments, and a review of regulations and standards. Chapter four synthesizes key aspects of the experience with the rear-facing position and discusses a number of the issues identified. Chapter five presents the conclusions of the study. Appendix A contains the survey forms (in English and French) and Appendix B a list of the contacts.

CHAPTER TWO

REAR-FACING POSITION: DESCRIPTION, DEPLOYMENT, AND RESEARCH IN EUROPE AND CANADA

REAR-FACING SYSTEM DESCRIPTION

As it has been deployed in European (Figure 1) and Canadian transit systems, the rear-facing position consists of a minimum rectangular clear floor space, typically 0.75 m (30 in.) in width and 1.3 m (52 in.) in length, with the long dimension along the longitudinal axis of the bus. A padded head and back panel facing the rear is located at the front end of the space, anchored to the bus floor or wall, or both. This panel is centered within the 0.75 m (30 in.) width and is narrow enough to allow the large wheels of a wheelchair to pass on each side, thus bringing the back of the wheelchair passenger as close as possible to the padded backrest or headrest. The primary feature of this system, in which the passenger faces the rear of the bus, is to have the back panel, against which the passenger's back rests, absorb the forces in a deceleration.

Once on board the transit bus, the wheelchair passenger positions his or her wheelchair or scooter with the back as close as possible against the padded back or head panel, facing the rear of the bus. A pictogram in that location, plus explanatory text, should indicate that facing to the rear is provided. The brakes are then applied for manual wheelchairs. In the case of power chairs and scooters, the power is turned off, which automatically applies the brakes. Application of the brakes will prevent movement of the mobility aid toward the rear during acceleration and on steep inclines uphill.

To prevent tipping or movement of the wheelchair/scooter into the aisle, a fixed-aisle stanchion, a foldable armrest, or other means are used (Figures 1–3). There are generally no straps or hooks that must be attached to the mobility aid for securement, although some agencies have installed such mechanisms. There is a horizontal handrail along the bus wall below the windows for holding onto, which can be used by those passengers with good upper body strength (Figure 2).

To enable the passenger to make a stop request, a separate call button is positioned within easy reach. It is operated by pushing with the hand, elbow, or arm. The stop request signal at the operator's station, from this call button, should have a different audible sound than the stop request signal provided for the general public, thus alerting the operator that the wheelchair passenger wants to exit. Such an alert is important, because the operator needs to advise boarding passengers and apply the ramp first.

FIGURE 1 Transport for London rear-facing position with back panel and aisle stanchion.

FIGURE 2 BC Transit rear-facing position with handrail and separate stop request button (located on wall below handrail).

FIGURE 3 Rear-facing position with movable armrest (shown in up position). Instead of stanchion, there is a handrail on the wall and a separate stop request button (located below the handrail).

Flip seats can be positioned in the wheelchair area as long as their dimensions do not interfere with the clear space required for the wheelchair (Figures 4–7). A sign in that area indicates that the seats must be vacated if a passenger in a wheelchair or scooter needs to occupy the space.

FIGURE 4 Montreal (Société de Transport de Montréal) rear-facing position adjacent to rear door, with stanchion to prevent tipping, designated priority markings on floor, and flip-up bench seating.

Priority seats for seniors and other disabled passengers are preferably not designated in the wheelchair location, because doing so can lead to conflicts.

The location of rear-facing positions varies depending on the bus design. They are typically located immediately behind the front wheel wells for bus models with wheelchair access through the front door, or toward the middle section of the bus for bus models accessible through the middle or rear door.

FIGURE 5 Paris (RATP) rear-facing position with flip-down seat built into back panel.

FIGURE 6 BC Transit rear-facing position with flip-down seats on bus wall and back panel.

FIGURE 7 Ottawa (OC Transpo) rear-facing positions with stanchion and separate stop request button located under flip-up bench (in middle of bench underside).

REAR-FACING POSITION IN EUROPE—DEPLOYMENT AND RESEARCH

Low-floor buses were introduced in Europe in the late 1980s with several objectives: to make access and egress for all passengers easier, faster, and safer to reduce dwell times, to decrease injuries to an aging passenger population from tripping or falling over steps, and to provide easier access for persons with strollers. Wheelchair accessibility was not the original motivation for deployment of low-floor buses (*8,9*). Originally, only the areas near the service doors were low floor; the rest of the bus could only be accessed over steps or ramped floors. As bus technology improved, "low-floor throughout" has become common as well. To avoid seat loss, some bus models have positioned some rear-facing seats over the wheel wells, although they may require one or two steps to get in and out of them.

Having improved the mobility for seniors and persons with mobility limitations by introducing low-floor buses, Europe turned its attention to the task of addressing the access for persons using wheelchairs. An answer was sought that would combine a place that would meet the needs of persons with strollers, with the needs of persons using wheelchairs. Across Europe, the use of urban buses by persons with strollers is greater than the use by persons in wheelchairs.

A total systems approach was pursued through a variety of research and demonstration efforts (*10*). In addition to improving bus design by reducing the height of the bus floor level and introducing the bus kneeling feature, efforts also explored improved stop design by raising curb height and reducing horizontal gaps through bus docking systems, both manual and electronic. Telescopic and flip ramps were developed for use either at the front or center door of the bus to overcome any remaining vertical and horizontal gaps (Figures 8 and 9).

FIGURE 8 Access over ramp at center door (United Kingdom).

FIGURE 9 Access over ramp at front door (Germany).

The remaining task in providing accessible transportation by bus was to answer the question of whether the safe transport of wheelchair passengers required special measures in transit buses, and what would be necessary to secure or restrain wheelchair passengers. One specific aspect was the choice between forward and rear-facing options for positioning the wheelchair within the bus.

Historically, the use of a designated "compartment" in Europe goes back to the 1930s. The subway system (S-Bahn and U-Bahn) in Berlin, Germany, introduced a "Mother and Child" section on each train, consisting of a large space with a central open area and seats along the walls facing the center. This arrangement accommodated several mothers with their strollers or those with young children and luggage. There were vertical stanchions in the center of the area, as well as near the seats, for the traveler(s) to hold onto. This design remains in use today.

In addition, it should be noted that rear-facing seats have traditionally been used in the design of urban buses, trams, subway systems, and intercity trains in Europe. The notion of rear-facing seating does not therefore have an image problem in Europe. That is contrary to the situation in North America, where bus designs have traditionally been based on all forward-facing seating, although heavy- and light-rail cars frequently have half of their seats facing the rear.

Findings from German Research on Wheelchair-Accessible Buses

Research conducted from 1990 to 1992 by the German Ministry of Transport, in cooperation with transit systems, provided the basic insight into the accommodation of wheelchairs on buses. Two studies, one by Glaeser (1990) and one by Kasten (1991) were conducted that explored the specific issue of securement requirements on transit buses (*11*,*12*). Both of these studies were published by the Federal Highway Research Institute of the Federal Ministry of Transportation in Germany (BASt) in *Die Sicherung Von Rollstuhlfahren In Linienbussen Und Behindertentransportwagen* (*The Securement of Wheelchair Passengers in Urban Transit Buses and in Motor Vehicles for the Disabled*).

The first study by BASt carried out deceleration tests with a manual and an electric wheelchair, each loaded with a dummy and placed unsecured on a moving test platform. The objective was to establish the acceleration and deceleration forces that occur to bring a wheelchair passenger into an unsafe situation without using a securement system. These tests showed that unsecured manual wheelchairs will start slipping at 0.18 *g* to 0.21 *g* and start tipping at 0.37 *g*. Electric wheelchairs start slipping at 0.37 *g* and tipping at 0.43 *g*.

To complement the first study, a second study involving tests was carried out by STUVA (Research Commission for Underground Traffic Installations) to analyze which acceleration/deceleration forces are experienced by a manual and an electric wheelchair in a transit bus under normal city operating conditions. Two regular low-floor transit buses and one small bus were tested for a total of approximately 300 km (190 mi) in the cities of Cologne and Wuppertal and on rural and regional roads with a topography that included typical hills, curves, and descents. The buses, because of their modular design, had two places for wheelchairs, always in the same location—at the midsection opposite the entrance/exit door. The bus floor was of nonskid commercial material typically used in these buses. The wheelchairs were the same type as used in the BASt study, one manual wheelchair and one electric converted wheelchair. A dummy of 75 kg (165 lb) was placed in the respective wheelchairs.

During the trips, tri-axial acceleration measurements were taken at the bus floor level and at the wheelchair seat height. The use of a dummy simulated an extreme condition of a wheelchair passenger, one who cannot intentionally shift body weight or hold onto a seat, stanchion, and so forth. The majority of the observed changes in the wheelchair position during trips could be eliminated if the wheelchair passenger could hold onto something.

Under normal operating conditions, accelerations of 2.4 m/s^2 (0.24 *g*) in vertical, horizontal, and transversal directions were occasionally exceeded by up to 5%. When curves were driven more forcefully, the rating was exceeded by up to 11%. (It should be noted that the variations of 5% and 11% were caused by the measuring equipment and occurred for only 1/200 s. This had no impact on the movement of the wheelchair.) In most cases, the wheelchairs remained in place. However, even under normal operating conditions, the wheelchairs placed facing sideways experienced turning of the front casters or sliding of the manual chair [up to 5 cm (2 in.)].

When an individual is facing backward and supported against the back panel, higher acceleration values—from abrupt braking to emergency braking—could be absorbed. The research found that it was important that the back panel be wide enough to support the full area of the wheelchair back. It was also important that both rear wheels touch the seat bench or support to avoid submarining.

In positions such as facing forwards, sideways, or to the rear but without support of a back panel, wheelchairs were found to slide severely or even tip under severe braking conditions.

It was generally observed that the electric wheelchair was less affected by acceleration and deceleration forces than the manual wheelchair, because of its total weight and lower center of gravity. The ratings of deceleration measured at wheelchair seat height are substantially smaller than the ones measured at the bus floor level, owing to the spring action of the air-filled wheelchair tires.

The conclusions of these two studies indicated that it was possible to transport wheelchair passengers (although these studies did not evaluate scooters) in a transit bus safely without a securement or restraint system given the following circumstances:

- There is a “confined space” with a back-support panel for a wheelchair passenger;
- The wheelchair passenger is facing rearward, with the wheelchair back in contact with the back support;
- The wheelchair brakes are firmly applied, if possible, on all wheels;
- The driver exercises reasonable driving habits; and
- The speed does not exceed city speed limits.

As a result of this research, a number of German transit systems developed a “protected position” design for accommodating mobility aids on board standard transit buses. A review of German experience with the rear-facing position was carried out 5 years after its introduction and included the following observation:

> The concept of the space arrangement for wheelchairs as well as the decision to waive complicated restraint systems, for example in the form of a safety belt, is justified from daily experiences. There has not been any reported accident involving a wheelchair passenger in a low-floor bus since the first vehicles have been placed into operation. The very first types of low-floor buses had been equipped with a safety strap system, but it was used by a minority of wheelchair passengers only.

According to German Standard DIN 75 077, "Buses for disabled persons; definitions, requirements, tests," a bulkhead or a restricted or confined space is required as a restraint system that fulfills the safety requirements (*13*).

European Perspectives on Accommodating Wheelchairs on Transit Buses

In the United States, the evolution of accessibility legislation has led to a situation in which different transit passengers are treated differently from a safety point of view. The ADA ensures a level of safety for wheelchair users that is greater than that offered for other passengers (e.g., standees). In contrast, Europeans have a different perspective than the United States with respect to accessibility for wheelchair passengers; they believe that wheelchair passengers should be treated in the same way, from a safety point of view, as are other passengers on the bus, including standees.

For example, one of the lead researchers defined the wheelchair safety problem in 1993 in the following way:

> In order to solve the new problem of safety for wheelchair users on regular bus routes, it is necessary to consider real transport conditions, i.e.:
>
> - Risks of accidents in urban areas are absolutely minimal and cases in which passengers suffer injury are rare. Accidents mostly involve pedestrians or cyclists and cause the bus driver to attempt to avoid them.
> - Not all passengers are seated in the bus and standing passengers must maintain their balance by holding onto handrails and posts during the journey, particularly when starting (acceleration), braking (deceleration) and taking turns (transversal acceleration).
> - Transport time is usually so short (from 10 to 20 minutes) that it is difficult to envisage requesting passengers to use a safety device requiring a maneuver and a constraint (*14*).

In a paper discussing the proposed Specifications for the Accessibility of All People to Urban Buses, the chairperson of the Working Group on Bus Accessibility of the National Advisory Committee for Transport of Disabled Persons in France stated that

> [T]he anchoring maneuver (for wheelchairs) requires that the bus driver leaves his place. Rational operating conditions make this procedure unacceptable, since it is most constraining for the driver and, moreover, resented by the disabled people as they are not considered as "normal" passengers free to move about themselves. Lastly, it became clear to the working group that, since urban buses are designed to transport standing passengers, the problem of wheelchair anchoring could be related to that of the balance and safety of standing passengers; other European countries such as Germany, for example, have expressed the same point of view (*15*).

In the actual proposed specifications presented by that working group in 1991, the following statement is made with respect to wheelchair security:

> [I]n the absence of any reference material on the subject, it does not appear that wheelchair passengers have any more problems with stability than standing passengers. Therefore the question of anchoring the wheelchair is not raised (*16*).

Similar perspectives are found across Europe. The basic rationale for the rear-facing position, from the European perspective, can therefore be summarized as follows:

- To provide a person in a wheelchair with the same level of safety as afforded to all other seated passengers, under regular operation of a transit bus, including severe braking and cornering;
- To provide the wheelchair passenger with the same degree of independence as had by all other bus passengers;
- To provide other passengers with large equipment, such as strollers, with a place to accommodate their requirements; and
- To remove the need for intervention by the bus operator.

COST 322 European Research Program

The European CO-operation for Science and Techniques (COST) program was established in 1971 to coordinate fundamental, prenormative, precompetitive research or activities financed at national levels in the 25 European member countries. The COST 322 Action started work in 1993 and involved 10 participants. Its objectives were to examine the needs of public transportation so that it could help reduce the use of personal cars; provide accessible, efficient, and reliable service for the population as a whole; and reduce the impact of traffic congestion and pollution (*17*,*18*).

Under the COST program, tests were carried out in 1992 by researchers in France with the participation of the Lyon Transit System. An experimental setup was designed to identify transport conditions that were dangerous for a wheelchair user and to demonstrate safety solutions that would minimize constraints on mobility-constrained passengers.

The test scenario included the use of manual and electric wheelchairs, using a 50th percentile dummy [75 kg (175 lb)] setup in a standard low-floor bus. The following forces were reproduced as a typical example of conditions that transit buses would experience:

- Sharp acceleration up to 0.4 *g*,
- Sharp deceleration from 0.4 to 1.0 *g*, and
- Lateral acceleration (violent change of direction) of 0.2 to 0.3 *g*.

Several wheelchair positions were selected:

TABLE 1
WHEELCHAIR SECUREMENT TEST RESULTS—COST 322

Securement Type	Facing Direction	Results under Following Conditions		
		Braking	Acceleration	Cornering
No securement, brakes only	front	bad	satisfactory	bad
Four-strap system	front	good, if straps used	good	good
Sideways with brakes	—	satisfactory	satisfactory	bad
Sideways with front wall and strap	—	good	satisfactory	satisfactory
Sideways with rear wall and strap	—	bad	good	bad
45˚ to rear	rear	satisfactory	satisfactory	bad
Vertical panel/bulkhead	rear	satisfactory	good	bad
Backrest and headrest	rear	good	good	bad
Backrest, headrest, and aisle support	rear	good	good	good

Notes: Evaluation criteria—good, wheelchair stays upright; satisfactory, wheelchair begins rocking, stress on dummy; bad, wheelchair tips, dummy falls.
Sources: Dejeammes and Bonicel (*17*) and European Community CO-operation for Science and Techniques (COST) (*18*).

- Facing front,
- Facing sideways,
- Facing 45˚ to the rear, and
- Facing to the rear.

A number of different securement scenarios and systems were used:

- No securement,
- Four tie-down straps,
- Bulkhead,
- Backrest and headrest (load-bearing device), and
- Backrest and headrest with aisle support (armrest).

Table 1 shows the test results.

The tests indicated that a safe position for the wheelchair passenger had been identified, namely a rear-facing position for the wheelchair, with the back against a load-bearing backrest and headrest, and an aisle-facing stanchion or armrest. This arrangement would not require the wheelchair to be tied down by any other equipment.

The results from the COST 322 project reconfirmed findings from the previous research by the German Ministry of Transportation, conducted in 1991 and 1992. As a whole, this body of research illustrated the acceptable level of safety offered by the rear-facing position design under normal bus operating conditions and it has lead to subsequent widespread adoption of this approach across Europe. An assessment in 1997 of progress to date concluded that:

> [U]rban bus services have been opened to people in wheelchairs by the combination of the low-floor bus with a simple ramp at one door and permitting the carriage of a passenger in an unrestricted wheelchair. The wheelchair passengers travel facing backwards, backed against a bulkhead at the front of a space opposite the second door but with no wheelchair or passenger restraint. The ramp is helpful for many people who have walking difficulties, and the boarding time for wheelchairs is not much longer than for other passengers. The driver does not need to leave his seat to attend to passengers in wheelchairs. Boarding times for passengers in wheelchairs are sufficiently short (usually well under one minute) for all these passengers to be carried in significant numbers without delaying the bus substantially (*19*, p. 56).

REAR-FACING POSITION IN CANADA—DEPLOYMENT AND RESEARCH

Providing mobility options to persons with disabilities has been a priority in Canadian cities since the early 1980s, resulting in the development of high-quality specialized transit systems across Canada. These systems have provided demand-responsive, usually reservation-based, service to eligible persons with disabilities and seniors, with the use of vans and small buses. These services were supplemented by taxi-based services. With respect to conventional transit, attention focused in the late 1980s first on improving access for seniors and frail ambulatory persons by improved features in bus design (e.g., high-contrast step edgings and improved lighting) and by introducing community bus services (i.e., fixed-route service specifically targeted to primary travel patterns and destinations of seniors using small buses). As in Europe, accessibility for persons in wheelchairs was served through specialized transit and not by trying to make standard buses accessible using wheelchair lifts, as was the policy in the United States. The inherent disadvantages of this policy were compounded by the difficulty of operating hydraulic wheelchair lifts in a cold climate and the difficulty of ensuring access to bus stops during winter snowfall. Only mild-climate Vancouver introduced wheelchair accessible buses before 1992, although this technology was common in the United States.

However, as in Europe, the advantages offered by the development of low-floor bus technology were quickly recognized and they drastically changed the accessibility debate. Low-floor buses were first introduced in 1992 by BC Transit in Victoria, followed closely by Kitchener, Calgary, and Edmonton. There was however considerable debate within the transit industry as to the best approach for accommodating wheelchairs on standard transit buses. The desire to enhance accessibility for persons with disabilities is a societal concern in Canada, but it is not governed by formal legislative requirements and prescriptive regulations. As a result, various approaches were experimented with, and different transit systems developed and adopted a variety of approaches to wheelchair securement. In the early 1990s, all of these approaches were based on a forward-facing position. However, transit systems recognized that the dynamic forces occurring on large transit buses, with their larger mass, were substantially lower than those on vans or even small buses. As a result, most approaches adopted designs that were simpler than those prevalent in the United States, in the hope of reducing the burden caused by the securement system on the wheelchair passenger, the bus operator, and the transit system.

At the time, the Canadian Urban Transit Association (CUTA) conducted, as part of its national cooperative Strategic Transit Research Program (STRP), a study entitled *Urban Transit Bus Accessibility Considerations* (STRP Report 10), the results of which were published in 1995 (*20*). This study examined the various approaches being adopted by the pioneer Canadian transit systems deploying accessible low-floor buses. Three main types of forward facing systems were identified:

- Four straps: two for the front, two for the rear;
- Wheel rim lock combined with one rear retractable strap; and
- Two rear straps with angled wheel stop for manual and power chairs, with one additional front strap for scooters.

Furthermore, the study identified the preliminary European research and emerging practice concerning the European rear-facing position approach. The findings of this study were disseminated through presentations at CUTA conferences and discussions of CUTA's Bus Design and Maintenance Committee. They also stimulated considerable discussion and reflection within the industry.

Transit systems, such as those in Montreal, Hamilton, and Ottawa, and BC Transit, which were introducing new and sometimes radically different bus models, took advantage of the opportunity to explore the potential adoption of the rear-facing position. Although initially skeptical, a few Canadian transit systems ran focus groups or pilot trials to get feedback from consumers. In addition, the rear-facing approach was studied and discussed by some provincial government agencies (Alberta, Quebec, and Ontario) that were seeking to encourage more widespread accessibility initiatives (*21*). As a result, several transit systems introduced the rear-facing system in the late 1990s. CUTA conducted a second study to identify pertinent research and document experience to date. This study, entitled *Accommodating Mobility-Aids on Canadian Low-Floor Buses Using the Rear Facing Position Design: Experience, Issues, and Requirements* (STRP Report 13), was published in November 2000 (*22*).

Currently, several major transit systems have adopted, or are adopting, the system for two major reasons: (1) it provides the passenger with independent and dignified access and (2) it provides the transit system with reduced dwell times and minimal involvement of the bus operator. Rear-facing systems are now implemented in 18-m (60-ft) articulated low-floor buses, 12-m (40-ft) low-floor buses, 12-m (40-ft) double-decker low-floor buses, and 10.6-m (35-ft) and 9-m (30-ft) low-floor buses, involving front or middle door access, depending on the bus model and transit system.

In addition, under the auspices of the Canadian Standards Association (CSA), the principle standards development organization in Canada, representatives of transit systems, of the wheelchair user community, and of bus and component suppliers, have been involved in the development of the new Standard for Accessible Transit Buses (D435-02), which was published in August 2002 (*23*). The development of this standard is intended to provide guidance to the industry and encourage greater transit accessibility. The D435 standard specifically recognizes the rear-facing position as acceptable practice.

This new standard is likely to encourage more deployment of the rear-facing position in Canada, as a result of its impact on suppliers. In Canada there are three domestic manufacturers of low-floor buses, all three of which were interviewed by telephone. Until August 2002 there had been no standards in Canada specifying the forces that a rear-facing back or head panel must withstand. This lack of formal standards had made the bus manufacturers uneasy and unwilling to assume the liability inherent in the installation of a rear-facing position on the bus. The situation has changed with the publication of the CSA D435-02 standard. As a result, the three bus manufacturers are now installing the rear-facing position as part of the manufacturing process.

Consultations were also held with staff from a manufacturer that supplies seats and related components to the manufacturers of standard transit buses. As with the Canadian bus manufacturers, the seat manufacturer had been concerned about liability issues with the rear-facing design. However, as a result of the demand placed on it by Canadian transit systems, this supplier now offers a back panel and installation frame, designed to the CSA standard specification, which can be used in a rear-facing position and installed either by the bus original equipment manufacturer or a transit system. The supplier is also hopeful that the promulgation of the CSA standard will be useful in addressing the remaining liability concerns.

CHAPTER THREE

CURRENT PRACTICE: CANADIAN TRANSIT SYSTEMS, INTERNATIONAL REGULATIONS AND STANDARDS, AND NEW DEVELOPMENTS IN NORTH AMERICA

SURVEY OF CANADIAN PRACTICE

Survey of Canadian Transit Systems Using the Rear-Facing Position

During the summer of 2002, transit systems in Canada that had adopted the rear-facing system were surveyed concerning their experiences. The questionnaire was also translated into French for the benefit of transit systems in Québec (see Appendix A). Responses were received from 100% of transit systems in Canada known to use the rear-facing position in accessible low-floor buses. The respondents were

- BC Transit (including Victoria and the municipal transit systems in the province of British Columbia),
- Grand River Transit (Kitchener, Ontario),
- Hamilton Street Railway (Hamilton, Ontario),
- Mississauga Transit (Mississauga, Ontario),
- Société de Transport de Montréal (STM) (Montréal, Quebec), and
- Ottawa–Carleton Regional Transit Commission (OC Transpo) (Ottawa, Ontario).

BC Transit and Grand River Transit had buses with forward-facing systems before adopting the rear-facing system. They will continue to operate those buses. BC Transit has recently adopted a "combi" design as its standard design for all future buses. This design involves a combination of both rear- and forward-facing positions and will be discussed in more detail later in this chapter.

The other four Canadian transit systems adopted the rear-facing position from the outset of their deployment of wheelchair-accessible buses.

In addition, the Edmonton Transit System has decided to adopt the rear-facing approach on its next bus order. It was learned that other transit systems in the province of Quebec operate low-floor buses, but they have yet to provide accessibility for wheelchairs. They plan to adopt the rear-facing system, similar to the one used in Montréal.

Basic information concerning the six Canadian transit systems that have adopted the rear-facing position is provided in Table 2. The majority of survey respondents provide two positions for wheelchairs on low-floor buses. The exception is STM (Montréal), which provides only one.

Rear-Facing System

Floor Dimensions

The length of rear-facing space (measured along the longitudinal axis of the bus) varies from 1.3 to 1.52 m (52 to 60 in.) for a single rear-facing space, and up to 2.41 m (96.4 in.) for combined contiguous rear- and front-facing spaces. These dimensions equal or exceed the European standard of 1.3 m (52 in.).

TABLE 2
INFORMATION ON TRANSIT SYSTEMS WITH REAR-FACING POSITION

	Primary System Information				
Transit System	Total Bus Fleet	Low-Floor Bus Fleet	% of Accessible Fleet with Rear Facing Position	Length	Width
BC Transit	491	399	41*	1.41 m (56.4 in.)	0.79 m (31.6 in.)
GRT	143	78	90	2 m (80 in.)	1 m (40 in.)
HSR	191	80	100	1.42–1.75 m (57–70 in.)	0.65–0.75 m (26–30 in.)
MT	327	101	100	1.3 m (52 in.)	1.2 m (48 in.)
STM	1,565	545	100	1.6 m (64 in.)	0.98 m (39 in.)
OC Transpo	900	330	100	1.52 m (60 in.)	0.75 m (29 in.)

*BC Transit has now adopted the rear-facing position as part of it's combi design for all future bus orders. BC Transit, British Columbia Rapid Transit (Victoria and British Columbia municipalities); GRT, Grand River Transit (Waterloo region); HSR, Hamilton Street Railway; MT, Mississauga Transit, STM, Société de Transport de Montréal; OC Transpo, Ottawa–Carleton Regional Transit Commission.

The width of the rear-facing position varies from 0.65 to 1.2 m (26 to 48 in.). The majority of respondents reported that they equal or exceed the European standard of 0.75 m (30 in.), with the exception of Hamilton, which was the first transit system to adopt the rear-facing position.

Back and Head Support

All respondents provide a rear-facing system with a padded combined head and back support that allows proximity of a passenger's back to the back panel. This arrangement requires that wheelchair wheels and handlebars be able to straddle the backrest.

Aisle Stanchions

All respondents use an aisle stanchion as a means of preventing wheelchairs and scooters from tipping or moving into the aisle.

Wheelchair Securement

One-half of the transit systems are using an additional strap to prevent tipping, but with the exception of Mississauga, its use is generally not mandatory.

Flip Seats in Wheelchair Location

All respondents provide flip seats in the area of the wheelchair position. Some seats are always in the up position when not in use (i.e., European style), but others are not.

Priority Seats in Wheelchair Location

Two-thirds of survey respondents have their priority seats in the area of the wheelchair position. Priority seats are dedicated for use by seniors or other passengers with disabilities.

Stop Request Button

All survey respondents provide a separate stop request button, mounted in the area of the wheelchair position, with a different audio tone to distinguish it from the general stop request. On the dash at the bus operator's position there is also a light indicator that is distinct from the general stop request indicator.

Stop Request Signs

Only one of the survey respondents, BC Transit, provides a visual next stop display that is visible for rear-facing passengers, who cannot view the upcoming stop and must rely on audio announcements from the driver. This second stop request sign, visible for rear-facing passengers, is not included as a standard feature on new BC Transit bus orders.

Other Rear-Facing Seats

One-third of respondents provide other rear-facing seats in their low-floor buses. These are typically in the rear section of the bus in a club (face-to-face) seating arrangement over the rear wheel wells.

Installation of Rear-Facing Systems

Rear-facing systems are currently being installed by the bus manufacturers who assume responsibility for their design. This was not the case initially; the first transit systems adopting the rear-facing position were obliged to install the equipment themselves because of liability concerns on the part of bus manufacturers. There are four manufacturers currently providing standard transit buses to Canadian transit systems, of which three are domestic.

Boarding Systems

Boarding and Alighting Door

Two-thirds of respondents use the front door for access by passengers using a wheelchair or scooter. The Montréal and Hamilton bus systems use the rear door for access.

Boarding Equipment

The majority of respondents use a flip or hinged ramp, a few use a sliding ramp, and one-half use both designs in their fleet, depending on the bus model.

Bus Operator Assistance and Training

Two-thirds of respondents noted that the bus operator provides assistance in positioning and securing a passenger with a wheelchair or scooter, whereas one-third said that they do not. All transit systems provide their bus operators with awareness and hands-on training for assisting passengers with disabilities.

Accessibility Committee and Focus Groups

Most transit systems have an accessibility committee and previewed the rear-facing system with the committee.

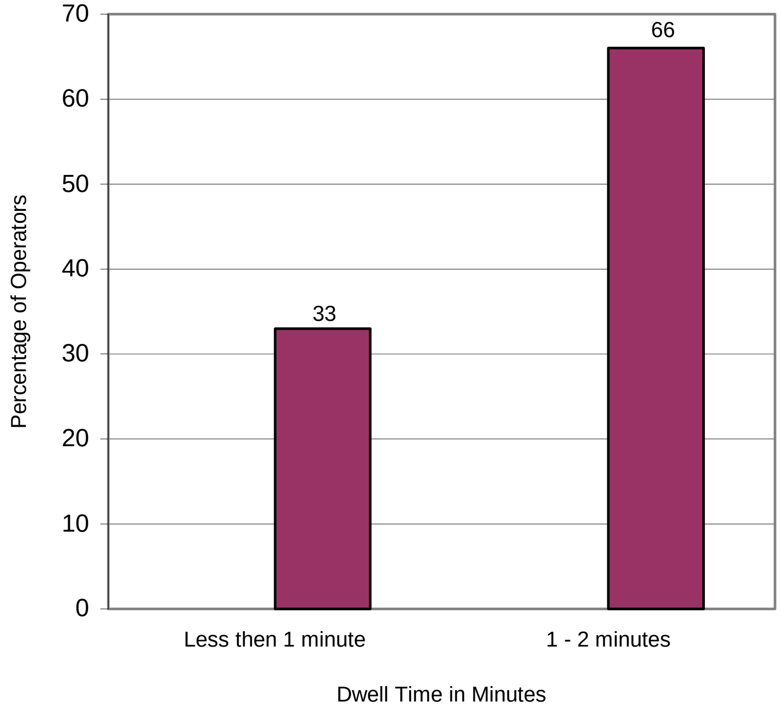

FIGURE 10 Dwell times with rear-facing systems.

Two-thirds have also reviewed the system with a focus group before implementation.

Operation

Transportation of Wheelchairs per Day

The number of passengers using a wheelchair or scooter transported by transit systems generally varies from 0.1 to 2 per day per accessible bus in the fleet.

Dwell Times

Two-thirds of respondents reported a dwell time of 1 to 2 min, with one-third reporting less then 1 min. One transit system that is also using forward-facing systems indicated that the average dwell time for forward facing is 3 to 4 min (Figure 10).

Customer Safety

All but two transit systems reported having had no safety incidents involving wheelchairs using the rear-facing position. One respondent reported that there had been one incident when the passenger turned the power back on to his scooter, thus releasing the brakes. As a result, the scooter rolled and tipped onto another passenger after the bus turned left.

A second transit system reporting safety incidents keeps detailed accident logs by date, bus number, and description and location of action. The following is a summary of the only three pertinent on-board incidents identified:

1. A wheelchair passenger ran over the toe of another passenger while maneuvering inside the bus.
2. A scooter and passenger tipped over when the bus cornered (in a bus without an aisle stanchion).
3. A wheelchair tipped over when the bus cornered (in a bus without an aisle stanchion).

Transit System Acceptance

According to respondents' comments, transit systems prefer the rear-facing systems on low-floor buses for the following reasons:

- The bus operator does not have to be involved in deploying tie-downs and belts—only for operating the ramp.
- There is little need to maintain and replace straps.
- The system adapts easily to most common wheelchairs and scooters.
- The time required for passengers using wheelchairs and scooters to position themselves in place is minimized, reducing dwell time and disruption to schedules.

Conversely, there are drawbacks. Components that are currently used to prevent wheelchairs and scooters from moving into the aisle require further study, for the following reasons:

- Fixed stanchions can take up space in aisles and interfere with passenger flow,
- Movable flip-up armrests cannot be operated by some passengers in wheelchairs, and
- The deployment of straps used to prevent tipping may require the assistance of other persons.

Customer Acceptance

Some respondents indicated that there had been some apprehension from the wheelchair user community concerning the rear-facing position before its implementation. However, informal feedback received by respondents suggests that, after implementation, consumer acceptance is positive.

- The rear-facing position provides great independence to the user and usually does not force them to rely on the assistance of other persons.
- There is usually no need for physical contact between the passenger and the bus operator to attach and remove straps.
- Very few passengers have indicated that they cannot ride facing to the rear.
- Freedom of choice has been enhanced with the introduction of BC Transit's combi design systems that allow the use of either the forward- or rear-facing position. However, rear-facing positions tend to be preferred by wheelchair users even when they have the choice.

Customer Suggestions

Respondents received the following feedback and suggestions for enhancing the rear-facing design:

- Provide a visual display of the next stop for rear-facing passengers; often oral announcements by bus operators are inaudible.
- Advise the bus operator not to start moving the bus before the wheelchair or scooter passenger is properly positioned.
- Do not place "priority" seats in the wheelchair area, because it creates conflicts with persons with other disabilities.

INTRODUCTION OF THE COMBI DESIGN BY BC TRANSIT

Profile of BC Transit System

BC Transit is the provincial Crown corporation charged with providing public transportation throughout the province of British Columbia, outside of the Greater Vancouver area. BC Transit plans, funds, manages, markets, and contracts for transit systems in 50 British Columbia municipalities. In total, BC Transit serves some 1.6 million people, providing more than 34 million unlinked revenue trips annually.

BC Transit has a fleet 491 buses, of which 399 are low-floor. BC Transit in Victoria, the capital of the province, has a fleet of 200 buses, of which 158 are low-floor. This case study was carried out in Victoria, the headquarters of BC Transit.

The provincial fleet of low-floor buses consists of

- Fifty-one 9-m (30-ft) low-floor buses equipped with two rear-facing systems in tandem,
- Eighty-four 10.8-m (35-ft) low-floor buses equipped with one combi system (i.e., combined rear- and forward-facing in one position),
- Twenty-nine 12-m (40-ft) double-decker buses equipped with one rear-facing and one combi system on opposite sides, and
- Two hundred and thirty-five 12-m (40-ft) standard buses equipped with two forward-facing systems.

BC Transit currently is using a variety of wheelchair securement systems and configurations in its fleet. The following are some of the features:

- Rear-facing system with fixed aisle stanchion and optional straps;
- Rear-facing system with straps only [on 12-m (40-ft) double-deckers];
- Combi 1 with one forward- and one rear-facing system in the same location, which can be used by only one wheelchair passenger at a time;
- Combi 2 with one forward- and one rear-facing system in the same location, but which can be used by two wheelchair passengers at the same time (this is to become the standard system); and
- Forward-facing system with two rear straps, plus one additional front strap for scooters.

Access to all buses for passengers using a wheelchair or scooter is by means of the front door over a ramp.

The demand for wheelchair transportation in British Columbia varies according to demographics. BC Transit in Victoria transports on average one wheelchair passenger per accessible bus per day. On some routes that cover areas where more persons with mobility disabilities live or need transportation to hospitals, shopping, etc., up to four wheelchairs per bus are transported on any given day. Victoria has a mild climate that is attractive as a retirement community. Its aging population creates a steady increase of demand for accessible transportation services. In addition to accessible low-floor buses, BC Transit provides specialized door-to-door service for those with mobility impairments who cannot use public transportation. An accessible taxi service is also available for people who are not mobility impaired but have other impairments and cannot use fixed-route public transportation; for example, persons with Alzheimer's disease, mentally impaired persons, and persons with heart and stamina problems. Trends related to the use of wheelchairs and scooters seem to indicate an increase in the number of scooters, especially by older seniors. Some designs exceed the standard wheelchair envelope [1.22 m (48 in.) long and 0.75 m (30 in.) wide] and cannot be accommodated within the bus, primarily because their limited turning radius prevents making the maneuver from the ramp into the aisle. BC Transit, in cooperation with its consumers, has provided decals for those wheelchairs and scooters that fit the available bus envelope and thus are certain that they can access any low-floor bus.

Initial Forward-Facing Design and Issues

In 1992, BC Transit in Victoria became the first Canadian transit system to equip its fleet with accessible low-floor buses. Because severe incidents are extremely rare on urban transit buses, BC Transit decided to develop its own forward-facing securement system, one that provided more flexibility than did prevailing systems at the time. This design is still used in BC Transit's 12-m (40-in.) low-floor buses. It consists of a horizontal wheel stop under a flip-up seat bench that is slightly angled toward the aisle to allow for easier getting in and out of the position. Two rear tie-downs, anchored to the wheel stop, are attached to the wheelchair to prevent forward and sideway movements. In the case of scooters, an additional strap is placed over the footrest, which prevents the scooter from tipping and sliding when the bus is cornering under regular and severe operating conditions (Figure 11). An additional passenger restraint is available; however, its use is not mandatory. This innovative forward-facing design is less laborious for the bus operator, who has only to attach two straps, or three in case of a scooter.

Although this innovative forward-facing design was effective, it nonetheless created a number of problems for the transit system and its passengers.

- To maneuver into the forward-facing position, the passenger must turn 180˚ in front of the position, requiring extensive swept floor space, and interfering with other passengers, especially when the bus is full.
- The dwell time is from 2 to 4 min per wheelchair passenger, with most of the time taken up by maneuvering into position and the attaching of straps by the bus operator.

FIGURE 11 Forward-facing position in combi design, with two rear tie-downs and one strap over the footrest of the scooter.

- The operator must leave his or her position and deploy straps and hooks to the wheelchair or scooter; alternatively, this function can be performed by a companion.
- Close physical contact between the operator and passenger is unavoidable and detrimental to a dignified procedure.
- The passenger depends completely on another person—operator or companion—to assist in securing the wheelchair or scooter.
- Straps require cleaning maintenance and are often lost or damaged, thus creating additional cost for the operator.
- There is a lack of designated attachment points on most wheelchairs and scooters, and this can result in damages or injuries if the straps cannot be properly attached.
- There is the risk of injury for operators when attaching or removing the straps, because of the awkward position they must assume, often on their knees, twisting behind the wheelchair. Such injuries can result in additional health costs and loss of productive labor for the transit system.

BC Transit's Experience with Rear-Facing Systems

To solve the previously mentioned problems, BC Transit opted in the late 1990s to introduce the rear-facing system on its new low-floor buses. BC Transit's own crash testing and experience, along with experiences from European operators and research, as reported in CUTA's STRP research, indicated that

- Large urban buses, with a larger mass, experience smaller forces at severe acceleration and deceleration then smaller vehicles with smaller masses.
- Collisions and crashes in urban buses are extremely rare.

- Generally, passengers in urban buses, especially those standing, are not provided with any safety provisions, except for handholds and stanchions. Passengers who are seated are not required to wear seat belts. The overall safety level provided is based on the regular operating conditions of the bus, or possibly for severe braking in the worst case.
- Passengers in wheelchairs are more protected than other passengers on the bus and possibly are singled out.
- The solution of the rear-facing position had been developed in the mid-1980s in Germany and the United Kingdom, based on the foregoing rationale and research for unsecured wheelchairs.

BC Transit, responsible for vehicle procurement in municipal transit operations in British Columbia except for those in the Vancouver area, introduced the first rear-facing system on its new 9-m (30-ft) low-floor buses in 2000. These buses were deployed in 16 municipalities. They enabled the introduction of accessible conventional service in several communities. BC Transit held open houses at its facilities to introduce the new accessible service (and on-board design) to its passengers using wheelchairs and scooters. Disability trainers and new low-floor bus models, equipped with rear-facing systems, were made available so that passengers could practice boarding and alighting. This effort helped to reduce dwell times once passengers became familiar with the system. It also helped passengers to evaluate their own skills, abilities, and mobility aid for accessing a bus, which was especially helpful for those persons with oversized mobility aids or who have very wide turning radii as commonly found in the new four-wheel scooters.

In 2001, BC Transit introduced two new low-floor bus models: the 10.6-m (35-ft) model and the 12-m (40-ft) double-decker (Figure 12). The 35-ft model was equipped with one combi system, and the double-decker with one combi and one rear-facing system. The combi design consists of one forward-facing and one rear-facing system in the same location. The reason for providing a combi system was threefold:

1. To provide those passengers who have difficulties traveling in the rear-facing position with a choice;
2. To make more effective use of the space available, because the maneuvering for forward- and rear-facing positions is shared; and
3. To make the transition easier for passengers who are used to the forward-facing system.

The 9-m (30-ft) low-floor bus is equipped with two rear-facing positions in a tandem configuration at curbside (Figure 13). Both positions have an aisle stanchion to prevent the tipping and moving of wheelchairs or scooters into the aisle. There are additional retractable straps to carry out the same function, but their use is optional, and not mandated. The straps provide additional safety, especially for passengers who lack the upper body strength to hold on to the handrails and stanchions provided. Both positions have a flip seat at each back panel, but no flip seats along the wall. This allows for the placement of stanchions as close as possible to the wall, to minimize interference with passenger flow in the aisle. Rear-facing flip seats for other passengers also help to minimize the negative image associated with wheelchair passengers' being the only passengers facing to the rear.

FIGURE 12 Transit double-decker bus.

FIGURE 13 Two rear-facing systems in tandem at curbside in 9-m (30-ft) BC Transit low-floor bus.

Combi Design

The combi design was first introduced by BC Transit in Victoria in 2001, but only recently installed in its low-floor buses (Figure 14). It is based on the principle for choice, giving passengers who cannot travel facing the rear the opportunity to use the forward position instead. Currently, several BC Transit buses are equipped with the combi system in a variety of design configurations. To date, BC

FIGURE 14 Combi system of forward and rear facing in one location, 10.6-m (35-ft) BC Transit low-floor bus (future standard for all buses).

Transit is the only transit system in Canada to have experimented with and adopted this design.

Currently, the combi design is used in two variations.

1. As a combination of one forward- and rear-facing system in the same position, with the possibility of a passenger in a wheelchair or scooter using either system, but not the two at the same time, owing to space limitations (Combi 1); and
2. As a combination of one forward- and rear-facing system in the same position, but using both systems at the same time (Combi 2), which is the preferred configuration where space allows.

The forward-facing component in the combi design is based on the previously described forward-facing design developed by BC Transit.

The rear-facing system consists of a combined padded back and head panel, a horizontal handrail on the bus wall, and an aisle stanchion (Combi 2) or a retractable strap (Combi 1). The back panel incorporates a flip-down seat that can be used when no wheelchair or scooter is using this position.

Combi 1

The Combi 1 design is used by BC Transit on its 12-m (40-ft) double-decker low-floor buses (Figure 15). Because of space limitations, it has no aisle stanchion to provide maximum space for wheelchairs to maneuver in and out of position. Instead, the rear-facing position has one retractable strap mounted at the vertical back panel aisle support at about seat height, and another retractable strap mounted at the wheel stop on the wall side. The two straps are hooked together to prevent the wheelchair from tipping or moving into the aisle, or they are connected directly to the wheelchair. The use of the straps is optional. The system was tested and meets or exceeds a dynamic force of 3 *g* toward the front and a recoil force of up to 1 *g* toward the rear. The same hooked strap system is used on the single rear-facing position on the opposite wall (Figure 16). The longitudinal distance between the forward- and rear-facing

FIGURE 15 Combi 1 design on BC Transit double-decker bus with front- and rear-facing design in same position, and hooked straps to prevent tipping.

FIGURE 16 Two straps hooked together wrap around scooter in rear-facing position to prevent tipping, moving into the aisle, or rearward movement on BC Transit bus.

FIGURE 17 Combi 2 design for two travelers in the same position on BC Transit bus.

systems is 1.41 m (56.4 in.). There are no additional flip seats in the wheelchair area.

Combi 2

The Combi 2 design is installed in 10.6-m (35-ft) low-floor buses, roadside. On the opposite side are aisle-facing flip-up seats, allowing for generous maneuvering room for wheelchairs and scooters. Combi 2 consists of one forward- and one rear-facing system, with both systems capable of being used at the same time for two travelers in wheelchairs and scooters (Figure 17). In this configuration, the longitudinal distance between the two systems is 2.02 m (80 in.). On the wall adjacent to the forward-facing system are flip seats. The rear-facing system has a flip seat incorporated into its back panel, and it has a fixed aisle stanchion. There are also two retractable straps for use by

FIGURE 18 Double-decker BC Transit low-floor bus: Combi system roadside, one rear-facing system curbside.

FIGURE 19 Combi system roadside in double-decker BC Transit low-floor bus.

wheelchairs and scooters in this position. Examples of the Combi 2 system are shown in Figures 18 and 19.

Experience with Combi Design

Depending on the layout restrictions, seat arrangements, and size of the bus, either the Combi 1 or Combi 2 design is used. Because the combi design has been only recently installed in the BC Transit fleet, there is little information available on its use. However, BC Transit staff were pleased to receive a complimentary personal letter from the vice president of the Action Committee of People with Disabilities. The author of that letter is a strong advocate of rights for persons with disabilities and has often challenged BC Transit to do more. However, the author finds that the new rear-facing combi design in the double-decker buses is a great improvement. He writes

> This is to tell you that after two trips in one of the double-deckers, this is the best bus for people in wheelchairs! No more waiting for the operator to find the hooks. The operator does not even have to leave his seat. Also, the entrance is more generous, and I think there's more room to turn.

Although he believes there is room for even more improvement, he continues: "Thank you very much for having brought this double decker, which is the most accessible bus so far, to our region" (From the Vice President of the Action Committee of People with Disabilities, Victoria, BC, personal communication to Mr. Dale Lapointe, Vice President, Fleet & Facilities, BC Transit, November 17, 2000).

Other reports from operators indicate that the rear-facing position is generally preferred and occupied as a first choice in buses with combi designs, because it provides greater independence. Transit staff also see the combi design as a transition for those travelers who are not yet used to the rear-facing system.

One remaining issue is that there still is no ideal solution to prevent the mobility aid from tipping or moving into the aisle within the rear-facing system, without assistance given to passengers with limited upper mobility. Wheelchair passengers with good upper mobility can attach the straps on their own; for those requesting it, assistance is provided by the bus operator. The use of straps is only recommended, not mandatory. Passengers in wheelchairs for the most part do not use the straps, which may result in the tipping of their wheelchair or scooter if they do not use the handrails or stanchions for support.

Incidents

BC Transit keeps a detailed log of incidents involving passengers using mobility aids, as well as for other passengers who have interacted with passengers using mobility aids or boarding equipment. The following are examples from the log of April 2000 to February 2002, covering 22 months. During that time, a total of 22 incidents involving wheelchairs or scooters were reported, of which 3 involved on-board incidents. However, the log does not distinguish between rear- and forward-facing positions involved in the incident. The three on-board incidents were as follows:

1. A wheelchair passenger ran over the toe of another passenger while maneuvering inside the bus.
2. A scooter and passenger tipped over when the bus cornered (in a bus without aisle stanchions).
3. A wheelchair tipped over when the bus cornered (in a bus without aisle stanchions).

The majority of safety incidents involving wheelchairs and scooters found in the safety log occurred while loading or offloading, outside the bus, etc., and were unrelated to the rear-facing position design.

Benefits

Several benefits of adopting the rear-facing design have been reported by BC Transit staff, including the following for the transit system:

- There is less demand for the specialized parallel HandyDART service (specialized vans equipped with lifts for door-to-door service). The growth in demand is down to 2% to 3%, compared with 8% to 9% in previous years.
- Dwell times have been lowered to about 1 min from the previous 2 to 4 min for the BC Transit's forward-facing securement system (which is considerably less complex than systems designed to meet the ADA standard).
- There is little involvement by bus operators for securement of wheelchairs and scooters.
- No injuries to bus operators have occurred.
- There is less cost for maintenance and replacement of straps.
- Liability for the transit system has been minimized.

Benefits to wheelchair passengers included the following:

- They experience a dignified and independent use of the system, not having to rely on other persons for assistance.
- There is little close physical contact with operators or other persons for attaching and removing straps.
- Freedom of choice is found in the combi system.
- There is more rapid boarding and disembarking, resulting in less time holding up other passengers, which can be a source of embarrassment

AC TRANSIT: A LEADER IN ADOPTING THE REAR-FACING SYSTEM FOR BUS RAPID TRANSIT IN THE UNITED STATES

The Alameda–Contra Costa Transit District (AC Transit), in the East Bay area of the San Francisco region, has been proactive in enhancing the access of wheelchair users to their transit system. Some of the initiatives that AC Transit has undertaken have included

- Wheelchair marking/tether strap program—This program encourages tape marking of appropriate attachment points on the wheelchairs or, if not available, the permanent attachment of fabric webbing tether straps.
- Newer securement equipment—There is procurement of enhanced systems as they become available, including remote release levers, automatic tensioning, and innovative stowage.

- Improved employee training and customer education—These programs use retired buses that are retained as "Securement Training Buses."
- Cleveland Clinic Foundation Securement Prototype—AC Transit was one of three transit systems to test the prototype of this new universal design system.

AC Transit recently purchased new standard and articulated buses for new BRT service, with limited stops and fast boarding by means of multiple doors. This new service and its vehicles provide an opportunity to deploy the rear-facing position common in Europe and Canada. The prototype vehicles for this new service were displayed at the 2002 APTA Exposition. Wheelchairs are accommodated by the use of a combi design involving one forward-facing position and one rear-facing position. Both positions are equipped with ADA-compliant tie-down strap securement systems, some with automatic retractable straps that are neatly stowed in compartments when not in use.

The following is a description by AC Transit's Accessible Services Manager Doug Cross from a 2003 paper (*24*) and a recent interview:

> Two securement stations are located on the same side of the bus, with easy access via a ramp in the second door. This eliminates the entry area constrictions common to traditional front boarding designs. The forward-facing securement area uses traditional strap-type securements (Figure 20). The adjacent rear-facing station features a padded backrest with grab rails, and seat belts (Figure 21). This design is intended to provide "containment" in the event of sudden stops or crashes, instead of relying solely on straps to hold the wheelchair in place.

FIGURE 20 Forward-facing position (combi design) on prototype AC Transit BRT service bus.

FIGURE 21 Rear-facing position (combi design) on prototype AC Transit BRT service bus.

> The rear-facing station is configured to also use ADA-style securement straps, and to be used as an optional forward-facing station in cases where passengers are not able to ride "backward" for health reasons. In this instance, strap-type frame securements are to be clipped into the floor for ADA-compliant securement. Time will tell whether this option is necessary.
>
> The regular seating areas throughout the bus feature rear-facing seating in opposing pairs. Therefore, "stigmatization" of the wheelchair user being forced to ride backward should not be an issue.
>
> The vehicles will be delivered to Oakland during 2003. Initial rides by wheelchair users on two prototype models in late 2002 were very positive, after some consumer apprehension about how such a different new layout would work.

In addition to carrying out the efforts made to develop an appropriate layout configuration, staff at AC Transit has focused efforts on how to articulate and communicate local policy with respect to securement on the new buses. They opted for the following wording, at the rear-facing wheelchair restraint location, on the buses:

1. Back up to padded backrest as close as possible. Make sure chair handles or backpacks don't prevent backing up all the way.
2. Set wheelchair brakes and/or turn off power.
3. IMPORTANT: Pull black lap belt around and clip low across your lap (underneath armrests if possible; also attach shoulder belt if desired). Ask driver for assistance if necessary.

4. Let the driver know you are set and ready to go!
- Wheelchair user may request, or driver may require, frame securements (red straps) or facing forward, for additional safety.
- If using this location facing forward, frame securements are required, and lap/shoulder (black) belts are at passenger's option.
- If possible, 3-wheeled scooter users should transfer to a regular seat.

It is clear that the choices made are a first effort to address several different and sometimes conflicting objectives. AC Transit has played a pioneering role in trying to adapt the rear-facing position to ADA-compliant systems. Doing so has involved some complexity and uncertainty. First, European and Canadian use of the rear-facing position does not have to accommodate ADA-compliant securement systems. Second, ADA securement systems were designed for use in a forward-facing position. Third, there is inadequate knowledge of applicable dynamic forces. The choices made therefore involve compromises. AC Transit staff believe that it will sometime be necessary to review the rear-facing position design in light of experience at AC Transit or other transit systems that adopt it. Such review should be done after there has been more research to gain a better understanding concerning dynamic forces, design requirements, and appropriate system designs (Interview with Doug Cross, Accessible Services Manager, AC Transit).

REGULATORY STATUS—EUROPE, CANADA, AND AUSTRALIA

The principle of the rear-facing position as a safe means to accommodate wheelchairs on board standard transit buses is now fully accepted and has become the norm in European transit systems. This approach is also becoming accepted practice in Canada and Australia. The research has identified a number of standards and legal regulations that include a rear-facing system.

- French regulation on the Construction of Public Transportation Vehicles (1992),
- U.K. Disability Discrimination Act (1995) and the 1997 recommended specifications for the U.K. Disabled Persons Transport Advisory Committee (DPTAC),
- European Directives for Urban Buses (2001),
- Australian Disability Standards for Accessible Transport Guidelines (2002), and
- CSA Standard D435-02 for Accessible Transit Buses (2002).

French Regulation on the Construction of Public Transportation Vehicles

The French Ministerial Directive Concerning the Construction of Public Transportation Vehicles of 1982 was amended in July 1992 to specifically permit a rear-facing position. The amendment allows for a rear-facing position including

- One wheelchair position;
- A back panel that must be able to retain a wheelchair (without brakes applied) when the bus is submitted to a deceleration force of 5 m/s^2 (0.5 *g*);
- A handrail on the bus wall;
- A retractable rail (or other means) to limit any lateral movement of the wheelchair;
- Anti-slip material on the floor; and
- A label designating that the space is reserved for a wheelchair and a second label indicating that the wheelchair should face the rear of the vehicle, be backed up to the back panel, and have the brakes applied.

U.K. Disability Discrimination Act (1995) and the 1997 Recommended Specifications for the U.K. Disabled Persons Transport Advisory Committee

In 1993 in the United Kingdom, the DPTAC issued an initial statement of recommended specifications that focused on increasing accessibility for elderly and ambulatory disabled persons (*25*). The introduction of low-floor bus technology in the early 1990s led to pilot projects, such as that conducted by London Transport in 1994 in Hounslow. In turn, there was the gradual introduction of low-floor buses in regular service and widespread discussions within the DPTAC, the government, and the transit industry as to the best approach to accommodate wheelchairs on standard buses. The Disability Discrimination Act of 1995 required improved access to land-based transport (*26*). This was followed in 1997 by the DPTAC's *Recommended Specification for Low-Floor Buses* (*27*). The formal Public Service Vehicles Accessibility Regulations (Statutory Instrument 2000 No. 1970) were promulgated in 2000 (*28*). The regulations require the following:

- A wheelchair space not less than
  - 1.3 m (52 in.) measured in the longitudinal plane of the vehicle,
  - 0.75 m (30 in.) measured in the transverse plane of the vehicle, and
  - 1.5 m (60 in.) measured vertically from any part of the floor of the wheelchair space.
- A backrest with the following dimensions:
  - The bottom edge of a backrest shall be at a height of not less than 0.35 m (14 in.) and not more than 0.48 m (19.2 in.) measured vertically from the floor of the wheelchair space.
  - The top edge of a backrest shall be at a height of not less than 1.3 m (52 in.) measured vertically from the floor of the wheelchair space.

- The backrest should have a width of
  - not less than 0.27 m (10.8 in.) and not more than 0.42 m (16.8 in.) up to a height of 0.83 m (33.2 in.) measured vertically from the floor of the wheelchair space, and
  - not less than 0.27 m (10.8 in.) and not more than 0.3 m (12 in.) at heights exceeding 0.83 m (33.2 in.) measured vertically from the floor of the wheelchair space.
- The backrest shall be fitted at an angle of not less than 4° and not more than 8° to the vertical width.

- The backrest shall be capable of bearing a load of 2000 N applied for 2 s [This implies that the back panel must withstand an acceleration force of 0.75 *g* given the standard weight of a common wheelchair].
- A horizontal handrail, as specified.
- A clear lateral space of not less than 0.75 m (30 in.) shall be maintained.
- To restrict the lateral movement of the wheelchair, there shall be a distance not greater than 900 mm between any two of the following adjacent means of support fitted on each side of the wheelchair space:
  - A vertical stanchion,
  - A retractable rail,
  - A partition, or
  - The equipment fitted to the side wall.
- Any stanchion, retractable rail, partition, or side wall shall be capable of bearing a load of 1000 N.
- A sign stating "Please give up this seat for a wheelchair user" or equivalent.

Draft of European Directives for Urban Buses

In Europe, Guideline 2001/85/EG 01, relating to special provisions for vehicles used for the carriage of passengers and comprising more than eight seats in addition to the driver's seat, was adopted in November 2001. All member states have an obligation to provide detailed guidelines for their countries for rear-facing systems on low-floor buses by 2003.

Provisions are similar to those discussed previously, except that the back panel must resist a force of 250 daN ± 20 daN for 1.5 s (paragraph VII, 3.8.3 d). This represents an acceleration force of just under 1 *g*.

Australian Disability Standards for Accessible Transport Guidelines

In August 2002, the Disability Standards for Accessible Public Transport and accompanying Guidelines, which were developed under the Disability Discrimination Act of 1992 [Subsection 31 (1)], were passed into law by the Australian Parliament. These standards and guidelines set out for the first time the formal requirements for accessibility to all modes of public transport in Australia.

The Australian Disability Standards for Accessible Transport Guidelines require that buses with more than 32 seats provide 2 allocated spaces for wheelchairs. The disability standards use the minimum 0.8 by 1.3 m (32 by 52 in.) dimensions for the allocated space. Division 9.2 of the Guidelines addresses Restraints. Division 9.5 (Active and Passive Restraining Systems) states that "The Disability Standards recognise the use of both active and passive restraining systems."

In addition, Division 9.7 (Passive Restraining Systems) defines the rear-facing system in the following terms:

> (1) A passive restraining system contains movement of a wheelchair to within an allocated space. A vertical surface that restricts the movement of a wheelchair is an example of a passive restraint.
> (2) An operator may rely on the sides of a conveyance, or a padded rail, to act as passive restraints against excessive sideways movement of a mobility aid. The allocated space could be located behind a bulkhead to prevent forward movement. The passive restraints bounding an area of this kind would then prevent a wheelchair from rolling or tipping.

Canadian Standards Association Standard D435-02 for Accessible Transit Buses

In Canada, there are no formal regulations governing wheelchair securement systems on public transportation vehicles. However, the CSA, the main standards development organization in Canada, had developed in 1984, and then revised in 1992, a standard (CAN/CSA D409-92) to protect passengers using mobility aids when being transported in small vans, and special paratransit vehicles [of less than 7000 kg (15,400 lb)], used in specialized transit service (*29*). However, the introduction of low-floor buses in urban transit has enhanced the ability to make conventional public transit accessible for persons with mobility impairments, particularly to persons using mobility aids. The CSA was in the process of updating its 1992 accessible vehicle standard; however, it opted to develop a new, separate standard for large conventional transit buses, especially as a result of the significantly different acceleration forces experienced by small and large vehicles.

After lengthy consultations and discussions among representatives of the various stakeholders (transit systems, wheelchair user community, bus and component suppliers, etc.), in August 2002, the CSA published a new standard, Accessible Transit Buses (CSA D435-02) (*23*). It marked the first time in North America that a very detailed standard was developed for a rear-facing system for use on large urban buses. The CSA standards development process accepted that

- Acceleration forces experienced by large transit buses with a GVWR of 7000 kg or more are much smaller than on lighter vehicles (e.g., small buses, vans, special vehicles), owing to their larger mass and lower operating speeds.
- This standard is supported by evidence from transit systems on how well the practices have worked on large accessible transit buses both in Europe and in Canada.
- On large transit buses, mobility aid users can travel safely in a rear-facing position without securement systems, provided that adequate provision is made for the location and positioning of their mobility aids and they have operable brakes.

Section 7 of the CSA addresses rearward-facing securement systems. The following are highlights of this section:

- In a transit bus, an area should be made available that allows accommodation of a wheelchair and its user to face to the rear of the bus.
- The area for the wheelchair should have a back panel located at the end of the area facing the front of the bus, with the padded part facing the rear, and centered laterally in the area.
- A horizontal handrail should be provided along the bus wall at a height of from 28 to 39.4 in. (700 to 1000 mm), not protruding horizontally more than 3.5 in. (90 mm) from the wall; have a diameter of 1.6 in. (40 mm); and have a clear space between the handrail and the bus wall of at least 1.4 in. (35 mm).
- A padded back panel should have a width between 10.5 and 16.5 in. (270 to 420 mm), a total height from floor to the top of the panel of 51 in. (1300 mm), and a clear dimension from floor to panel of between 13.8 and 19 in. (350 and 480 mm).
- The back panel should be angled in the vertical plane between 4° and 8°, with the top of the panel toward the front of the vehicle.
- The back panel should be flat within 1 in. (25 mm) and padded with closed-cell foam of at least 2 in. (50 mm).
- The back panel should not detach or show fractures when a force of 8000 N (1800 lbf) is applied for 30 s. This implies that the back panel must withstand a deceleration force of 3 *g*, given the design, weight of the wheelchair, and weight of the passenger.
- To prevent a wheelchair or scooter from moving or tipping into the aisle, a fixed aisle stanchion, a pivoting arm, a wall partition, or other means should be used.
- A clear envelope should be provided in the area of the wheelchair that is at least 29.5 in. (750 mm) wide laterally, when measured vertically from 28 to 39.4 in. (700 to 1000 mm) from the floor. To prevent lateral movement of the wheelchair or scooter, the lateral width of 35.5 in. (900 mm) should not be exceeded.
- Specific measurements for stanchions, retractable rails, partitions, and the side wall are provided in the standards. Any of these devices should be built to withstand a force of 1325 N (300 lbf) for 30 s through a block of 8 × 8 in. (200 × 200 mm) in the transverse direction at a vertical height of between 23.6 and 31.5 in. (600 and 800 mm), with a deflection of not more than 2 in. (50 mm), or deformation or damage.

CHAPTER FOUR

EXPERIENCE AND ISSUES RELATED TO THE REAR-FACING SYSTEM

CUSTOMER ACCEPTANCE

In Europe, rear-facing systems have existed for more than a decade, especially in Germany, the United Kingdom, and France. Consumers who have used the system appreciate the independent use of public transit buses. Contrary to the North American situation, where, in the 1980s, large transit buses were equipped with lifts for passengers using wheelchairs, European and Canadian transit systems avoided deployment of lift technology, and transportation for people in wheelchairs was provided primarily by specialized transit. The introduction of low-floor buses with a rear-facing system represented the necessary acceptable technological step forward for making public transit on conventional buses accessible for passengers with wheelchairs.

Interviews with bus operators in Germany, England, and France indicated that the rear-facing position is primarily occupied by standees, persons with strollers, and passengers with large baggage. Use by passengers with wheelchairs is minimal. It has also been observed that rear-facing systems are designed and applied differently in several cities; some European transit systems have provided only an open space with a padded bar at both ends, without a back panel, and some bus operators do not insist that passengers face to the rear in the compartment. According to observations by bus operators, the majority of passengers in wheelchairs are those who use manual and sports chairs—persons who therefore have good upper body strength and are able to hold onto the handrails in the compartment while riding the bus.

In Canada, rear-facing systems are relatively new; the first pilot programs began in the end of the 1990s in Hamilton, Kitchener, Montréal, and Victoria. The following information was received from transit systems as part of the discussions with their accessibility committees and from discussions with focus groups.

Initial reaction from consumers was often skeptical, especially from those passengers who had not yet used the system but believed that they could not travel facing toward the rear. Because wheelchair users are used to being secured with several straps on specialized transit service, some voiced concern about the proper level of safety. Many transit systems have helped to overcome skepticism among wheelchair users by holding open houses in their facilities for potential passengers to familiarize them with the use of ramps, interior maneuvering spaces, and the rear-facing position. Doing so has helped many consumers not only to get to know the systems, but also to confirm whether their mobility aid and personal skills and abilities would actually make access to a low-floor bus possible.

Consumer reaction, as related by transit system staff, has been positive. Initial concerns about facing toward the rear and safety generally appear to disappear once individuals use the system and experience firsthand the greater independence that the system provides

- The survey did not reveal any strong feedback received by transit system staff once the system was deployed.
- In BC Transit, on buses where both forward- and rear-facing options exist with the combi design, bus operators report that the rear-facing position is generally occupied first, indicating a preference by wheelchair passengers.
- BC Transit staff have also received positive personal comments about the rear-facing position on double-decker buses.
- Some systems that initially started with the forward-facing system (e.g., BC Transit and Grand River Transit) have successfully adopted the rear-facing system. The research did not identify any transit systems that have abandoned the rear-facing system in favor of the forward facing system.

Some users feel singled out by being the only passengers facing to the rear. This perception can be minimized if there are other seats in the bus facing to the rear, as is typical in rail transit and in European bus models. Rear seats have started to appear in some low-floor bus models being used in North America (e.g., Montréal, BC Transit, and new AC Transit buses). The rear-facing regular seats are typically positioned over the wheel wells to counter the reduction in seat capacity inherent in low-floor buses.

Some wheelchair users are still concerned about lateral stability and various approaches to allay these concerns are being explored.

Contrary to the situation among consumers in Europe, there appears to be a larger percentage of consumers in Canada who use scooters. Also, with an increasingly elderly population, this percentage will probably grow. At the same time, new four-wheel scooter designs are becoming longer and heavier, and they require a larger turning radius, thus creating a challenge for transit buses. However, the rear-facing design generally offers greater flexibility to accommodate noncommon wheelchairs.

TRANSIT SYSTEM EXPERIENCE

As stated previously, the rear-facing system is now the norm for most transit systems across Europe, including Germany, the United Kingdom, France, Poland, Austria, Spain, the Czech Republic, Sweden, and Belgium. It is expected to be used in the future by most European countries. The system is currently being deployed in Australia as well. As of 2002, six transit systems in Canada had implemented the system in their low-floor buses, with at least one other large system (i.e., Edmonton) adopting it in its next bus order. It is anticipated that, with the publishing of the CSA D435 standard, more systems will adopt the rear-facing system.

There are a number of advantages for wheelchair passengers and the transit system, as identified through the survey, case studies, and discussions with transit staff. The advantages for wheelchair passengers include

- Independent and dignified use of the system, without, for most wheelchair passengers, the need for assistance by others;
- Faster boarding and alighting, causing less embarrassment with respect to other bus passengers;
- Little need for physical contact with other persons;
- Adaptation to most commonly used wheelchairs and scooters, and even some noncommon wheelchairs, without the need for attachment points; and
- Less damage to the mobility aid from the securement system.

Advantages for the transit system include

- Reduction of dwell times at stops (under 1 min, as compared with more than 3 min with the forward-facing design),
- Little involvement of the bus operator,
- No injuries to or awkward working position for bus operators,
- Reduced maintenance cost for the system, and
- No maintenance of straps and hooks or need for replacement.

The primary disadvantages identified through the research are the following:

- The wheelchair passenger cannot see or identify the upcoming stop.
- The wheelchair passenger is facing toward the rear. This situation creates an image problem if he or she is the only passenger facing to the rear. In addition, there is a concern that some passengers may have difficulty facing this direction because of motion sickness, although no specific cases were identified during the research.
- The position may not prevent tip-overs of three-wheel scooters under severe braking, sharp turns, and curb hopping.

SAFETY EXPERIENCE AND APPROACHES TO PREVENT TIPPING UNDER SEVERE CONDITIONS

To provide uniform standards and guidelines throughout the European Union, Guideline 2001/85/EG was introduced in November 2001. It requires that all member states develop their own implementation guidelines by 2003. The main challenge relates to the prevention of wheelchairs from tipping under severe conditions. To prevent wheelchairs from tipping or moving into the aisle, transit systems in Europe have used three different approaches.

1. A fixed aisle stanchion (United Kingdom),
2. A wall-mounted retractable strap at waist height that can be attached to the wheelchair frame or armrest by placing it over the passenger’s lap (Germany), and
3. A pivoting armrest or extending rail attached to the back panel’s vertical support (France and United Kingdom).

Interviews with European experts indicate that the armrest and extending rail are sometimes structurally unreliable. Stanchions are preferred but tend to protrude into the bus aisle, impeding passenger movement.

In Canada, transit systems have expressed no significant safety concerns, according to the survey conducted for this project. They consider the rear-facing approach safe, provided that there are proper means installed to prevent wheelchairs and scooters from tipping into the aisle. Several approaches are being used.

- A fixed aisle stanchion (Montréal), or a stanchion in combination with other means (BC Transit, Ottawa, etc.);
- Two straps that are hooked together across the mobility aid, or attached directly to the mobility aid, with one strap positioned at the rear, seat height at aisle side, and the other on the wall in front of the chair (Victoria and municipal BC Transit systems); and
- A wall-mounted strap to be attached to the wheelchair or scooter (Ottawa).

All approaches have advantages and disadvantages.

- The aisle stanchion works well for manual, sports, and power chairs, but its location may interfere with

the passenger flow in the aisle and restrict maneuvering space for wheelchairs getting into and out of the rear-facing position. For three-wheel scooters it does not provide good protection, because the geometry of the scooter allows for easy sideways tipping, and the position of the fixed stanchion cannot prevent this.
- Hooking two retractable straps together seems to prevent the scooter from tipping or moving, but this approach is currently used by only one transit system, and results to date are limited. The disadvantage of this system is that, if requested by the passenger, it has to be applied by the bus operator, who must get out of his or her seat to attach and/or detach the straps if the passenger cannot do so independently. Because the straps supplement aisle stanchions, their use is not mandatory.
- The use of a wall-mounted retractable strap is not mandatory, and many passengers in a wheelchair or scooter may not be able to attach and/or detach the strap themselves, thus requiring operator involvement. In addition, the strap may not be correctly attached, rendering it ineffective.

Experiments were carried out by one transit system to use a pivoting armrest that would be attached to the vertical support of the back panel's aisle side. Although it seemed to prevent tipping with the armrest down parallel to the scooter's armrest, it presented a problem primarily for the passengers who had difficulty in reaching behind to move the armrest from its vertical stored position into the horizontal protecting position and vice versa. In addition, the transit system staff felt that this component could be misused or could create a hazard for other passengers.

Prevention of the mobility aid from tipping remains a challenge. At this point, there does not appear to be a solution in use that would both prevent tipping and not involve assistance by the bus operator or by an attendant or companion for some passengers.

However, it should be reiterated that, notwithstanding this concern, no serious safety incidents directly linked to rear-facing systems have been reported in Canada or in Europe. That is the case, although thousands of buses have now been operating with rear-facing positions—in many instances for more than a decade.

OTHER ISSUES

For the appropriate use of the rear-facing position, several conditions should be met whenever possible:

- Proximity of a passenger's back to the back panel, which requires wheelchair wheels and handles to be able to straddle the backrest;
- Application of brakes on manual chairs; and
- Turning off the power for scooters and power chairs, which will automatically apply their brakes.

A number of additional issues have been identified in the course of this research, as discussed in the following paragraphs.

Maneuvering Space and Location of Stanchions

One of the most challenging aspects for wheelchair access in a low-floor bus is to provide the necessary maneuvering space for the wheelchair or scooter to get into and out of the traveling position. Ideally, maneuvering in and out should be accomplished in one or two movements. The narrower the space, the more movements are required, the longer is the time spent to get into or out of the position, and the higher is the risk for interference with other passengers; for example, contact with the wheelchair and rolling over another passenger's toes. In addition, the location of stanchions creates a particular challenge; stanchions have proven valuable in limiting wheelchair tipping; however, if placed in ways to maximize wheelchair maneuvering space, they may impede the flow of other passengers in the aisle.

Loss of Seating Capacity and Design of Flip Seats

The loss of seating capacity on accessible buses presents a concern for the transit system. To minimize seat loss, many transit systems have installed two or three flip seats in the wheelchair area along the wall, or even a flip seat in the back panel of the rear-facing position. However, a flip seat located in the back panel may prevent the passenger from getting his or her back sufficiently close to the back panel. Tests should be carried out to verify the design. In some cases, it will be necessary to choose aisle-facing flip seats instead, to allow for sufficient traffic flow and maneuvering space for the wheelchair.

Dimensions and Position of Back Panel

There is still a diversity of approaches being used to dimension and position the back panel as seen in Table 3. The padded back panel should be dimensioned and positioned in such a way that it allows for close contact with the passenger's back. This requires that enough space on both sides and underneath the panel is available to clear the handles and large wheels of manual and sports chairs, as well as the rear ends of scooters and power chairs. A typical problem for scooters is that they may have bags or baskets attached to the rear that prevent the person from getting close to the back panel. Still, it is important that the

TABLE 3
DIMENSIONS FOR BACK PANELS IN SOME CANADIAN TRANSIT SYSTEMS

	BC Transit	Montréal STM	Ottawa OC Transpo
Total vertical panel height	1295 mm (51 in.)	1346 mm (53 in.)	1370 mm (54 in.)
Panel orientation	100% vertical, but with jump seat	100% vertical	100% vertical
Panel's floor clearance	355 mm (14 in.)	457 mm (18 in.)	420 mm (16.5 in.)
Panel width	305 mm (12 in.)	305 mm (12 in.)	305 mm (12 in.)
Panel thickness	76 mm (3 in.)	76 mm (3 in.)	76 mm (3 in.)

back panel act as the primary barrier for absorbing acceleration forces. It will be necessary to further review the ideal dimensions of the backrest after more practical activity has been experienced.

THE REAR-FACING POSITION AND THE ADA

The ADA and related guidelines and requirements issued by the Architectural and Transportation Barrier Compliance Board define a large number of requirements for accommodating and integrating persons with disabilities into society by providing accessible transportation (*1*). Several of these affect the use of the rear-facing position on U.S. transit buses.

In 2001, the FTA's Office of Civil Rights published a document on ADA Information (*30*) that identifies "Questions and Answers Concerning Common Wheelchairs and Public Transit." Some of the interpretation of the ADA is pertinent to the discussion of the rear-facing position.

- Securement Equipment to Be Provided—"Section 38.23 (d) of the DOT's ADA regulations requires all ADA-compliant vehicles to have a two-part securement system, one to secure the common wheelchair, and a seatbelt and shoulder harness for the wheelchair user. Section 38.23 (a) requires vehicles over 22 feet in length to have enough securement locations and devices to secure two common wheelchairs." [In addition, one of the two positions must be forward facing.]
- Local Policy Concerning Securement—"Transit operators may adopt a policy that allows common wheelchairs to ride unsecured. If the rider wishes his or her wheelchair to be secured, however, the operator's personnel must provide the required assistance."
- Common Wheelchairs That Are Difficult to Accommodate—"Section 37.165 (d) states that transit operators cannot refuse to accommodate a common wheelchair because the wheelchair cannot be secured to the driver's satisfaction."
- Acceleration Force Requirements of Securement System—"Securement systems on vehicles with GVWRs of 30,000 pounds or above, and their attachments to such vehicles, shall restrain a force in the forward longitudinal direction of up to 2,000 pounds per securement leg or clamping mechanism and a minimum of 4,000 pounds for each mobility aid. Securement systems on vehicles with GVWRs of up to 30,000 pounds, and their attachments to such vehicles, shall restrain a force in the forward longitudinal direction of up to 2,500 pounds per securement leg or clamping mechanism and a minimum of 5,000 pounds for each mobility aid" [49CFR 38.23 (d)].

In other words, for transit buses weighing more than 13 600 kg (30,000 lb), securement for mobility aids must withstand an acceleration force of 6.7 *g* (4,000 lb for a 600-lb combination of wheelchair and wheelchair passenger).

An assessment of these requirements would suggest that a rear-facing position can be provided under the ADA if the following conditions are met:

- The transit system establishes a policy stating that securement is not required in the rear-facing position. Alternatively, if it does not have a mandatory securement policy already in place, it may opt to not establish any policy.
- There must be two wheelchair positions, one of which must be forward facing.
- Both wheelchair positions must be equipped with ADA-compliant securement and occupant restraint equipment to accommodate the request of a passenger who wishes to be secured. Inclusion of an ADA-compliant securement system in a rear-facing position would be done to comply with the ADA, but without necessarily adding a safety benefit, because these systems have been designed for forward facing and most users will likely not use them.

Thus, the transit system must provide the equivalent of a Combi 2 design, as discussed earlier, but include ADA-compliant securement equipment for both positions. However, to date ADA-compliant systems have all been designed for use in forward-facing positions, not for rear-facing positions, and adapting them involves compromises among conflicting objectives. There should be further review of the rear-facing design from a systems point of view, based on transit system experience as well as on future research concerning dynamic forces, appropriate design requirements, and effective system designs. However, based on experiences elsewhere, it is likely, that many, if not most, wheelchair passengers will independently use the rear-facing position of the combi design without the securement straps. One of the potential benefits of the rear-facing position will be to accommodate common wheelchairs that are difficult to secure with strap systems.

DYNAMIC FORCES AND REQUIREMENTS

The forward-facing securement system in use today by U.S. transit operators complies with the ADA by requiring that two rear and two front tie-downs be attached to the wheelchair by the bus operator, who is responsible for the correct attachments. The securement guidelines and requirements issued by the Architectural and Transportation Barrier Compliance Board were developed based on research carried out by Battelle in the mid-1980s (*31*). Interviews with experts involved in this research indicated that the basis for evaluating the acceleration forces that the securement system would need to resist was based on work carried out by the NHTSA on school buses, on the requirements established for passenger car restraints systems (designed for deceleration forces of 20 *g*), and on the original Canadian CSA D409 Standard for Motor Vehicles for the Transportation of Persons with Physical Disabilities (*32*), designed for vehicles under 7000 kg (15,500 lb). There did not exist at the time any data related to the deceleration forces experienced by large transit buses.

This situation led to the ADA requirement of a 4,000-lb (or 6.7-*g*) force mentioned previously. The securement systems designed to meet this stringent requirement are complex, involving separate securement straps for the wheelchair, plus restraint belts for the wheelchair occupant. Although very secure in protecting the occupant, when properly used their design has created practical challenges for transit agencies and for wheelchairs users, as discussed.

A growing body of research has been emerging over the last decade that explores the actual deceleration forces experienced on large buses. It is not surprising that this research indicates that standard buses, with their large mass, experience substantially lower deceleration forces than do smaller lighter-weight vehicles.

First, the German research (*12*), outlined in chapter two, found that deceleration forces for transit buses under normal operating conditions were in the order of 0.24 *g*. The French research conducted for COST 322 used deceleration forces of 0.4 to 1 *g* as part of their securement system testing (*17*,*18*).

Subsequent research in Ontario was conducted by the Ministry of Transportation of Ontario (*33*). The tests involved operating a 12-m (40-ft) low-floor bus at speeds up to 50 km/h, and in maneuvers involving severe acceleration, severe braking, and lane changing. Maximum dynamic forces recorded were 0.65 *g* in straight-line braking at 50 km/h and 0.3 *g* for evasive maneuvering.

Most recently, a major new initiative on transportation for individuals with disabilities has been sponsored by the U.S. Department of Education's National Institute of Disability and Rehabilitation Research, through the creation of the Rehabilitation Engineering Research Center (RERC) on Wheelchair Transportation Safety. One of the recent research efforts carried out by the RERC has focused on wheelchair protection in buses, involving a comprehensive review of existing research on bus safety. The various preliminary findings of the RERC study (*34*) included the following:

- There is very little published information on transit bus safety and crash environment. There is no information to suggest that wheelchair passengers face undue risks aboard transit buses. The focus of most reported wheelchair incidents has been on noncollision events in which an inappropriately secured wheelchair passenger or unrestrained rider was injured.
- The few reports of severe bus passenger injury, coupled with no reports of severe wheelchair passenger injury, suggest that severe bus crashes are uncommon. Because there are very few wheelchair passengers relative to other passengers, it is not surprising that severe bus crashes involving wheelchair passenger injuries have not been reported. Despite serious deficiencies in bus crash reporting systems, it is very unlikely that there have been substantial numbers of wheelchair passengers injured in bus crashes.
- Much more information was found for more commonly occurring noncollision incidents. Noncollision incidents have been the focus of research efforts designed to characterize the *g*-levels associated with vehicle motion in normal operation and during evasive maneuvers. Reported deceleration and acceleration levels range from 0.3 to 0.8 *g*.
- This study found little justification for the ADA-mandated level of frontal impact protection in regard to published data on crashes and injuries. There were no reported analyses of actual crashes, nor reports of severe crashes equivalent to the 32-km/h, 8- to 10-*g* frontal barrier crash that formed the basis for the ADA Wheelchair Tiedown and Occupant Restraint System requirements.
- The results of the RERC study indicated that protection at the 1 *g* level is more justifiable than at the ADA-implied 8- to 10-*g* level. However, further investigation of the rare transit bus crashes that exceed 1 *g* is warranted. Such information would facilitate the development of an improved system that would better balance the need for occupant protection with the needs for efficiency, convenience, user acceptance, and cost.

The findings from these various studies need to be compared with the requirements with respect to acceleration forces found in different regulations or standards.

- ADA (1990), 6.7 *g*;
- France (1992), 0.5 *g*;
- UK (2000), 0.75 *g*;
- European Union (2001), 1 *g*;
- CSA D435 (2002), 3 *g*; and
- Australia (2002), No requirement with respect to deceleration forces.

It is clear that significant differences underlie these requirements. Europeans tend to view the topic as one of providing safety to the wheelchair passenger under severe operating conditions, but equivalent to the levels of safety provided to other passengers (particularly standees). The ADA requirement provides a high level of confidence of the wheelchair passenger's survival in a frontal crash situation, but it uses a safety standard that far exceeds levels of safety for other passengers. As revealed in the interview with Alan Little, Manager, Conventional and Custom Fleet, BC Transit, and member of the CSA D435 Technical Committee, the CSA requirement is a compromise between these two perspectives. It sets a requirement for acceleration forces that is lower than those in the ADA, in recognition of the lower acceleration forces of large buses. However, it provides a somewhat higher safety margin than those required in Europe. The requirement can still be met relatively simply and accommodates the flexibility offered by the rear-facing position.

Research has yet to determine what are the acceleration forces experienced by transit buses in freeway operation or in crash situations.

APPLICATION TO BUS RAPID TRANSIT

The FTA has been actively encouraging transit systems to consider implementation of BRT systems, in particular as an alternative to light rail. However, BRT systems involve high-frequency, large-capacity vehicles, operating in tight corridors; expectations of high levels of service reliability; and short dwell times. Current securement practice using the complex four-strap system is likely to be a source of disruption to BRT systems.

The rear-facing system may offer a number of potential benefits with respect to transit systems implementing BRT, including the following:

- Significantly decreased dwell times when boarding and positioning a wheelchair passenger (from more than 3 min in a majority of cases to less than 1 min in a majority of cases);
- The ability to accommodate in a more timely manner those common wheelchairs that are difficult to accommodate, or even noncommon wheelchairs (these represent the greatest source of dwell time);
- The ability to better accommodate passengers with large objects, such as parcels, strollers, and bicycles, and in a timelier manner—the rear-facing position in Europe is more commonly used by persons with strollers than with wheelchairs;
- Increased service reliability resulting from the elimination of the spikes in dwell times caused by the aforementioned sources of delay; and
- Reduced need for the bus operator to have to leave his or her seat—an even more significant benefit in BRT service that is anticipating the use of articulated buses carrying large numbers of people.

Transit systems that have high-capacity service with heavy loadings (e.g., Germany and Montréal) have typically positioned the wheelchair position(s) across from the rear door. Doing so greatly increases maneuverability for the wheelchair passenger who does not have to make the sharp turns and tight maneuvers required in a front-door access and passage between the front wheel wells. A rear-door access and location for the wheelchair thus decreases dwell time required for boarding and positioning. This may be very attractive to meet BRT system requirements and is the approach being adopted by AC Transit. However, it raises three considerations for U.S. BRT systems:

- Is the design of the BRT system such that rear-door access by wheelchairs is easily achieved? Systems that are being designed with rail-type standards (e.g., precision docking, high platforms, and level boarding) may be more easily able to fulfill this requirement than is arterial-based service, in which parallel approaches to stations may be hindered by illegally parked cars. Cooperation of local authorities responsible for street design and strict enforcement of no-parking regulations will become essential in the latter case.
- The distance that the bus operator must walk for rear-door access and wheelchair position will be greater if the consumers request assistance to position themselves, thus increasing dwell times.
- Fare collection from wheelchair passengers using a rear-door access may pose a challenge.

CHAPTER FIVE

CONCLUSIONS

The objective of this synthesis of transit practice was to survey current practice with respect to the use of the rear-facing position for accommodating "common wheelchairs" [as defined by the Americans with Disabilities Act (ADA)] on large transit buses [more than 13 600 kg (30,000 lb)], and to identify pertinent issues related to the transferability to the U.S. context.

The synthesis observed that over the last decade the rear-facing approach to accommodating wheelchairs on large transit buses has moved from its use in a few leader transit systems to widespread adoption by an ever-growing number of transit systems around the world. This adoption by the transit industry abroad is being accompanied, or in some cases spurred on, by the inclusion and definition of this approach in legislation, regulations, and standards in many countries.

The synthesis included a review of literature from many sources and countries, a survey of all the Canadian transit systems that have adopted the rear-facing system, case studies, and interviews with experts in several countries. The following elements were observed among Canadian and European transit systems that have adopted the rear-facing position:

- An accessible path from the service door to the wheelchair position;
- For rear-facing positions accessed through the front door, enough floor space to back into the position and then execute a 180˚ turn when exiting (including floor space under seats overlapping the maneuvering space of the mobility aids);
- For rear-facing positions accessed through middle doors, enough floor space to turn 90° and back into the position and then execute a 90˚ turn when exiting (including floor space under seats overlapping the maneuvering space of mobility aids);
- A designated floor space (although wheelchair dimensions vary);
- A load-bearing back panel that allows proximity of a passenger's back to the back panel, which requires that wheelchair wheels and handlebars be able to straddle the backrest (although dimensions and design characteristics with respect to deceleration forces vary);
- A vertical aisle stanchion, wall-mounted lateral straps, or other means to prevent the wheelchair or scooter from sliding or tipping into the aisle;
- A horizontal handrail along the bus wall;
- A stop request button with a separate signal displayed at the operator's workstation;
- A visual stop display that can be seen by the wheelchair passenger; and
- A process for consulting with users, through advisory committees or focus groups, before adoption of this approach.

The review, survey, and consultations have helped to identify a number of the benefits derived from the rear-facing position. Benefits for wheelchair passengers include

- Independent and dignified use of the system;
- Faster boarding and alighting;
- Limited need for physical contact with other persons, such as the bus operator;
- Adaptation to the most commonly used wheelchairs and scooters, and even some noncommon wheelchairs, without the need for attachment points; and
- Less damage to the mobility aid from the securement system.

Benefits for the transit system include

- Reduced dwell times at stops;
- Limited involvement of bus operator;
- No injuries to or awkward working position for bus operators; and
- Decreased maintenance costs for the system.

Such benefits clearly make this approach particularly attractive to transit systems implementing Bus Rapid Transit systems, including those in the United States, provided that certain conditions are met, given their requirements for short dwell times; high-frequency, large-capacity vehicles operating in tight corridors; and expectations of high levels of service reliability.

Nonetheless, a number of challenges remain with respect to the rear-facing system including

- The need to better understand and determine a level of safety for all passengers on board transit buses, including standees and those using mobility aids.
- The need to better understand the dynamic forces for different size transit buses under different operating speeds and conditions (e.g., acceleration on a steep hill) and crash conditions.
- The need to evaluate the diverse dimensions and design characteristics being put forward for the space

itself, the back panel, and other components (e.g., stanchions, armrests, and handrails).

- The need to develop effective means to prevent scooters or wheelchairs from tipping or moving into the aisle without the assistance of bus operators.

Future study could also be undertaken

- To develop visual display systems in the bus for upcoming stops that are visible from a rear-facing position; and
- To conduct a general review of the rear-facing design from a systems perspective based on transit system experience and on future research concerning dynamic forces, appropriate design requirements, and effective system designs.

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APPENDIX A

Survey Forms

USE OF REAR-FACING POSITION FOR COMMON WHEELCHAIRS ON TRANSIT BUSES

TRB SYNTHESIS TOPIC SC-6

QUESTIONNAIRE FOR TRANSIT OPERATORS USING REAR-FACING POSITION

The purpose of this survey is to gather information on the experience of rear-facing securement systems for passengers traveling in wheelchairs on low-floor urban transit buses. This is part of a Synthesis of Practice being prepared for the U.S. Transportation Research Board. "Wheelchairs" in this questionnaire refer to manual, sports, and powered wheelchairs.

Transit System: ____

Date: ____

Contact name: ______________________________ Title: ____________________

Telephone: (   )______________________________ E-mail: ____________________

1. Description of transit system

1.1 Total bus fleet size: ______________________________

1.2 Number of low-floor buses in service: ______________________________

1.3 Number of lift-equipped buses: ______________________________

2. Number of wheelchair places per bus

2.1 Wheelchair places per standard bus — forward ( ) rear-facing ( )
combination rear/forward in one position ( )

2.2 Variations in fleet (please describe): ______________________________

____

3. Description of rear-facing systems

3.1 Floor space for wheelchair: length ____________ width ____________

3.2 Padded back/head support: ( )YES ( )NO

3.3 Aisle stanchion: ( )YES ( )NO

3.4 Flip-down armrest: ( )YES ( )NO

3.5 Is another mobility securement system provided? ( )YES ( )NO

3.5a Please describe: ______________________________

3.5b Is its use mandatory? ( )YES ( )NO

3.6 Is a passenger restraint system (e.g., lap belt) provided? ( )YES ( )NO

3.6a Is its use mandatory? ( )YES ( )NO

3.7 Flip seats in wheelchair area: ( )YES ( )NO

3.8 Priority seats in wheelchair area: ( )YES ( )NO

3.9 Stop request button: ( )YES ( )NO

3.10 Visual "Next Stop" display visible from rear-facing position: ( )YES ( )NO
3.11 Other rear-facing seats in bus: ( )YES ( )NO
3.12 Was rear-facing position installed by bus manufacturer? ( )YES ( )NO

4. Boarding systems on low-floor buses

4.1 Boarding/alighting through: ( ) front door ( ) center door
4.2 Boarding/alighting via: ( ) flip/hinged ramp ( ) sliding ramp

5. Driver's responsibility and training

5.1 Do drivers assist passengers using wheelchairs? ( )YES ( )NO

Comments:____

Do drivers receive training for transportation of passengers using wheelchairs? ( )YES ( )NO

5.2a Description: ____

6. Access policy

6.1 Are scooters allowed on board buses? ( )YES ( )NO
6.2 If wheelchair dimensions exceed common wheelchair envelope (length: 48 inches—120 cm; width: 29.5 inches—75 cm; turning radius: 36 inches—91 cm) will access be denied? ( )YES ( )NO
6.2a If YES, which alternative(s) will be provided? ______________________________

____

7. Operation

7.1 How many wheelchair passengers do you transport per bus per day? _______________
7.2 Please indicate the average <u>dwell time</u> for the boarding and positioning of a wheelchair passenger using the <u>rear-facing position</u>:
( ) less then 1 minute
( ) 1–2 minutes
( ) 2–3 minutes
( ) 3–4 minutes
7.2a If you used the forward-facing position previously, what was the average dwell time? ____________________

7.3 Do companions of wheelchair customers assisting with travel ride for free? ( )YES ( )NO

7.4 If boarding is through center door, how do wheelchair customers pay their bus fare?
( ) cash in farebox/pass to operator ( ) free of charge ( ) honor system

8. Customer feedback

8.1 Do you have an accessibility committee? ( )YES ( )NO
8.2 If so, did you preview the system with the committee? ( )YES ( )NO

8.2a If YES, please describe ____________________________________

____

8.3 Did you conduct any focus groups prior to implementation? ( )YES ( )NO
8.4 Have you had any passenger comments concerning the rear-facing position? ( )YES ( )NO

Positive ____

Negative ____

9. Customer safety

9.1 Have you had any safety incidents involving customers in wheelchairs using the rear-facing position? ( )YES ( )NO

9.2 If YES, please describe____

____

9.3 Have you done any safety-related tests (severe operations, crash, sled, or other) with low-floor buses and rear-facing wheelchair positions? ( )YES ( )NO

9.4 Could you share the results of these tests? ( )YES ( )NO

9.5 Do you have any safety concerns? ____

____

10. Comparison and other comments

10.1 Have you always used rear-facing positions since you have carried mobility devices? ( )YES ( )NO

10.2 If not, how would you compare the forward and rear-facing positions?________________________

____

____

10.3 Other comments: ____

____

Thank You for Your Assistance.
For any questions, please contact:
Uwe Rutenberg (tel. 613-831-9339; rutenbrg@magma.ca) or
Brendon Hemily (tel. 416-466-5635; brendon.hemily@sympatico.ca)

Please return Survey by Fax by August 2, 2002 to U. Rutenberg
by Fax (613) 831-9337 or by e-mail (rutenbrg@magma.ca)

SUJET DE SYNTHESE SC-6 DU TRB

UTILISATION DU POSITIONNEMENT VERS L'ARRIERE POUR ACCOMMODER LES AIDES A LA MOBILITE SUR LES AUTOBUS DE TRANSPORT EN COMMUN

QUESTIONNAIRE À L'INTENTION DES RÉSEAUX DE TRANSPORT EN COMMUN

Objectif : L'objectif de cette enquête est de connaître l'expérience des réseaux de transport en commun concernant l'utilisation du positionnement vers l'arrière pour les clients en fauteuils roulants et scooters à bord d'autobus urbains. Ceci fait partie d'une étude de synthèse préparé pour le U.S. Transportation Research Board. Il est à noter que dans ce questionnaire, «fauteuil roulant» s'applique aux fauteuils roulants manuels, électriques et de type sport.

Réseau de transport en commun : ____

Date: ____

Nom de contact: ________________________ Titre ________________________

Téléphone:________________________ E-mail:________________________

1. Description du réseau

1.1 Flotte d'autobus (nombre total): ______________________

1.2 Nombre d'autobus à plancher surbaissé en service: ______________________

1.3 Nombre d'autobus équipés de lift:______________________

2. Nombre d'emplacements pour fauteuil roulant par autobus

2.1 Emplacements (nombre) par autobus standard Vers l'avant ( ) Vers l'arrière ( )
Emplacements (nombre) avec positionnement arrière-avant combiné ( )

2.2 Variations dans la flotte (veuillez décrire): ______________________

____

3. Description des emplacements orientés vers l'arrière

3.1 Dimensions de l'emplacement: longueur ______________ largeur ______________

3.2 Support arrière d'appui-tête rembourré: ( )OUI ( )NON

3.3 Poteau vertical du côté de l'allée: ( )OUI ( )NON

3.4 Barre horizontale basculante: ( )OUI ( )NON

3.5 Est-ce qu'il y a un autre système d'attache pour fauteuil roulant? ( )OUI ( )NON

3.5a Veuillez décrire: ______________________

____

3.5b Est-ce que son utilisation est obligatoire? ( )OUI ( )NON

3.6 Est-ce qu'il y a un système de retenu pour le passager (par ex. ceinture au niveau de la taille)? ( )OUI ( )NON

3.6a Est-ce que son utilisation est obligatoire? ( )OUI ( )NON

3.7 Y-a-t-il des strapontins dans l'emplacement ( )OUI ( )NON

3.8 Y-a-t-il des sièges réservés aux personnes âgées dans l'emplacement ( )OUI ( )NON

3.9 Bouton pour appel d'arrêt ( )OUI ( )NON

3.10 Indicateur de "demande d'arrêt" visible de l'emplacement ( )OUI ( )NON

3.11 Y-a-t-il d'autres sièges orientés vers l'arrière dans l'autobus ( )OUI ( )NON

3.12 L'aménagement de l'emplacement a-t-il été fait par le manufacturier de l'autobus? ( )OUI ( )NON

4. Systèmes d'embarquement

4.1 Montée/descente par: ( ) la porte avant ( ) la porte centrale

4.2 Montée/descente via: ( ) rampe basculante ( ) rampe à coulisse

5. Responsabilité et formation du chauffeur

5.1 Le chauffeur aide-t-il le client en fauteuil roulant? ( )OUI ( )NON

5.1a Commentaires ______________________

5.2 Le chauffeur reçoit-il une formation concernant le transport des clients en fauteuil roulant? ( )OUI ( )NON

5.2a Description ______________________

6. Politique d'accès

6.1 Est-ce que les scooters sont permis à bord? ( )OUI ( )NON

6.2 Si un fauteuil roulant dépasse les dimensions communes (120 cm de long, 75 cm de large, 91 cm de rayon de tournant), son accès est-il défendu? ( )OUI ( )NON

6.2a Si oui, quelles alternatives sont offertes? ______________________

7. Exploitation

7.1 Combien de clients en fauteuil roulant sont transportés par jour par autobus? ______________

7.2 Quel est le <u>temps d'arrêt moyen</u> pour l'autobus pour la montée et le positionnement du client en fauteuil roulant utilisant <u>l'emplacement vers l'arrière</u>

( ) moins d'une minute
( ) 1–2 minutes
( ) 2–3 minutes
( ) 3–4 minutes

7.2a Si vous utilisiez un emplacement vers l'avant auparavant, quel avait été le temps d'arrêt? ________________

____

7.3 Est-ce que les compagnons d'aide aux clients en fauteuil roulant voyagent gratuitement? ( )OUI ( )NON
7.4 Si l'accès pour fauteuils roulants se fait par la porte du centre, comment se fait le paiement?
( ) monnaie dans boîte de perception/laissez-passer au chauffeur
( ) voyage gratuit
( ) système d'honneur

8. Feedback des clients

8.1 Avez-vous un comité d'accessibilité? ( )OUI ( )NON
8.2 Si oui, leur avez-vous présenté l'approche avant sa mise en place? ( )OUI ( )NON
8.2a Veuillez décrire leur réaction: ________________________________

____

8.3 Avez-vous menés des groupes de discussion (focus group) sur l'approche avant sa mise en place? ( )OUI ( )NON
8.4 Avez-vous reçu des commentaires sur le positionnement vers l'arrière? ( )OUI ( )NON
Positifs ____

Négatifs ____

9. Sécurité des clients

9.1 Y-a-t-il eu des incidents de sécurité depuis la mise en place des emplacements pour fauteuils roulants orientés vers l'arrière? ( )OUI ( )NON
9.2 Si oui, veuillez décrire: ____

____

9.3 Avez-vous conduit des tests concernant la sécurité (conditions sévères d'exploitation, tests d'impacts, ou autres)? ( )OUI ( )NON
9.4 Pouvez-vous partager les résultats de ces tests? ( )OUI ( )NON
9.5 Avez-vous des soucis avec cette approche au niveau de la sécurité des clients?

____

____

10. Comparaison et autres commentaires

10.1 Avez-vous toujours utiliser le positionnement vers l'arrière depuis la mise en place d'autobus accessibles? ( )OUI ( )NON
10.2 Si non, comment comparez-vous les deux approches: vers l'avant et vers l'arrière?

____

10.3 Autres commentaires: ____

____

Merci pour votre aide avec cette enquête.
Si vous avez des questions, n'hésitez-pas à nous contacter
Brendon Hemily (tel : 416-466-5635; brendon.hemily @sympatico.ca)
Uwe Rutenberg (tel : 613-831-9339; rutenbrg @magma.ca)

Veuillez renvoyer l'enquête avant <u>le 2 août, 2002</u>
à Uwe Rutenberg par fax (613) 831-9337 ou par e-mail (rutenbrg@magma.ca)

APPENDIX B

Contacts

Transit Systems Contacted

- BC Transit (including Victoria Regional Transit System and the municipal transit systems in the province of British Columbia)
- Grand River Transit (Kitchener, Ontario)
- Hamilton Street Railway
- OC Transpo (Ottawa, Ontario)
- Mississauga Transit
- Société de Transport de Montréal
- Edmonton Transit System
- Alameda–Contra Costa Transit District (AC Transit)

Experts Contacted

United Kingdom

- Dr. C.G.B. (Kit) Mitchell, Transport Scientist and Engineer, former Director, Research Division, Transport Research Laboratory
- Andrew Braddock, Head of Access & Mobility, Transport for London
- Donald Macdonald, Mobility and Inclusion Unit, Department of the Environment, Transport, and the Regions (DETR)
- Colin Copeland, Technical Executive, Confederation of Passenger Transport

France

- Maryvonne Dejeammes, Project Manager, Centre d'études sur les réseaux, les transports, l'urbanisme, et les constructions publiques (CERTU)
- Christiane Briaux-Trouverie, Consultante, former Chairperson of the Working Group on Bus Accessibility of the Comité de liaison pour le transport des personnes handicapées (COLITRAH)

Germany

- Dr. Ing. Friedhelm Blennemann, STUVA, Cologne, Germany

Sweden

- Jan Petzall, Swedish National Road and Transport Research Institute, Lund Institute for Technology, Lund, Sweden

United States

- Doug Cross, Accessible Services Manager, AC Transit
- Rolland King, Consultant, former Director, Transportation Safety Group, Battelle
- Alan Little, former Manager of Conventional and Custom Fleet, BC Transit
- Dr. Greg Shaw, Center for Applied Biomechanics, Department of Mechanical and Aerospace Engineering, University of Virginia

Abbreviations used without definition in TRB Publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation