

STANDARDS RESEARCH

The Effects of Powered Wheelchairs and Related Powered Mobility Devices on Loading and Design Requirements for B355 Platform Lifts

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Table of Contents

Executive Summary 5

1 Introduction 7

2 Methods 8

2.1 Environmental Scan of Canadian and International Authorities 8

2.2 Review of Scientific and Grey Literature 8

2.3 Interviews with Subject Matter Experts 9

2.4 Focus Groups with End Users 9

2.5 Online Survey 9

3 Results 10

3.1 Environmental Scan and Review 10

3.1.1 Standards 10

3.1.2 Mobility Devices 11

3.1.3 Incidents, Accidents and Safety Considerations 16

3.1.4 Key Takeaways 17

3.2 Interviews with Subject Matter Experts 17

3.2.1 Context-driven Standards 17

3.2.2 Space Constraints 18

3.2.3 Maneuvering 19

3.2.4 Safety 20

3.2.5 Key Takeaways 21

3.3 Focus Groups with End Users 21

3.3.1 Demographics 21

3.3.2 Lift Design 22

3.3.3 Environment 28

3.3.4 Lift Maintenance 28

3.3.5 Accessibility 29

3.3.6 Lift-specific Feedback 29

3.3.7 Key Takeways 30

3.4 National Online Survey 30
3.4.1 Demographics 30
3.4.2 General Lift Questions 32
3.4.3 Lift-specific Information 33
3.4.4 Key Takeaways 35

4 Discussion 36
4.1 Context-driven Standardization 36
4.2 User-centred Design 36
4.3 Safety 37

5 Recommendations 37
5.1 General 37
5.2 Space and Load 37
5.3 Safety 38
5.4 Design 38

6 Limitations and Future Directions 39

7 Conclusions 40

References 41

Appendix A Interview Questions 43

Appendix B Summary of Studied Wheelchairs 45

Appendix C Summary of Wheelchairs and Add-ons 48

Appendix D List of Relevant Standards 50

Executive Summary

Power mobility devices present challenges for equipment covered in CSA B355-19, *Platform Lifts and Stair Lifts for Barrier-Free Access.* Power chairs exceed the weight limits previously established for traditional wheelchairs, and their larger size can be challenging to accommodate. Advanced models offer adjustment capabilities that drastically alter the centre of gravity of the chair/user system, introducing tipping hazards not previously considered. Rollaway protection may be insufficient to prevent the chair from accidentally falling from the lift.

Several types of power assist "add-on" components exist that turn the manual wheelchair into a power wheelchair, providing additional weight, mobility, and power that lift manufacturers may not have considered. The risk of unintended movement is also a factor.

The project objectives were to:

- Review power wheeled mobility devices for rated load, speed, and user positioning capabilities;
- Examine the effects of motorized mobility devices on loading and design requirements for CSA B355 equipment;
- Identify and review international standards related to CSA B355 lifts;
- Obtain feedback from end-users and subject matter experts on using powered mobility devices and CSA B355 equipment;
- Provide recommendations to consider for inclusion in the next edition of the standard.

The research included a literature review and environmental scan, interviews with subject matter experts, focus groups with platform lift stakeholders and a national survey of lift device users. The BCIT Research Ethics Board provided ethical approval for this research.

The scan and review identified a variety of platform lift and wheeled mobility devices, new research on anthropometry for wheeled mobility and built environment design factors, device specifications, and local, national, and international standards and statutes relevant to CSA B355. For simplicity, lift devices were categorized as vertical and inclined platform lifts, and mobility devices were identified and separated into five categories based on design similarities. The research identified load capacity, maximum speed and power, wheelchair and lift control inputs, wheelchair footprint and turning radius, and tipping and protrusion hazards as standard parameters requiring review. Accidents and incidents were also reviewed for additional safety considerations.

The Standards review revealed that the CSA B355 platform size, turning radius, and minimum rated loads are inadequate for many mobility devices. Some devices have an increased risk of tipping hazards from access ramps and safety flaps. Protrusions within the lift can interfere with chair controls, leading to inadvertent loss of control. Safety flaps are inadequate for some devices' maximum speed and power, as evident from accident reports. Lifts and lift controls are poorly labelled, and the need for continuous pressure to operate the lift is problematic for some users.

The needs for public vs residential lifts can be very different; hence there should be different requirements for each within the standard. With public lifts, there appears to be little forethought around device selection and there is often a deficiency in jurisdictional responsibility and enforcement around repairs and maintenance. The standards and building codes should be harmonized, and a legislative and regulatory body should make compliance mandatory and enforceable.

Suggested improvements include automated safety features to mitigate accidents. Greater attention to human factors and universal design is recommended; public lifts should be accessible to a range of users, and controls should be operable with one hand, without awkward hand/wrist postures and with limited force. They should not require a key for access. Nearly half of all users have a second person/animal with them or may carry additional equipment that should be considered in the lift design.

The research findings identified limitations within the current standard and made suggestions for improvement. While some findings were outside of the standards domain, by bringing some of the issues experienced by lift users to the attention of stakeholders, groups may be able to act on them and make continual improvements.



"By 2012, the Canadian Survey on Disability estimated that 288,800 community-dwelling Canadians aged 15 or older used mobility devices—about 1.0% of the total population."

1 Introduction

The United Nations declared 1981 the International Year of Disabled Persons, the theme of which was "full participation and equality" [1]. That year, a Special Parliamentary Committee on the Disabled and the Handicapped issued the first-ever report on barriers facing Canadians with disabilities [2]; and the Canadian Standards Association introduced CSA B355, *Platform lifts and stair lifts for barrier-free access* [3]. While power wheelchairs did exist, there were few; wheelchairs were limited in design and almost exclusively manual. As a result, residential and commercial access adaptations, such as wheelchair platform lifts, were designed around a typical manual wheelchair. However, in a 2011 US study of manual versus powered wheeled mobility devices in three senior residential settings, 60% of those assessed were power chair users, and another 10% were scooter users [4]. By 2012, the *Canadian Survey on Disability* estimated that 288,800 community-dwelling Canadians aged 15 or older used mobility devices—about 1.0% of the total population. Of those users, 108 550 used a mobility scooter, and 42 360 used a power wheelchair [5].

Wheelchairs today continue to evolve to meet user needs. In addition to the standard manual wheelchair, there are electric wheelchairs propelled by a motor and battery; ultralight manual sports wheelchairs; power sports chairs; standing wheelchairs; power and manual pediatric chairs; all-terrain chairs; and three-wheeled chairs for more stability and maneuverability over rough terrain. More recent advances incorporate improved functionality for manual chairs. They do so through motorized add-ons or advanced power chairs, like the iBOT, which incorporates gyroscopic technology, enabling the chair to balance and run on only two of its four wheels or climb stairs [6].

CSA B355 states the minimum requirements for designing, constructing, installing, and operating platform lifts and stair lifts that provide barrier-free access for persons with limited mobility. These devices enable or enhance travel between fixed points of a building or structure, including a private residence. Platform lifts make buildings more accessible, come in various styles and designs and can be installed in most indoor and outdoor spaces. They are a relatively low-cost, retrofit option for business owners, especially those based in historic buildings with steps or awkward entrances. Platform lifts also help to future-proof a home, providing access to upper floors and are small enough for installation in most residential buildings. The standard intends to help protect against the risk of accidents associated with the operation of such equipment [3].

The growing use of power chairs, scooters, and manual wheelchairs with power-assist devices presents challenges concerning the equipment covered in CSA B355. Powered wheelchairs could exceed previously established weight limits for CSA B355 equipment based on traditional wheelchair designs. They may also present additional hazards concerning damage to the vertical boundaries of the platform from possible

impact. The large size of some mobility devices can also be difficult to accommodate within existing design parameters. Newer models offer seat elevation and standing capabilities that drastically alter the chair's and user's centre of gravity, potentially presenting additional tipping hazards not currently considered in CSA B355. Manual wheelchairs have also evolved to include several types of power assist "add-on" components that, in effect, turn manual wheelchairs into powered wheelchairs. These advances provide additional mobility power (and added weight) to manual wheelchairs that lift manufacturers may not have considered. Requirements for rollaway protection (e.g., safety flaps) may also be insufficient to protect users in some power chairs, especially those designed to climb obstacles like curbs.

The main objectives for this research were to:

- Review power wheelchairs and related powered mobility devices for rated load, speed, and user positioning capabilities;
- Examine the effects of new motorized mobility devices on loading and design requirements for CSA B355 equipment;
- Identify and review international standards related to platform and stair lifts;
- Obtain feedback from end-users and subject matter experts on using powered mobility devices and CSA B355 equipment; and
- Provide recommendations for consideration by the CSA B355 technical committee for the next edition of the standard.

2 Methods

The study was conducted between September 2021 and June 2022. It employed a mixed-method approach that included an online review and environmental scan, interviews with subject matter experts (SMEs), focus groups (FGs) with lift stakeholders and a national survey of lift device users. The BCIT Research Ethics Board reviewed and approved this study.

2.1 Environmental Scan of Canadian and International Authorities

The focus of the environmental scan was to identify local, national, and international standards and guidelines similar to CSA B355. The following terms delineated the scope of the scan: “platform lift standards,” “platform lift safety”, “wheelchair lift standards”, “wheelchair lift codes”, and "wheelchair lift regulations”. Relevant statutes were reviewed for reference to platform lifts and wheeled mobility devices. The details were extracted and recorded when a regulatory document contained information significant to the study.

2.2 Review of Scientific and Grey Literature

The research team identified and agreed upon the initial parameters and strategy for the literature search, which included English language articles published from 2012 to 2022. Online bibliographic databases[1], standard search engines[2] and reports from SMEs provided information about existing platform lifts and related standards, wheeled mobility devices and add-on companies, relevant peer-reviewed articles and data sheets, and incident reports. Search terms included: “platform lift,” “wheelchair lift”, “accessible lift’, “vertical platform lift”, “platform stairlift” (stair lift), “inclined lift”, “advanced wheelchair”, “power chair parameters”, “bariatric wheelchair”, and “tilt-in-space chairs”. Grey literature included unpublished works, publicly available information and device specifications.

The search focused on accessible platform lift factors most impacted by changing wheelchair design. These included dimensions, safety flaps and gate height specifications, and an extensive search of existing power mobility devices and specifications related to rated load, speed, effects of new mobility devices, known limitations, and incident statistics. A summary[3] of findings from the online search was provided to the interviewer and FG attendees before their participation to ensure a similar baseline understanding of the essential elements.

1 EBSCOhost Academic Search Complete, Google Scholar, PubMed, Scopus, WebofScience
2 Google, Bing, Yandex
3 B355 Standard, types of platform lifts, mobility devices and add-ons

2.3 Interviews with Subject Matter Experts

Subject-matter experts were identified through an online search of suppliers and mobility specialists, discussion with project stakeholders and researcher contacts. The researchers conducted one-on-one interviews over Zoom and, although scheduled for 30min, many experts had much to contribute, and most interviews extended to 1 hour.

As previously noted, all interviewees observed a slide presentation outlining the research goals, basic information about the standard, and a summary of findings from the online review. Findings included general information and specifications around control inputs, weight, load capacity, footprint and other details for the following 11 mobility device designs:

- power assist wheels
- integrated power assist
- rear-end attachments
- front-end attachments
- passive front end
- stand up chairs
- Segway chairs
- bariatric wheelchairs
- stairclimbing chairs
- mobility scooters
- tilt-in-space wheelchairs

After receiving the background information, interviewees answered a series of open-ended questions (see Appendix A: Interview Questions) covering various topics on B355 lifts and the users and devices that might occupy them. Topics included:

- adaptation
- center of gravity/tipping hazards
- controls (wheelchair; lift)
- device categorization
- education
- environment/building code
- financial considerations
- footprint
- gates, doors, barriers
- maintenance
- maneuverability
- protrusions
- secondary users
- speed, power
- transitions/safety flap/slope
- turning radius
- vertical/ground clearance
- weather
- weight

All sessions were recorded, transcribed and reviewed by team members. The transcriptions were then coded and collapsed into a summary document.

2.4 Focus Groups with End Users

Researchers recruited FG participants via social media, flyers, and word of mouth from a list of previous study volunteers who had consented to contact them about future studies. Attendees included power wheelchair users and users of add-on devices. Each FG was carried out over 90 minutes using the Zoom video-conferencing service, and all sessions were recorded, transcribed and reviewed by team members. Transcriptions were coded and collapsed into a summary document.

To supplement findings from the FGs, researchers went into the community to find and observe lifts to improve their understanding of lift use. They documented observations and took photos of wayfinding, use practice, level of maintenance and learnability in the context of a higher learning campus (University of British Columbia), a rapid transit site and a medical office servicing young families.

2.5 Online Survey

An online survey was distributed to the attention of platform lift users to query their experience with platform lifts. Responders required 15-20 minutes to complete the survey, which included Likert scale and open-ended questions. In addition, they could submit photos and

videos of themselves using platform lifts to demonstrate perceived problem areas within these devices.

Survey access extended across Canada under the same recruitment methods as FG and SME strategies. Disability groups also shared the recruitment flyer through their newsletters, bulletin boards, and social media.

3 Results

3.1 Environmental Scan and Review

This section of the report presents the online search results, including other related standards, a description of B355 lift devices, mobility devices that a wheelchair user might use on these lifts, and any noted safety issues.

3.1.1 Standards

The research team identified the following standards as potentially relevant to B355 (see Appendix D for descriptions and additional standards considered):

- ASME A18.1, *Safety Standard for Platform Lifts and Stairway Chairlifts* [7]
- ADA 2010, *Standards for accessible design, Section 410 Platform Lifts* [8]
- CAN/CSA B651-18, *Accessible design for the built environment* [9]
- AS 3695.2:2019, *Wheelchairs, Part 2: Requirements and test methods for electrically powered wheelchairs (including mobility scooters)* [10]
- ISO 9386-1:2000, *Power-operated lifting platforms for persons with impaired mobility — Rules for safety, dimensions and functional operation — Part 1: Vertical lifting platform* [11]
- ISO 9386-2:2000, *Power-Operated Lifting Platforms for Persons with Impaired Mobility — Rules For Safety, Dimensions And Functional Operation — Part 2: Powered Stairlifts For Seated, Standing And Wheelchair Users Moving In An Inclined Plane* [12]

While other standards also refer to platform lifts, their sections typically reference one of the above standards or, at the time of this report, duplicated the information within those listed.

In the US, ASME A18.1-2000 significantly impacted lift device requirements and related standards by eliminating the use of keys to restrict lift access, increasing allowable vertical travel, strengthening ramps for improved safety, and permitting improved integration of lifts into existing stairways [13]. The most recent updates to the Standard (A18.1-2020) include [7]:

- a new "re-locatable" lift class with associated requirements;
- new limits to grabrail protrusion;
- extra edge protection for sidewalls;
- improved audio alarms that must be between 70 and 80dBA when 120" from the lift; and
- lifts in unoccupied areas provided a means of a two-way conversation with building or emergency personnel.

With increases in the size and weight of wheeled mobility devices, additional changes to the standards could include increasing platform space to 2000 mm^2 and increasing the minimum weight capacities of lifts [14]. The ASME A18.1 Standard also requires that all devices receive routine maintenance and inspections; failure to take action on repairs may be considered a violation of Federal laws.

ADA 2010 has been another essential regulation for accessible platform lifts in the US, providing public and commercial accessibility requirements [8]. Section 410 provides specific rules for using platform lifts. The guidelines harmonize with ICC A117.1, *Accessible and Usable Building and Facilities* [15], which is referenced by state building codes and is enforceable. Sections relevant to B355 include 305 and 404.2.4, which specify the floor space clearance requirement of 30" x 48" and sections 302, 303 and 404.2.5 give guidelines for surfaces and flooring, including the following requirements in the case of gaps:

- up to a ¼" gap – no edge treatments are needed;
- if between ¼" and ½" – a bevelled edge must accompany the change; and
- if greater than ½" – a ramp must be installed.

The recently updated CSA B651-18 [9] contains significant changes to accommodate manual and powered wheelchairs and scooters, dimensional updates from anthropometry research on wheeled mobility device users and changes to align with the National Building Code of Canada's section on accessible design [16]. It also includes specifications for accessible routes, including sloped access, door maneuvering and egress guides.

AS 3695.2:2019, *Wheelchairs, Part 2* is an Australian standard that specifies requirements and test methods for electrically powered wheelchairs [10]. These include electrically powered scooters having three or more wheels, with a maximum speed not exceeding 15 km/h and intended to carry one person of mass not greater than 300 kg. While this standard is not specific to platform lifts, it is worth noting the insight it provides into the design of international devices that may use them.

ISO 9386 was last reviewed in 2019 with no changes [11, 12]. The information within was not dissimilar to the current B355; however, as it originates from a worldwide federation of national standards bodies, the researchers felt it necessary to reference the current state of this important standard.

An SME suggested the following international standards. Members of the research team could not access them in time for this report; however, as they may contain helpful information, they are being included here for future reference.

- SS-EN 81-40:2020, Safety rules for the construction and installation of lifts – *Special lifts for the transport of persons and goods – Part 40: Stairlifts and inclined lifting platforms intended for persons with impaired mobility,* (Sweden) [17]. This is the Swedish standard for lifts and deals with safety requirements for the construction, manufacturing, installation, maintenance and dismantling of electrically operated stairlifts (chair, standing platform and wheelchair platform) affixed to a building structure, moving in an inclined plane and intended for use by persons with impaired mobility.
- GB/T 24806-2009, *Stairlifts for persons with impaired mobility* is the Chinese standard applicable to platform stairlifts [18].

The team identified five categories of lift devices from the review:

- fully enclosed lifts
- standard enclosed lifts
- unenclosed lifts
- straight inclined lifts
- turning inclined lifts

Each category was discussed with research participants in interviews and referenced in FGs. The discussion feedback indicated few relevant accessibility differences between the three enclosed/unenclosed lifts or the two inclined lifts. Thus, device categories were simplified into two categories, "Inclined or Stair Platform Lifts" and "Vertical Platform Lifts," for the project's final survey stage.

3.1.2 Mobility Devices

Categories for mobility devices have not been standardized; thus, there are variances between Canada, the US, and the EU. For this report, the 11 mobility device designs were collapsed into the following five categories based on design similarities to simplify the results of the review:

- power assist wheels and rear-end attachments
- front-end attachments
- tilt in space chairs (typically a tilting manual chair with an add-on)
- advance wheelchair design (includes power chairs, stair climbing and standing chairs)
- bariatric chairs and scooters

Within these categories, the interviews and FGs, supplemented by the peer and grey literature findings [19-25], identified the following areas as potential parameters requiring review within the current B355 standard. (See Appendix B and Appendix C for more detail):

- load capacity, overall weight
- maximum speed and power
- control input
- wheelchair footprint, turning radius

- tipping hazard (height of center of gravity/seat elevation)
- protrusion hazards

It should be noted that while the team aimed to be thorough with the review, a comprehensive search of all chair designs was beyond the project's scope. The goal was to provide a representative sample of existing designs and trends to be shared and verified with device experts and users in the interviews and FGs for inclusion in a review of the B355 standard.

The following sections summarize findings from each mobility device category for each parameter. For detailed findings, see Appendix B Summary of Studied Wheelchairs and Appendix C Summary of Wheelchairs and Add-ons.

3.1.2.1 Weight

Figure 1 summarizes weight statistics for each wheelchair category compared with CSA minimum-rated loads.

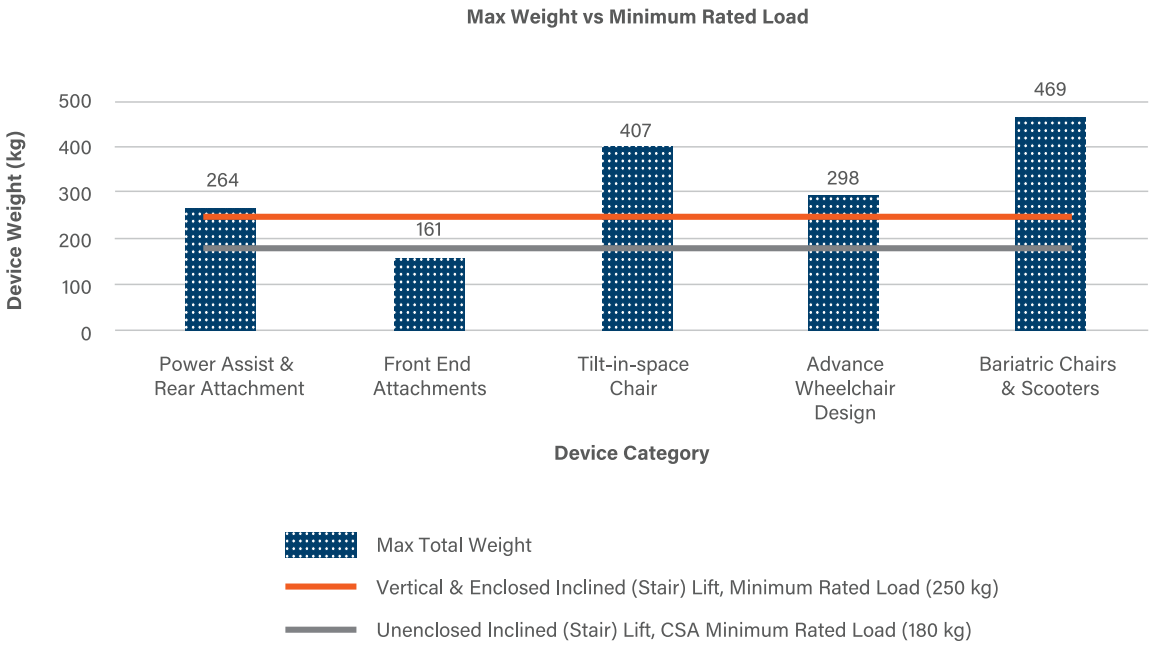
3.1.2.2 Dimensions and Footprint

Figure 2 and Figure 3 display the wheelchair categories in the study that fit within specific wheelchair dimensions, according to width and length, respectively.

In 2010, Steinfeld et al. presented a concise collection of wheeled mobility dimensions and device user anthropometry [23]. This data has been the basis for recent changes to CSA B651, *Accessible design for the built environment* [9]. While this data has been taken into consideration here, the current research also compares the largest device footprints found in the literature at the time of this study with the CSA lift standard requirements for minimum width and length (Figure 4).

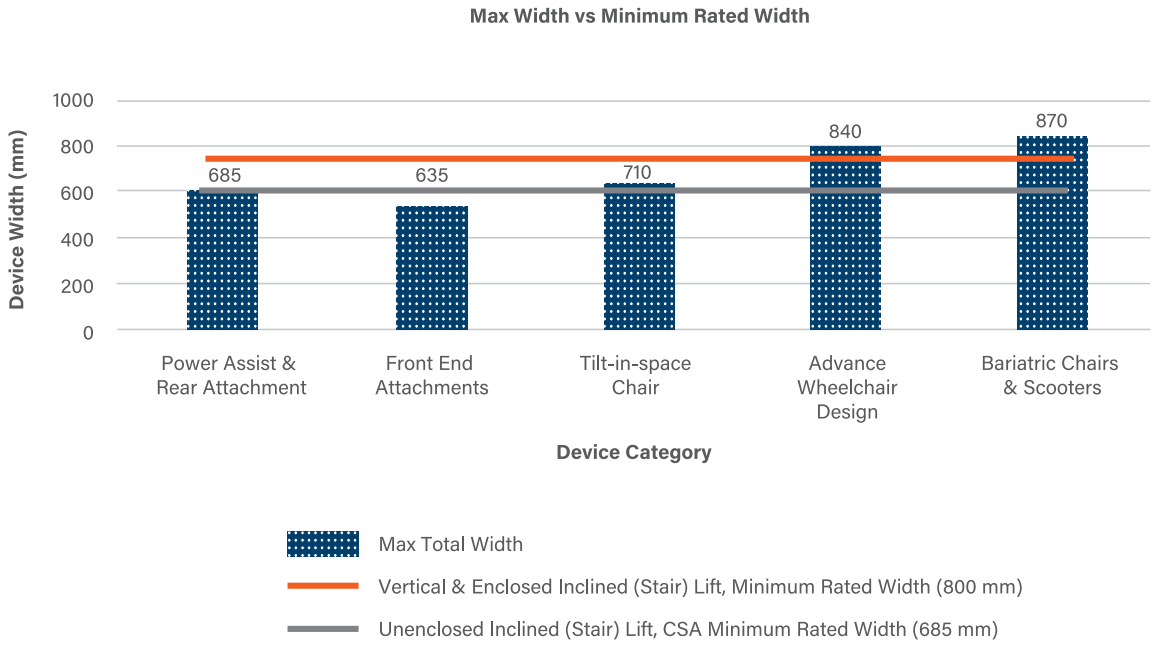
In Figure 5, one of our participants presents her chair with a front-end attachment. Front-end attachments can add up to 107 cm in additional length to the mobility device. As the image below demonstrates, this user cannot use the inclined lift without removing her front-end attachment.

Figure 1: Wheelchair weight* by category



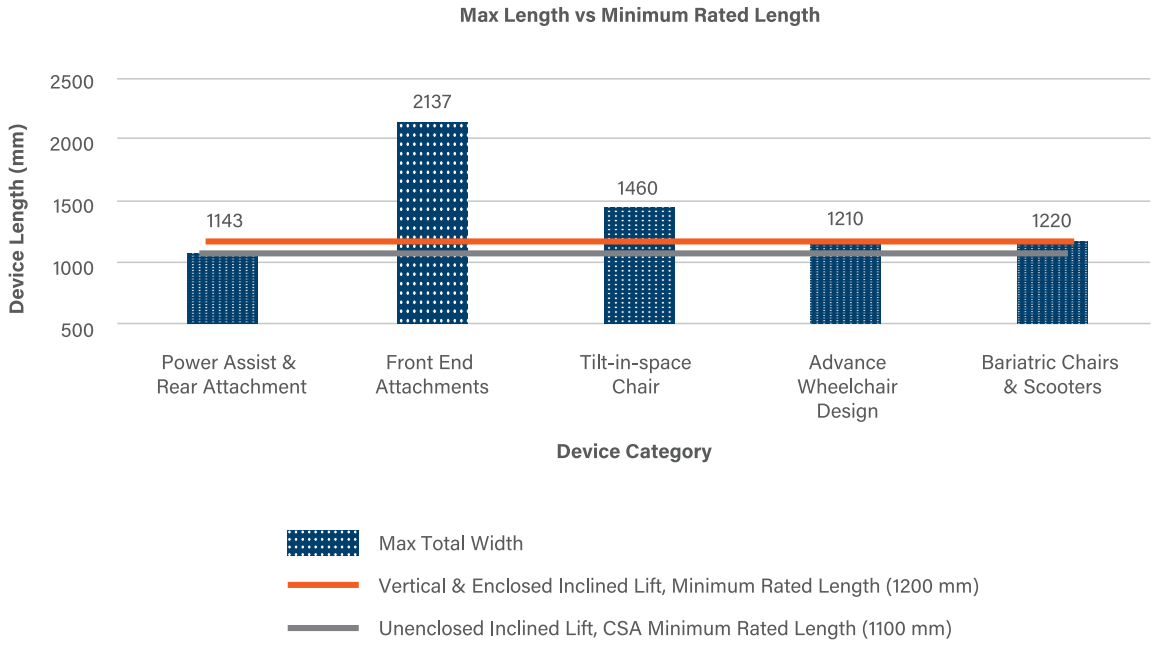
*Attachments have an average representative add-on weight of 27 kg. Total weight includes wheelchair+add-ons+load capacity.

Figure 2: Wheelchair width by category*



*Attachments have been given an average representative add-on width of 635 mm

Figure 3: Wheelchair length by category*



*Attachments have an average representative add-on length of 1067 mm. The tilt-in-space chair was in the upright position.

Figure 4: Tilt-in-space wheelchair dimensions (top and right dimensions, purple text) in the upright position compared to current CSA B355 minimums (bottom and left dimensions, black text)

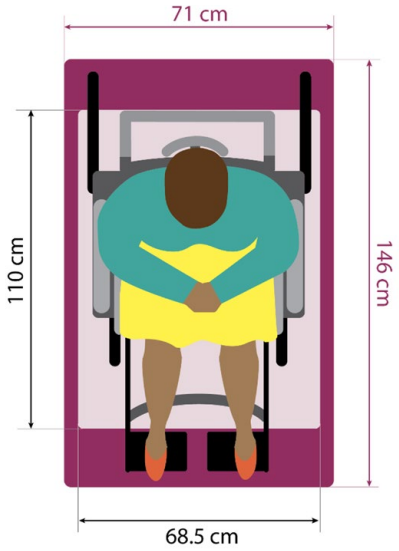


Figure 5: Chair with front-end attachment compared with lift length



3.1.2.3 Turning Space/Radius

Devices with the largest turning radii (i.e., tilt-in-space chairs and scooters) were compared with the CSA B651 standard minimum platform size. Revised accessibility standards for wheeled mobility devices now require a 1700 mm circle to accommodate a 180-degree turn for manual wheelchairs, power wheelchairs and scooters, an improvement from the previous 1500 mm requirement [9]. Scooters are less manoeuvrable than wheelchairs, often requiring a 3-point turn instead of turning in a full circle. The turning radius of a chair has implications for both lift ingress and egress, given the space constraints of the surrounding environment. Turning radius also impacts maneuverability from within lifts. A review of device specifications from a representative sample of tilt-in-space chairs presented a 1676 mm turning radius, while scooters presented a 1555 mm radius.

3.1.2.4 Center of Gravity

Center of gravity (COG) changes and tipping hazards are likely problematic for stair climbers and tilt-in-space chairs. The extended footprint of the tilt-in-space chairs is too long to fit in a lift. To reduce the space required, some users must change the seat or backrest and raise or lower the chair as needed. Changing the seat lift, seat tilt, or backrest recline consequently changes the COG of the chair-occupant system and increases the risk of tipping over, especially if done while moving, on an incline, or entering or exiting a lift.

3.1.2.5 Safety Flap Height

Safety flaps are solid barriers designed to perform as a ramp when in the down position or as a safety barrier in the upright position to prevent runaway wheelchair events. CSA B355-approved flaps must be a minimum of 150 mm in height in their guarding position and designed to withstand a force of 556 N applied on any 102 mm x 102 mm area without permanent deformation [3]. A review of the grey literature revealed lifts with flap heights ranging between 203 mm and 508 mm. Wheelchair users also indicate using them for tactile sensing when positioning within the lift. There is some concern that the wheeled mobility devices' power and speed capabilities may exceed the safety flap's stopping capabilities.

3.1.2.6 Speed and Power

Other factors to consider are the speed and power of powered mobility devices. Should the user move their device in error, the force applied to the safety flap may exceed its effectiveness and create the potential for falling off a lift. Hundreds of mobility devices are on the market, with new models and features becoming available each year. The research team elected to search grey literature for specifications on the maximum speed and power of currently available devices (see Appendix C: Summary of Wheelchairs and Add-ons). They found that most power chairs have a top-rated speed of 6.5 to 8 km/h; however, some more advanced chairs were capable of much more. Table 1 shows the maximum rated speed and power of powered devices. Stand-up devices presented the most power; front-end attachments had the fastest speed. Tilt-in-space chairs are typically manual with added power assistance; other tilting chairs are classified as power chairs. Some of the fastest mobility scooters currently available can travel up to 29 km/h. Most of these are considered recreational and are not classified as medical devices. Like the power wheelchair, the average scooter's top speed can range between 6.5 and 8 km/h.

Table 1: Max speed and power by device category

Device Category	Power (watts)	Max Speed (km/h)
Power assist & rear attachment	640.0	10.1
Front-end attachments	1620.0	30.0
Tilt-in-space	—	10.0
Advanced wheelchair design/power wheelchairs	3000.0	20.0
Bariatric chairs & scooters	419.0	13.8

3.1.2.7 Protrusion Hazards

Protrusion hazards are a reported concern that, although not prominent issues in the literature, have emerged multiple times in the study discussions. Personal belongings attached to the chair can get pinched or caught on the lift as it is moving and potentially tear off or tip the chair.

3.1.2.8 Controls

In updates to B355, it will be essential to consider the operation of the lifts as well as the devices used within them; therefore, this study references both wheelchair controls and the controls for the platform lifts.

3.1.2.8.1 Wheelchair Controls

Wheelchair controls can be anywhere on the chair or user and pose a safety risk if accidentally bumped while accessing a lift. Users can also lose control of their chairs, and there is little room for error when on the lifts. It is essential to appreciate all a user has to consider when using a lift to understand how easily an accident can occur.

Wheelchair controls are available in a wide range of shapes and sizes:

- The conventional gimbal knob joystick for the hands appears as the well-known mushroom stick; low, wide domes for weak hands; thin sticks for fingertips; u-shaped for finger and wrist; or the more compact stick, ball or cup controlled by the chin.
- For actuation by the head, the gimbal is on the headrest; the user pushes back on the headrest to move forward and either the left or right side for directional control. To back up, the user must activate another switch, push the headrest straight back, and then activate the switch again to move forward. The user may need several backward and forward movements to enter or exit the lift.
- Other controls include finger boxes, touchpads, switches activated by proximity rather than pressure, wafer boards mounted on a tray or used on the lap, tongue or sip'n'puff for control by mouth for those who are unable to use other parts of their body.
- There are also more complicated dynamic seat or control systems for postural support and stability and push rim controllers for integrated power assist.

As a safety precaution, it is general practice to turn off a power chair when using the lift. However, this does not always occur, nor does it eliminate error or potential for an accident when entering or exiting the lift. Loss of control of the chair while on a lift can cause it to tip over or fall off the lift or ramp, resulting in serious injury (See 3.1.3). Safety measures must be in place to help avoid such incidents.



"Platform lift access can be an incredibly complex series of movements for a mobility device user. It behooves the manufacturers to make lift controls as easy to use and safe as possible."

3.1.2.8.2 Platform Lift Controls

Vertical platform lifts have three important controls:

- Constant pressure controls – The user must continuously push and hold the button until the lift reaches the selected floor, where it will stop automatically.
- A key at the controls – The key must be in place to activate the control.
- A large red emergency button – This button stops the lift immediately when pushed in.

Platform lift access can be an incredibly complex series of movements for a mobility device user. It behooves the manufacturers to make lift controls as easy to use and safe as possible. The current B355 standards indicate that controls should be accessible to the user, may be located at any landing and shall be mounted anywhere between 890 to 1370 mm above the adjacent floor level [3]. The ADA states that the reach range should be between 380 and 1220 mm for an unobstructed user [8]; the newly updated CSA B651-18 states a range of 230 to 1400 mm for a side reach or 400 to 1200 mm for a forward reach [9]. These latter values are based on an anthropometric study of power chair and scooter users [23]. The ADA Standard section 309.4 also states "that operable parts shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate operable parts shall be 5 pounds (22.2 N) maximum" [8].

3.1.3 Incidents, Accidents and Safety Considerations

Cursory discussions with Technical Safety Standards Authority and Régie du bâtiment du Québec highlighted several serious accidents on lifts. Experts described users falling from the lifts when trying to straighten their chairs. Another incident described a secondary user falling due to poor lift maintenance. Other individual reports from internet sources and project stakeholders have identified the following areas of concern when reviewing safety considerations [26]:

- poor/insufficient management
- operator error
- lack of maintenance (periodic inspections)
- broken/unusable parts (e.g., safety switches/ emergency stop buttons, alarm bells)
- carriage misalignment with floors
- mechanical breakdowns and malfunctions
- space (e.g., lift too narrow, appropriate clearance around lift landing)
- ground/lift surface and protrusions (e.g., stable and slip-resistance area for a wheelchair to get on and off the lift)
- passenger safety
- accidents while loading or unloading, e.g., wheelchair falling/rolling off the platform surface

- accidents while storing lift
- being pinned inside or under a lift
- deaths and injuries

Based on this study's focus group and interview findings, was evident that many incidents go unreported.

3.1.4 Key Takeaways

- Lack of planning by lift owners (including building developers/architects, residential and commercial owners), related to unit repairs and maintenance, acceptance of jurisdictional responsibility and enforcement.
- Weight – Many mobility loads have exceeded the minimum rated loads of CSA B355-18.
- Dimensions – Many mobility loads have exceeded the minimum length and width (footprint) of CSA B355-18.
- Turning radius –The turning radius for larger mobility devices (tilt in space, scooters) exceeds the CSA B355-18 minimum platform size.
- For stair climber and tilt-in-space chairs, there may be tipping hazards, particularly on ingress and egress when using angled flaps or ramps.
- Safety flaps may not be adequate for maximum speed and power of some devices.
- Protrusions from chair may increase dimensional minimums.
- Operational controls should be operable with one hand, without awkward hand position and with limited force.
- Additional safety features should be in place to avoid errors in chair control.
- Reported incidents highlighted numerous safety concerns including accidents while loading/unloading/storing lift; user being pinned inside or under a lift and carriage misalignment with floors.

3.2 Interviews with Subject Matter Experts

One research team member interviewed fifteen SMEs to get the stakeholders' perspectives on wheelchair users. Those interviewed included people from the medical community, elevator and lift manufacturers, and specialists in providing and developing mobility devices and equipment. Not all topics reference B355 directly. However, most notes are pertinent to outstanding issues and thus have been retained and summarized for this report.

While feedback was offered on anticipated areas of the B355 standard that require revision, such as a desire for larger platforms driven by the increasing size of chairs, participants also emphasized the application context and a more holistic analysis of the usability of these devices. Experts interviewed felt the standard needed to consider all forms of chairs and focus more on universality, a broader, more inclusive range of disabilities and use practice.

3.2.1 Context-driven Standards

Residential lifts and lifts in public spaces are impacted differently by universally applied standards. Participants described significant differences in the economics, design, maintenance, and safety that call for enhanced universality and usability in public lifts serving a broad array of users compared to the personalization applied in residential settings. While prioritized less in the discussion, other considerations included revisiting indoor vs outdoor and new building vs retrofit lift applications and requirements.

3.2.1.1 Residential vs Public Lifts

Increasing minimum weight capacity and footprints comprehensively in the standard could impact the number of people who can afford or fit lifts into their private residences. Lift manufacturers and distributors offer people in private residences a range of products to address their individual needs and, thus, are viewed as a lower safety risk. Ensuring the correct installation through a certified professional could further limit risks in the home context.

Lifts designed for public spaces need to consider a broader range of users, chairs and use cases to ensure safe and effective use. There is an interface between the building itself and the lift, which, while not covered within the B355 standard, significantly impacts use, inclusion, safety, and usability. For example, the researchers found multiple sites where the location of a retrofit accessible lift was hard to find and/or located behind doors that were difficult to access. Sometimes, the lift area was dark, and the lighting was poorly maintained. Building owners, architects or developers can make purchasing decisions based on the minimum requirement of the building code. Lift manufacturers understand these limits and factor them into their design. Information gleaned from the interviews indicates that, in the case of public/commercial lifts, the manufacturers design the lifts to accommodate the range of devices, use practices and accessibility requirements of people using them. However, the purchasers (i.e., building owners or managers) decide on lift selection. Improved dialogue between the B355 standard and building code requirements would likely significantly improve lift accessibility, usability, and safety.

In the case of a private versus public lift, the ownership and responsibility for the device also has implications for the maintenance and corresponding safety of lifts. SMEs felt that public lifts were better maintained as there is often budgetary forecasting for maintenance costs and associated licensing programs to ensure lifts are kept in good working order in a public space.

3.2.1.2 Retrofit vs New Build

Increasing minimum requirements of lifts can have negative implications for lifts being retrofitted into existing structures due to spatial limitations. New builds have the potential to offer broader spatial considerations, informed by the standard, which could increase their safety, accessibility, and usability. Needs can also shift after a lift is installed, such as a residential user moving from a manual to a power chair.

3.2.1.3 Indoor/Outdoor Lifts

Weather can impact lift performance and requires different maintenance connected to weather-incurred damage. Lifts filled with snow need to be cleared and checked for seasonal damage.

3.2.2 Space Constraints

Experts responded that spaces that serve the public require a larger minimum footprint to accommodate a wide range of existing wheeled mobility devices and keep up with technological advances and trends. Furthermore, the dimensions of the entry and exit areas outside of lifts impact some larger chair users' ability to access the lift.

3.2.2.1 User(s) Dimensions

Experts understand that people are getting heavier as a population, including people using lifts [27]. In general, people carrying more weight also take up more space. People's bodies can also extend beyond the dimensions of how we understand the rectilinear box of a chair footprint. Some users require non-linear body alignments to support turned-out footrests, bent knees, deformities, hip abduction, and muscle tightness. Tilt chair lengths exceed the current B355 footprint minimums, sometimes causing users to remove their headrest, bend their legs, and reduce their chair tilt to fit, which raises their centre of gravity and gives them the uneasy feeling of instability, although they are now making some chairs with zero center-of-gravity shift resulting in improved positioning.

People using lifts are also often accompanied by a secondary user, whether that be a support animal, care aid, or companion that can support their advanced needs and operate the lift on their behalf. Making accommodations for secondary users increases the inclusivity and safety of those with advanced disabilities.

People travel with a range of personal items and devices such as oxygen tanks, ventilators, and feeding pumps, extending wheelchair footprints, and presenting safety hazards. Screens, push canes, armrests, footpads, and headrest stems were highlighted as protruding areas of the chair that can incur or cause damage. Personal items like backpacks extend the space a chair occupies and risk getting caught against moving walls and pulling on a user.

3.2.2.2 Mobility Device Variability

The width, length, and centre of gravity of the chair and its attachments have increasing variability. Experts feel lift manufacturers are responding to these changes, and

lifts are being produced to accommodate them. One SME shared that vertical enclosed lifts can carry up to 1400 lbs and outdoor platform lifts 800 lbs, although this is yet to be verified. Advanced wheelchair designs are also increasing overall chair weights with technology such as power tilt/recline, power legs, seat elevation, environmental controls and batteries.

Another of our experts commented that there are no existing standards for wheelchair "add-ons." While there is currently a standard under development for wheelchair add-ons, it is still in the initial development stages. A limiting factor is that there are many different styles of devices. Wheelchair add-ons can extend the form of a chair to mimic a 3-wheeled scooter, altering its speed and maneuverability and a user's ability to approach, fit and exit some lifts. Experts expressed an increased prevalence of power assists such as front-end attachments, which can be very long.

When considering weight minimums, it is essential to include the user-related dimensions and weights described above together with the device weights and dimensions. SMEs shared that, in their experience, most lift users do not have a strong awareness of their overall weight, which should be considered when revising the standard lift weight requirements. Again, it is also critical to consider the implication of changing the standards to impact residential buyers who can tailor purchases to their needs instead of the universality required of lifts in public spaces.

3.2.2.3 Lift Features

Features that extend into the lift, such as switches or keys, are prone to damage when users navigate these tight spaces. While offering a sense of safety, side panels and handrails can also protrude into the limited interior space and can be damaged or interfere with wheelchair controls.

3.2.3 Maneuvering

Experts shared that people often get stuck or lodged in lifts, unable to maneuver out. Directly connected to space, maneuverability in and around lifts represents a category where space, interface, and building design intersect.

3.2.3.1 Maneuvering Heavy Users

Heavier chairs can be difficult to move over inclines, creating an increased challenge for support staff. They are also described as having a high incidence of knocking controls against railings during attempts to maneuver into the lift.

3.2.3.2 Entry and Egress Maneuvers

Experts recommend that lifts be installed so that they do not encroach on required means of egress or entry, a sentiment echoed in the American Disabilities Act Standards [8]. The experience of encountering an impossible 90 degree turn on egress is a common issue. Chairs such as tilt-in-space, scooters and chairs with front-end attachments have larger turning radii and will more commonly use a 3-point turn [25]. Turning to line up to board the lift can be challenging for these users given this limitation, so wider entry and exits would improve maneuverability.

Scooter and power chair users often back into lifts and prefer not to have their back to the door. Users who need to maneuver in reverse upon exit have limited visibility and awareness of the environment. This issue is made more complex by the restrictions of a confined space with 90° degree egress. Exiting a lift and maneuvering from a tight space makes correction and navigation challenging. It can create a greater risk of error, such as accidentally going forward instead of the reverse.

3.2.3.3 Negotiating Doors and Controls

There is an interplay between a user's approach to a lift, engaging buttons, maneuvering a wheelchair to get out of the door swing path, potentially overcoming a transition and boarding the lift.

3.2.3.3.1 Controls Designed for Disability

Lift manufacturers must consider the user's mobility and dexterity impairments when designing lift controls. Factors such as button size, location, and force required to depress and maintain pressure to operate the lift all impact the user's requirement and ability to maneuver their chair. Depending on their hand dominance or general hand function, users may need first to maneuver to engage the controls, then



"Experts highlighted opportunities to improve safety, stating that most incidents occur because the user is unaware of the existing danger, either because they cannot see."

quickly reposition themselves for ease of entry or exit. Experts have also emphasized the need for contactless controls, such as voice commands, to allow for independent lift use by a broader range of users.

3.2.3.3.2 Door Motion

Related to 3.2.3.3.1, when the external lift controls are engaged, users must maneuver out of the door's path to allow it to open. Once the lift arrives and the door opens, they have a limited time to enter the lift or risk having to reposition themselves back to the button to re-open and attempt to approach it again. Experts prefer automated doors to improve the device's ergonomics; however, they represent an additional cost and are not a current code requirement. Better design, such as consideration of hinge placement and swing path, would reduce the multiple moves needed to get into the lift.

3.2.3.3.3 Wheelchair Controls

Interview respondents restated that wheelchair controls are vulnerable to accidental engagement from contact with protrusions when the user tries to enter or exit the lift. Platform handrails and barriers should never be the same height as wheelchair controls. Door motion can also cause wheelchair controls to engage erroneously. Moreover, some users are prone to unavoidable spasms that increase the potential to bump the wheelchair controls erroneously. Further efforts can be made to improve the platform lift design to limit such errors and ensure safety mechanisms are in place to limit the risk of injury.

3.2.4 Safety

Experts highlighted opportunities to improve safety, stating that most incidents occur because the user is unaware of the existing danger, either because they cannot see it, e.g., the rear wheels are not entirely on the lift, or the lift device does not have the necessary automated safety features built in to avoid an error.

3.2.4.1 Lift System Validates the Correct Use

An improved design would have automated safety features to avoid an error. Participating experts suggest that safety could be improved if users were made aware that:

- they are overweight for this device (e.g., by way of signage or alarms);
- they are not entirely inside the lift as it is difficult for the user to know if their rear casters have made it onto the lift;
- the door, flap, or barrier has not closed completely.

3.2.4.2 Implications of Powered Chairs on Safety

Powered chairs are faster and more powerful today, with some front-end attachments permitting speeds of over 30 km/hr. Users with a range of experiences and cognitive and physical abilities have different skill levels in driving their powered devices. While most experts did not express concerns about the user's ability to control the device itself, they did share concerns about these chairs' ability to overcome safety flaps given their increase in speed, weight, and power.

Height discrepancies between the lift platform surface and the building floor surface cause unexpected chair motion. This unexpected movement at an angle is concerning, given the range of centers of gravity (COG) offered in chairs today. Experts expressed that there are challenges in testing and understanding the consequence of a shifting COG and what this might mean for the increased risk of tipping. Heavier frames, scooters, varying tilt configurations, elevating seats, and other seating adaptations are all less stable. The concern for tipping is particularly problematic as power chairs can overcome these height discrepancies at greater speed. Experts were of mixed opinions as to the effectiveness of barriers. As with all categories described, different standards should be considered for residential vs public lifts when considering standards for barriers.

3.2.5 Key Takeaways

- Attention to universal design in public/commercial lifts and improved ease of personalization in residential lifts would greatly increase accessibility.
- Improved connection and relationship building between national, provincial and/or municipal building codes would bring a level of enforcement around access, safety and usability of platform lifts that currently does not exist.
- Lift surroundings should have requirements around providing adequate maneuvering space for larger chairs.
- Lift footprint minimums should be big enough to include:
  - a secondary user/assistant;
  - personal items and medical support devices;
  - all five mobility device categories; and
  - internal maneuvers for better access to controls and alignment in preparation for exit.
- Future-focused design to accommodate trends in increasing user weights and associated chair sizes.
- Improve human factors and ergonomics of controls:
  - Change the requirement to continuously depress the lift control button for movement by reducing required pressure, changing the type of button or remove the button altogether.
  - Position buttons where they can be easily reached.
  - Allow for left and right hand access.
- Doors need to move at a speed that allows for the user to maneuver out of the way or be light enough to move manually with low hand function.
- Include automated safety measures to inform correct/incorrect use.
- Include a requirement that ensures the lift terminates flush with the landing surface.

3.3 Focus Groups with End Users

3.3.1 Demographics

The research team conducted five FG sessions with a maximum of four participants per group. The sessions included 16 participants (6 female, 9 male, 1 no response) aged 35-71 yrs. (mean 53.8) with a range of disabilities and experiences with chairs and platform lifts. Table 2 displays a detailed breakdown of other demographic information collected to improve the understanding of lift user requirements. Though not listed here, many participants had a secondary assistive device that included a power chair, manual chair with add-on, scooter, crutches, or standard manual chair.

Table 2: Focus group participant demographic summary

		n=16
Disability	Spina bifida	1
	Spinal cord	10
	Multiple sclerosis	2
	Cerebral palsy	1
	Hemiplegia (stroke)	1
	Urosepsis	1
Attendant	Dog	2
	Support worker	5
	Family member	1
Disability	Manual chair+add-on	6
	Advanced (sip'n'puff)	1
	Power chair	9

3.3.2 Lift Design

"If better designed, I would use it much more."

Participants indicated that they would like lift designs to keep up with technologies and automation available to non-disabled people. They also stated that people in their chairs do not physically fit within the lift; they have trouble negotiating the layouts of the buttons, doors, and ramps; and there is significant concern about the reliability of these devices. They also have real fears of getting stuck without help. Generally, lifts make wheelchair users feel stigmatized and participants reported that current designs re-enforce stereotypes about disability.

3.3.2.1 "Tight" Footprint

The word that was repeated in users' experience of lifts was *"tight"* – that people barely fit in the lift, to the point where its use is an impediment. For example, people in tilt chairs, considered the longest wheelchair, must change their tilt angle, making them feel off balance when attempting to fit within most lifts. Those who use manual wheelchairs with add-ons indicated that they feel the figurative pinch as their adopted attachments give the sensation that they are either squeezed in (enclosed lift) or at risk of dangling off the lift (unenclosed or inclined lift). Power chairs and scooter users also reported this "tight" experience even without personal items.

The small space limits maneuverability and can cause damage either to the user's feet, footpads, armrests, controls, hands, headrest, or the lift itself in attempts to fit. One participant explained that the door closing behind sometimes hits the headrest, pushing the head forward while toes are pressed against the wall or jutting out. Another participant and lift use trainer of new wheelchair users explained that teaching people to become accustomed to and unafraid of spring-loaded doors slamming into the back of their chair as they try to fit inside the lift is part of the training.

Furthermore, users 'live' in their chairs; thus, they may carry anything they need to remain independent throughout the day. Users described purses or backpacks hanging either off the back or side of their chair for easy access and expressed concern about wall movement catching personal items and consequently pulling them in the motion of the device. It is common to hold temporary items, such as groceries, in the lap, further impeding mobility. Users must often reach across their bodies to access controls and maneuver to enter or exit the lift.

Lift device users who require assistance to operate the lift or travel with a support person stated, *"Even where it is possible to have someone get in first, it is neither safe nor comfortable."* A secondary user risks personal injury due to wall motion and raises concerns about how much weight a lift can support. Secondary users were described to encounter the following experiences:

- Difficulty accessing the buttons that the chair may block;
- Unable to fit, leaving the person in the chair unattended to run to the next floor to push the button to call the lift;
- Two people with disabilities supporting each other in the use of the lift;
- When the secondary user is a service animal:
  - The service dog is unable to travel on the lift;
  - Concerns about the dog's foot getting caught on moving parts;
  - Need to maneuver the service dog in first; locate the dog at the front, not behind, so it does not get caught up or in the way when reversing;
  - Consideration of how platform surface design, such as grids, may impact the animal's feet.

- If the user needs to ask a stranger for help:
  - The stranger must be willing to ride the lift with them and push the buttons;
  - It can take a long time to find a willing volunteer;
  - The volunteer has had to squeeze in, making for a very close ride with an unknown person.

3.3.2.2 Lift Controls

Participants highlighted lift control usability and learnability as areas requiring improvement. Lift operations vary, as do symbols and conventions for use. User experience, location of the controls and travel time (i.e., the length of time required to hold down the button, influence the chair's maneuvering requirements within the lift). The user's level of disability further influences this.

Lift controls were described as challenging to reach and designed without consideration for left- or right-hand limitations (e.g., hemiplegia). Situations where the wheelchair controls are opposite the lift controls (e.g., wheelchair controls on the user's right, and lift controls on the left, may necessitate a destabilizing, crossbody reach or extra maneuvering). Users with limited or no hand function or requiring a sip and puff-controlled chair require the support of a secondary user and are keen to see further hands-free automation to better support their agency.

Controls located close to the door can require additional maneuvers making access challenging for some. Controls located further away and that are usable from both the left and right allow for greater accessibility for more people.

One of the most consistently raised complaints about lifts was the need to hold down the button when in motion, with comments such as:

- *"It's not always easy."*
- *"It seems you're asking the user for too much because sometimes you gotta lean on it; it feels like a long time."*
- *"You have to lean very heavily on it...sometimes you lessen the pressure a bit, and it stops, so it seems counterproductive."*
- *"A real pain in the butt."*
- *"One of the main things on those stair lifts that I know always irritates the heck out of me ...that's having to press the button all the way going all the way up or all the way down."*
- *"I've never understood why it's a requirement."*

Lifts were consistently described as moving far too slowly. Many users also felt the hold duration is too long and must stop 3-4 times to make it up one floor. Users described experiencing unexpected, jolt-like stops when they could not sustain the pressure. One user described that his friend, who has a degenerative disease, has taken to creating tools specifically designed to hold down buttons for extended periods by leveraging their chair. Users felt that lift movement should be automated somehow, with apps, touch, wave and voice all raised as possibilities. It was unclear to them why people had the ease of automated buttons in general-use elevators while users of lifts needed to hold down buttons, that it "seems backward," especially for a publicly accessible lift.

Finally, controls for lift devices are not standardized and it was unclear to users how the buttons are intended to operate, with each lift having a slightly different interface. Figure 6 shows an image of the controls for a device located in a medical office building. Lift users were unclear about what the lines meant on the black up and down buttons. They were also unsure how to open the locked door, often confused enough to feel trapped and press the safety alarm button, resulting in the device locking itself out.

Figure 7 shows just how complicated using the devices can be. In this office, expectant mothers with small children were required to navigate the controls to access their doctor. In other on-site observations, many lifts had hand-drawn symbols or signage to indicate what the symbols communicated on the lifts (Figure 8 and Figure 9).

Figure 6: Up/down operation buttons unclear



Figure 7: Signage for lift that provides access to a doctor's office

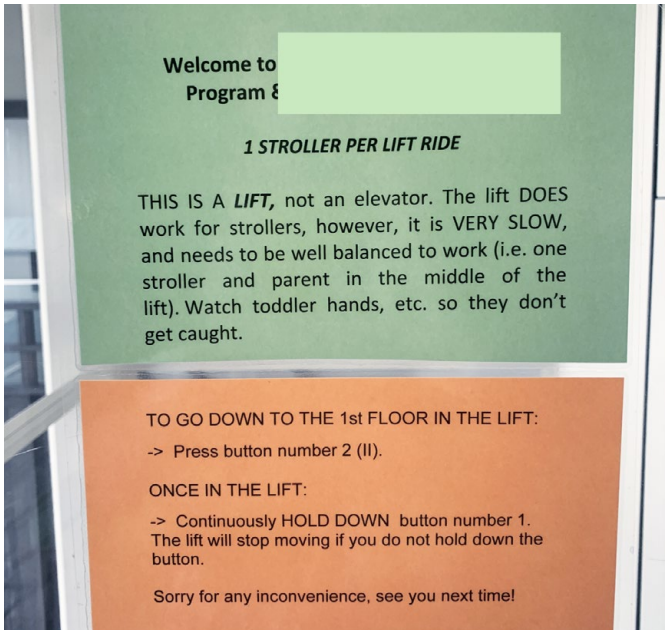




Figure 8: Signage for lift that provides access to a doctor's office



Figure 9: Location of controls close to entry illustrating proximity to the doorway swing path, biasing left-hand dominance and the need for additional labelling to clarify the button's intention



3.3.2.3 Doors

In general, platform lifts with doors have users feeling better contained within a lift. Latched doors were described as less secure. Door location, mechanics and hardware, its orientation within the entry and exit, and its relationship to the entry controls were all described as impacting lift usability.

The handles in manual doors need to be installed to allow for left- and right-hand access. Many lift doors are fitted with vertical D handles like the one shown in Figure 9 (top right). One participant, self-described as having 'flat hands,' or hands with limited mobility, is unable to grip these handles and struggles to maneuver around the door with their manual chair. Users suggested that lift doors be fitted with accessible handles that are a lever or hook to allow better ease of use for users with limited hand function.

As previously mentioned, reaching forward or across the body can put some users in awkward positions and impede access for some. Having to reach forward to pull open a door, described by some as heavy at times, towards the body while turning to get into the lift can be a complicated maneuver.

The location of the buttons and swing path of an automated door upon entry may require multiple maneuvers depending on the positioning of these features. This is sometimes compounded by the user's hand and arm ability. Whether automated or manual, the swing path of a door can represent a challenge, prompting users to suggest the use of pocket doors.

While participants shared a strong preference for automated doors, the timing of motion presents a challenge. Whether spring-activated or programmed with specific timing, users do not feel either case adequately allows for the maneuvering time required to get in.

Users generally prefer not to have their back to doors as it is difficult to confirm that they are entirely safe inside or that the door is closed behind them. Furthermore, lift users report using their chairs as a "battering ram" to exit due to lift usability issues. While serving its purpose, they fear this use of "brute force tactics" brings unwanted attention and increases the stigma around their disability, supporting the false assumption that physical disability means intellectual disability. Comments heard in the FGs included *"you shouldn't need to bowl your way through,"* and lift manufacturers make exiting *"more difficult than it should be."*

3.3.2.4 Transitions/Safety Flaps

Safety flaps, when down, act as ramps or transitions between the ground or floor and the platform. When up, they stop the wheelchair from rolling off the platform. FG participants identified ramp angle, dimension, strength, and, in the absence of a flap, uneven or wide transition as key areas of concern. Focus group participants generally preferred transitions and safety flaps to be level with the ground to reduce the feeling of being bumped and the fear of tipping over.

When the safety flap is down, the ramp angle on ingress or egress gives some users the sense of falling and may provide the potential to tip over. This is especially true for users of tilt-in-space chairs because they would often adjust their chairs to sit higher, raising their COG to fit into the lift and leaving them *"hoping you remembered to put chest strap on."* The lift platform is too small to turn around within, and users have feared flipping out of the chair when exiting backwards down the ramp, feeling the need to lean forward onto their lap to avoid a fall.

Safety flap size was frequently described as *"little,"* while other users expressed concern that a more extended safety flap would take up too much space. One user removed the safety flap in their home to better support maneuvering in the limited space at its location.

Some users expressed concern that the safety flap is not strong enough to hold them, that the chair will overcome the flap, and they will topple out. *"You're at the mercy of that six-inch flap"* was one of the comments heard in the FGs. Fitting the chair into the platform lift requires the user to come right up against the flap. Wheels that hit the flap can cause the chair to stop. However, there are still concerns about rolling backward or tipping backwards and falling out.

Uneven transitions are created when the platform does not line up with the ground or floor surface, creating a 90-degree angle or bump. Power chair users travel at speed to overcome the bump, introducing safety issues such as collisions with people or objects, loss of control of the chair or overshooting the platform. Manual chair users lift casters, creating instability. If there is a gap in the transition, mobility device add-ons could get stuck in the gap or catch and cause the chair to flip over.

3.3.2.5 Emergencies

Users described multiple incidences of "*getting stuck.*" Significant fears in this area have caused many participants to choose a different option or simply not go to places with lifts.

Lift failures are the cause of many of these emergencies. Door malfunctions are consistently reported as locking people in, namely:

- it does not detect arrival at the landing, and thus user remains locked inside;
- the button sequence makes the door appear locked to the user, causing the user to set off an alarm;
- the door does not match the level of the platform;
- unlike a manual chair, a heavy power chair is difficult to lift if the platform lift becomes stuck.

Setting off emergency stops due to wall touches often leaves users stuck because of the inability to access help, or untrained lift owners are unsure of how to restart the device.

Lifts are not always designed or supported in a way that allows users to get help when needed: *"I can remember being super scared because I couldn't get the attendant."* Participants described that getting help to override emergency lockouts or getting professional help to remove them from the device was difficult to access. "*You're absolutely stuck.*" Lack of visibility (would anyone know they were there and needed help) in an emergency was another concern; in lifts with high opaque walls, the person inside is not easy to reach, and users feel claustrophobic. While power chair users often feel unsupported on stair lifts, those in manual wheelchairs felt safer as people could easily lift them out of the device should they become stuck *"I am liftable, myself and my chair separately are liftable if something were to be broken down."*

Some lifts were described as not having alarms, and some commented that even if *"you press the alarm button, nobody answers anyway."* Users would like clear instructions on what they can do in an emergency and a way to connect with and communicate directly to help from within the lift.

The nervousness expressed by users in their use of lifts was evident, with many participants having a negative experience. Many people avoid lifts where possible *"I don't even want to deal with that if I have another option, even if it takes longer"* again reinforcing the stigma they feel these devices create *"really enforces a feeling of how different and helpless I can be for someone like myself."*

3.3.2.6 Psychology

Users reported feeling stigmatized by lifts. They also generally mistrust the device and feel unsafe while using them. People with disabilities would like to be accepted and included. However, users consistently stated that using a lift *"adds to the presumptive public perception of a) pity and b) kind of a mental situation."*

Loud, blinking alerts draw unwanted attention to the device; lift motion is jolting, sometimes causing pain in the hips and lower back but also appears shaky and unstable in its motion – this feels scary to users. In a general sense, users felt that *"you become a spectacle"* and that poorly maintained lifts prevented access *"I just simply don't go, I just can't stand them."*

Users consistently reported frustration with waiting for support to use a lift – *"everything takes a lot longer for us, the last thing we need is to be sitting and doing nothing."* Multiple users said they would prefer to find another way, even if it takes longer. Having to always ask for help reinforces feelings of being disabled. Waiting for a key holder was a frustration shared by participants.

Improving aesthetics to move away from an industrial "hospital yellow" and modernizing to reflect what has been made available in related technologies such as elevators would help users feel less stigmatized. Transparent walls would help reduce the claustrophobic feeling and aid visibility in getting assistance when necessary.

3.3.3 Environment

"Like the wild west of attempted accommodation and you never know what you're going to get."

Safe and effective lift use starts with finding the lift, maneuvering for entry and understanding the exit space. Many lifts are located in out-of-the-way areas, making the user feel unsafe. Some lifts are used as garbage or storage closets, have syringes around them, or are blocked by large items such as planters or garbage bins. Many buildings do not consider the space required to maneuver into and out of the lift. Participants felt that greater emphasis should be placed on the universality of design in the public space with a separate standard for residential lifts, which has specific requirements for the user.

3.3.3.1 Lift Wayfinding

When a user is in unfamiliar surroundings, lifts are sometimes challenging to find, and administrators and facility staff are often unaware of lift locations. Signage to try to find the lift is itself difficult to find. Lifts are also often installed in less-than-ideal or accessible locations. One user describes how they needed to travel through a dark back alley to access a lift; another had to navigate through kitchens. These back entrances reinforce stigma and can put users in a position of personal safety they feel is *"not acceptable."*

3.3.3.2 Area Around Lift

The spatial dimensions of the approach and exit area can make maneuvering into and out of a lift difficult, if not impossible. Lifts need to have enough space around them for the required maneuvers with particular consideration for:

- maneuvering around a door;
- maneuvering when the lift is installed in a corner;
- backing up into an unknown space;
- clear pathway in a building wide enough to get to the lift area; and
- physical barriers, which were regularly described as obstructing access to public spaces.

3.3.3.3 Lift In Use

Lifts open up into spaces catching passers-by off guard, and users are *"worried [they are] going to maim somebody."* Users would like to move with the flow of non-disabled people as much as possible and feel they can have visibility into exterior spaces to avoid hitting something or someone with the door. Lifts need to look like they are usable and maintained to be safe, or there is the risk of them being occupied for other purposes.

3.3.3.4 Built Environment and Building Code

Users would like to maintain the flexibility in their own homes for lifts to be adapted to their specific needs. They also suggest that the disability community needs to play a more active role in the design and layout of publicly installed lifts. Users would prefer that the building code contain more requirements connected to lifts to ensure accessibility.

3.3.3.5 Weather

Weather can influence electrical components, and ice or snow impedes access. A common weather-based complaint described by users was the rate of travel of a lift and precipitation. Users spend a lot of time waiting for the arrival of a lift and then spend a long time riding inside it getting wet. One user even described frequently being unable to use a lift because of uncleared snow within the device.

3.3.4 Lift Maintenance

"Whenever you are going toward one, you will always have a feeling of - is this gonna work? ...Is it going to stop half way... or break down? "

Users do not feel lifts are reliable and have no way to validate the safety of a lift before riding on it. They described a significant portion of lifts as dysfunctional or completely non-functioning, *"... possibility of failure would be more than 50%".* The maintenance level and/or frequency is unclear in public spaces, with many lifts feeling rickety and unclean.

Users felt owners of lifts in public spaces do not always take responsibility for the device adequately in their maintenance. Public lifts seldom have an available attendant trained in the technology in the case of an emergency; to maintain the device if it breaks down or to support users in the use of the device. Users described trying to train support attendants on the device to the best of their ability based on previous lift experiences.

3.3.5 Accessibility

"Make them accessible by everyone and for everyone."

Participants felt lifts should support the increased agency of people in motorized mobility devices, stating that existing designs only support high-functioning users. Lifts need to service a broader range of physical and intellectual disabilities. Users would like an increased emphasis on automation, facilitating greater independence for more people. Participants advocated for the inclusion of the disability community in the design and installation of lifts.

The need to locate and wait for an attendant or keyholder and the associated wait time poses a significant barrier for most wheelchair users participating. This was one of the most highly reported feedback from users. *"The key is painful," "pain in the behind," "the d**n key," "when you're always waiting, that's annoying," "you're lucky if you can find one," "a horrible feeling,"* and *"frustrating."*

Figure 10 shows one example of the location and condition of the key required to operate an inclined platform lift at one of the sites visited by the research team.

3.3.6 Lift-specific Feedback

Lifts support different mobility devices in different ways. Power chair users were very uncomfortable using inclined lifts. There is nothing to prevent them from tipping over nor is there adequate support for the weight of their chair. In contrast, people using manual chairs were generally less wary of inclined stair lifts and appreciated the openness of inclined lifts that can facilitate being "rescued" should they become lodged or stuck. Vertical platform lifts, while described as "claustrophobic," did make powered chair users feel safer given that they tend to support higher weight and have walls that prevent tipping out of the device.

"Stair lifts, in general, make me feel uneasy, period" and *"I find the stair lifts ...to be quite dodgy"* summarize the sentiments of many users. Users are looking to find another way to access a space if their only option is an inclined lift.

Beyond the distrust, users also had trouble accessing inclined lifts. Often, they are folded up and locked out and it is difficult to find a person or a key to get the device into a horizontal position and operational. In addition, users felt the motion around the bend was difficult to anticipate for turning inclined lifts.

Figure 10: Key is bent and is slightly obscured by railing, which limits access angles



Some users do appreciate that with inclined lifts, when accessible, safe and maintained, they can move through the same channels that non-disabled people move and be less segregated through these devices.

3.3.7 Key Takeaways

Space

- Footprint minimums are so small that they can cause harm to the wheelchairs and sometimes users.
- Lift entrances and exits need to afford users adequate space to maneuver in and out of the lift.
- Secondary users are common and need to be accommodated.
- Public lifts are installed in areas which are difficult to access or cause the user to feel unsafe.

Safety

- Users experience fears of tipping over as a result of having to re-position themselves to fit
- Transitions are often out of alignment with approach/exit surface.
- Safety flap angles impose a feeling of instability; they should be close to level upon approach or exit.
- Maintenance quality can be very low in public lifts.
- Lifts are not reliable or trusted – getting trapped is a common concern and access to aid is difficult.
- Lift key access requirement limits the usability of the lift.

Design

- Controls are not intuitive and are difficult to physically activate and reach.
- Signage, symbols and instructions are confusing or absent.
- The sequence of steps to open a door and move into a lift can be complex; space limitations can be aggravated by door swing paths.
- Users feel stigmatized by some design features.
- Increased automation is preferred for public spaces.
- Include wheelchair users in the design and implementation of lifts.

3.4 National Online Survey

3.4.1 Demographics

There were 90 respondents to the survey. They represented a wide range of age groups (under 19 to over 80 years), with the largest demographic aged between 35-49 years, including 47.8% who identified as men and 51.1% who identified as women. Most respondents were from British Columbia (63.3%), with 65.6% living in urban areas and 26.7% in suburban regions (see Table 3).

Table 3: Demographic summary of platform lift survey respondents

Variable	%	n=90
Respondent		
Wheelchair user	87.8	79
Parent/caregiver of a wheelchair user	12.2	11
Both wheelchair user & caregiver	1.1	1
Bariatric chairs & scooters	419.0	13.8
Age		
19 or under	2.2	2
20–34	22.2	20
35–49	40.0	36
50–64	23.3	21
65–79	10.0	9
80 or over	2.2	2
Gender		
Man	47.8	43
Woman	51.1	46
Prefer not to answer	1.1	1
Province		
Alberta	12.2	11
British Columbia	63.3	57
Saskatchewan	2.2	2
Manitoba	1.1	1

Variable	%	n=90
Province		
Ontario	11.1	10
New Brunswick	4.4	4
Prince Edward Island	1.1	1
Northwest Territories	2.2	2
Nunavut	1.1	1
Yukon	1.1	1
Residence		
Urban	65.6	59
Suburban	26.7	24
Rural	7.8	7

There was a wide range of mobility impairments and some with multiple conditions, leading with spinal cord injury (37%), joint-related issues (11.2%), and amputation (8.9%) – see Table 4. Respondents also had a range of upper extremity limitations.

Table 4: Survey responses to limiting physical conditions

Physical Condition Limiting Mobility	%	n=90
Spinal cord injury	36.7	33
Hip/knee replacement or other joint problem	11.1	10
Amputation	8.9	8
Stroke	7.8	7
Spina bifida	7.8	7
Arthritis	7.8	7
Muscular dystrophy	6.7	6
Cerebral palsy	6.7	6
Parkinson's	5.6	5
Multiple sclerosis	5.6	5
Post-polio	4.4	4
Diabetes	3.3	3
General aging	3.3	3
Traumatic brain injury	2.2	2
Other*	8.9	8
Prefer not to answer	1.1	1

* Includes neuropathy, orthopaedic conditions due to physical trauma (MVA), toxic leukoencephalopathy, spinal muscular atrophy, and aneurysm hemiplegia neuropathy

Many respondents (53.3%) reported having a caregiver or attendant (human or animal) accompany them when using a lift; in most cases, this was a family member (Table 5).

Table 5: Caregiver support breakdown

Caregiver is a...	%	n=90
Family member	35.6	32
Service animal	4.4	4
Support worker	10.0	9
Other*	3.3	3
No Caregiver	46.7	42

*A combination of family, assistant, and Handy-DART[4] driver.

The most common weights of chairs+user were between 100 and 250 lb (41.1%) and between 250 and 400 lb (30.3%). In addition, there were reported weights of over 400 lb (13.5%) (Table 6).

Table 6: Chair/user self-reported weights

Weight of Primary Chair + User	%	n=90
Less than 100 lbs (45 kg)	12.2	11
100–250 lbs (45–115 kg)	41.1	37
250–400 lbs (115–180 kg)	30.0	27
400–550 lbs (180–250 kg)	8.9	8
550–700 lbs (250–318 kg)	4.4	4
over 700 lbs (318 kg)	1.1	1
I don't know	2.2	2

Respondents used a range of mobility devices, including power wheelchairs (38.9%), manual wheelchairs (27.8%), manual wheelchairs with add-ons (11.1%), and bariatric wheelchairs - manual or power (14.5%) (Table 7). Sixty percent of respondents used secondary or multiple secondary devices, the most common being a power chair or manual chair with an add-on.

4 Handy-DART is a public transit door-to-door, shared-ride service in BC for people who cannot navigate conventional public transit without assistance.

Table 7: Mobility device use amongst survey respondents

Mobility Device	Primary Device		Secondary Device
	%	n=90	n
Power/electric chair	38.9	35	22
Manual chair, no add-on	27.8	25	11
Manual chair with add-on(s)	11.1	10	14
Bariatric chair (power)	7. 8	7	10
Bariatric chair (manual)	6.7	6	10
Cane/walker/ crutches	4.4	4	6
Scooter	3.3	3	6
I do not use any secondary devices	30.0	27	—

3.4.2 General Lift Questions

A summary of responses to multiple choice questions is presented in Table 8 below. The table presents the percentage of respondents in agreement (agree/strongly agree) or disagreement (disagree/strongly disagree) with select accessibility statements in the survey.

When asked if they had ever experienced any accidents or close calls that, in their opinion, may be attributed to lift design, 27.8% of survey respondents reported that they had. These included:

- Multiple situations where the lift stopped working when going up, and the user either had to go back or was stuck altogether until help arrived. In some cases, this was a long period of time.
- The Emergency Stop became non-functional from exposure to all four seasons.
- Multiple instances where the platform did not stop level with the floor, in some cases higher, making it a challenge to enter; or *"scary"* to exit from the lift when it's *"about 4 inches"* above the floor.
- Sometimes there is a steep ramp or transition from the floor to the lift that can be difficult or sketchy to navigate.
- A user tried to maneuver off the platform from an upper level. They gave the chair too much power with their joystick and ended up with their front wheel and part of the middle wheel off the platform. They were about to tip over, but they managed to move their head and torso to the other side to act as a counterweight. The attendant and another person were able to rock the power chair back onto the ramp, avoiding potentially serious injury.

Table 8: Summary of survey responses to general agree/disagree questions

Survey Statement	Agree / Disagree (%)
Assuming I don't need to contact someone to get the lift key, I can operate a lift independently.	66.7 / 17.78
I have experienced being unable to use a lift because I couldn't make contact with the person who had the lift key	73.3* / 26.7
In my experience, lift attendants are generally able to help me when needed.	63.3 / 15.6
I don't worry about getting stuck between floors when using platform lifts.	47.8 / 28.9
In my experience, lifts are generally well-maintained and in working order	53.3 / 22.2
When using the lift controls, I find that the control buttons are a good size for me	53.3 / 22.2
When using the lift controls, I find it's easy to reach the controls INSIDE these kinds of lifts	61.1 / 21.1
When using the lift controls, I find that the control buttons are a good size for me	53.3 / 22.2

*Note, for this question, agreement indicates a negative accessibility

- The chair casters catch on the safety flap.
- Other comments included:
- The lift I use at [location] is designed so poorly that when the button to open the automatic door surrounding the lift is pushed, the door quickly smashes into my chair before I can back out of the way. Then, for the lift to move, the rider must push the button hard for the entire ride. If you release the button at all, the lift stops abruptly. Furthermore, the lift is incredibly noisy and frequently out of service because the coffee shop beside it uses it to transport supplies and garbage, increasing the wear and tear on the lift.
- The operations panel is in an awkward spot; lifts are in poor condition, and there are maintenance issues.
- The lift was too short for my chair.
- Lifts with non-moving walls which could catch clothing or limbs.

3.4.3 Lift-specific Information

Those surveyed also answered questions specific to each platform lift type (vertical and inclined). Overall, 97.8% of respondents had used vertical platform lifts (42.1% used in the community, 39.8% in the community and private residence), and 66.7% had used inclined lifts (39.3% in the community, 36.1% in community and private residence). Of those who had not used inclined lifts, 69.0% said they had never encountered them. Other reasons for not using these lifts included not feeling safe (31.0%), not thinking it would support their weight (10.3%) and feeling too self-conscious (10.3%).

Responses to agreement/ disagreement questions are summarized in Table 9 below.

Table 9: Summary of survey responses by specific to lift type

Survey Statement	Agree / Disagree	
	Vertical Platform Lift (%)	Inclined Platform Lift (%)
These types of lifts work well for me	72.7 / 13.6	53.3 / 23.3
I feel safe using these kinds of lifts	72.7 / 13.6	46.7 / 33.3
The motion of these kinds of lifts feels smooth and steady	59.1 / 22.7	58.3 / 25.0
I generally find these kinds of lifts to be well maintained	52.3 / 23.9	45.0 / 28.3
These kinds of lifts are easy to operate	75.0 / 15.9	55.0 / 30.0
The platform on these kinds of lifts is large enough	65.9 / 18.2	48.3 / 36.7
I feel self-conscious using these kinds of lifts	44.3 / 39.8	50.0 / 25.0
I find it easy to maneuver INTO these kinds of lifts	64.8 / 18.2	48.3 / 30.0
I find it easy to maneuver WITHIN these kinds of lifts	50.0 / 31.8	45.0 / 36.7
I find it easy to maneuver OUT OF these kinds of lifts	60.3 / 23.9	65.0 / 20.0
The door for these kinds of lifts is light enough for me to open	58.0 / 26.1	—
The door for these kinds of lifts is easy to use to ENTER the lift	62.5 / 25.0	—
The door for these kinds of lifts is easy to use to EXIT the lift	50.0 / 23.9	—
The door has a handle that is easy for me to use	49.6 / 27.3	—
I feel that all vertical platform lifts in commercial/public buildings would be safer and easier to use if they all had power doors	77.3 / 9.1	—
Access ramps on these kinds of lifts generally open to an angle that feels safe to me	63.6 / 12.5	63.3 / 23.2
When in the up or closed position, I feel like the ramp flap on unenclosed lifts would prevent my chair from rolling off	56.8 / 20.5	—
I feel like the safety flaps on these kinds of lifts would prevent my chair from rolling off	—	58.3 / 13.3

Respondents of open-ended questions also described issues specific to vertical platform lifts and Inclined Lifts. A summary of concerns is outlined below.

Briefly describe any other issues you have had with vertical platform lifts:

Forty-two of those surveyed gave responses to this optional opportunity to provide feedback. Five people stated they had no issues. Twelve responders indicated that poor maintenance/reliability were the biggest issues, including that often the lift was out of service, and the motor kept breaking down part way up or down. Many commercial/public devices are poorly maintained and several who have devices in their home found it difficult to nearly impossible to get them serviced when they broke down. Seven people stated that the devices are just too rickety, or the jerky movement scares them, sometimes enough to keep them from using the device. Having to access the key or the inability to find the person with it was noted multiple times, as were the controls being placed too high or on the wrong side, and the platform is too small. Wayfinding and poor signage were also issues. Other problems mentioned included:

- inability to use due to weather conditions and the related wear
- the control button was hard to hold down
- the safety flap was too steep, or there was a fear it would not hold
- a fear of heights with the unenclosed lift
- wishes for an automated door

One responder shared their experience:

"... I run into constant maintenance troubles, and it is too expensive to fix and there was no one in my city to fix it so not only do I have to wait for someone to be available to come to my city, but I have to pay for their travel and their time and their gas and the hourly time that they are here and the parts. It is incredibly expensive for someone in my position. The platform, when resting on the top of the stairs, always gets caught up in my casters so I'm terrified to use the lift at any point. I barely go downstairs in my own home anymore because I am scared for that to happen with the casters or for the lift itself to stop working Midway down the staircase as it has done many, many many times before. I have also been trapped in the basement and have had to crawl up the stairs and crawl through the floor in my house and crawl through the garage to get my manual wheelchair. My children have had to carry the over 250 lb power chair from the basement so I could continue to use it because the business owning the lift was closed on the weekend or as I said it would take months for them to be able to come here. Also, when the power goes out due to a thunderstorm when the power comes back on the lift beeps constantly unless you can get into the inside of the lift and turn it off. The way it is placed on the wall against the staircase it is physically impossible for me to reach and do this myself so if no one is home I have to listen to the constant beeping 24/7 until someone can come and help me. The lift is unreliable and unpredictable and terrifying to me and in that case I only see 50% of my house most of the time because I am in such fear of it...."

Briefly describe any other issues you have had with inclined platform lifts:

Twenty-seven of those surveyed provided additional feedback about their experiences with inclined lifts. The most common issue described (7 responders) stated that these lifts were unreliable; either not working at all or they were always afraid it would fail before reaching their destination. Three respondents stated they felt stigmatized because they were not permitted to run the lift on their own (they had to find a key). When they did, it made loud noises that brought attention to them and they felt exposed. A few mentioned that the platform did not stop right at the floor level and that there was a vertical gap. So, when the ramp/safety flap came down, it was too steep to navigate safely.

Other responses included:

- maintenance issues
- the platform was too small
- it felt rickety and unsafe
- they were afraid of heights

One responder shared the following experience:

"...I found this lift great when it worked, but it is the least reliable lift I have had as it would break down often. The power box is very complicated, and I have gotten stuck numerous times without a way to restart it. If one switch is off, the whole lift won't work, and there are approx. 15 switches in the power box. If it bottoms out, the lift will not work. The cable had to be replaced numerous times, which is a huge cost in labour, and I am not a heavy person, so it wouldn't be due to overweight loads on it. I had to build an extra ramp to enter it as it was too steep, and I fell back on numerous occasions. To anyone looking for an interior option, I would recommend paying the extra $5,000 and going for an elevator instead."

Final thoughts:

Many people stated they were happy with some lifts, lifts are convenient, and users are thankful and supportive of the concept of improving them. Here are some of the final comments:

- It is not convenient to open and close the door.
- The biggest thing is for them to be available and not locked off. I shouldn't have to use my phone to call someone to get a key or find the one person in the building who knows how to get it moving.
- The hope is to design a smarter and safer elevator.
- We need more simple, easy to operate and safer.
- Lifts are important for me to access places. I wish they were faster. The slow speed is highly annoying when you're in a rush, which I always am.
- Had to disengage one of the safety switches (1 of 3) due to the lift stopping two feet down from floor level.
- Too small, tight, and hard to maneuver
- I have met with an accident while using this kind of lift. Since then I use these lifts very carefully. The open area associated with these kinds of lifts is quite dangerous and looking below is also dreadful.
- I would never recommend a stair roll on platform lift for any house."
- No one should be trapped in a space and need someone to let them out. It's the equivalent of locking the doors for non-disabled people. Why should we be ok with that for disabled people?
- I want to be independent and resent having to find an operator with a key.
- Not enough consultation with users.
- It would be nice if the corners had vertical posts to show riders like me, where exactly the edge of the platform is, to give a sense of personal safety that I'm far enough away from the edge.
- ...we put ourselves at risk each time we must use those types of lifts. Thank you for finally redesigning them.
- Thought: All lifts should be tested by the installers, using the extremes of user types (e.g., heavy chairs with shopping bags hanging off handles, 4-wheel scooters; & ask them how safe they felt.
- I approach with trepidation at every one but have no choice.

3.4.4 Key Takeaways

Both Vertical and Inclined Platform Lifts - User Comments

- Getting trapped or fear of getting trapped inside
- Maintenance/ repair issues, including not being able to rely on lift working, cost and availability of people to repair; freezing in winter
- Maneuverability – difficulties turning around, platform too small
- Controls – should not need to hold down, location should be lower and not one-sided
- General safety/ feelings of insecurity (including feeling vulnerable to injury, stability concerns, feeling scared, does not inspire confidence)
- Stability concerns and jerky movement
- Need for a key to gain access; not right that the user cannot operate independently
- Stigma – feeling on display, embarrassed
- Casters getting stuck, possible fall
- Need for better signage for wayfinding as well as for controls
- Cleanliness
- Door safety (for enclosed) – difficult to know if properly closed; preference for automated doors)

Additional Comments on Inclined Lifts

- Getting stuck partway up the stairs or unable to get down
- General safety/ feelings of / insecurity (wobbly)
- Lack of training for people who operate
- Not reliable ; costly repairs
- Slow
- Lift sometimes does not go all the way down
- Loud, draws unwanted attention (loud signal when in use)

- Flap angle is too steep, sometimes related to lift not adequately meeting landing surface
- Maintenance quality can be very low in public lifts.
- Lifts are not reliable or trusted – getting trapped is a common concern and access to aid is difficult.
- Lift key access requirement limits the usability of the lift

4 Discussion

There are opportunities for engagement between standards developers, building owners, device manufacturers and people with disabilities. Traditionally these groups have not worked together. However, for wheelchair users and other accessibility user groups to truly achieve independence and societal inclusion, a collaboration between these groups must be achieved. With the state of device application and maintenance, the overall message from user groups and SMEs is that Canada needs to harmonize with National and/or provincial building codes. Compliance should be made mandatory and enforceable by the applicable provincial legislative and regulatory body (e.g., for British Columbia, it would be Technical Safety BC). Key areas for collaborative discussion should be centred on the three areas.

4.1 Context-driven Standardization

Initial online research emphasized the geometries and metrics of powered mobility devices in relation to existing lift standards. Online review findings were supported by the lift advisory community (both SMEs and users). SMEs felt that lifts are designed to support a broader range of chair sizes and weights. However, the correct selection and appropriate implementation of these products within buildings left many wheelchair users unsupported. Both communities agree that the context within which a lift is installed significantly affects its usability. The lifts installed in public spaces do not effectively serve a wide enough range of the disability community and require minimums that support more. Yet, these same minimums should not constrain residential selections that can be customized to one user.

In the same way, the economics of lift selection should also be considered. Lift standards can influence who can afford to be included and can ask more of institutions and businesses servicing a broader spectrum of disabilities. Increased minimums can impede the ability to retrofit lifts into existing structures, while new buildings have a greater opportunity to consider the best selection for the population it serves. Public institutions and businesses such as shopping malls and rapid transit were consistently reported to have poorly maintained or non-functional lifts leaving users without options. The disability community is looking for a greater agency to make decisions for themselves in their home use of lifts and to have independent access to lifts for a greater range of disabilities in public spaces. It is recommended to separate lift devices for public applications from residential applications to accommodate the differences in design requirements, as has been done in the US [7].

4.2 User-centred Design

Users are not central in the design and implementation of platform lifts. Thus, their needs are not adequately met. Often described as mimicking old freight elevators, these devices emphasize engineering solutions over the complex usability requirements of people using mobility devices. This is evident in the experiences described by lift device users. The discrete, quantifiable engineering standards miss how people use lifts, such as carrying a load of grocery bags, travelling with a toddler and/or stroller, or interfacing with lift controls that mirror industrial machinery. Further, users felt stigmatized by devices that emphasize what they **cannot** do. Current designs call them to use their chairs as battering rams, require assistance to operate and lack the maintenance that makes them feel cared for and safe. Users feel that lifts make them appear more disabled than they are – their design reinforces the ableist perception that those with physical disabilities also have intellectual disabilities.

Field analysis confirmed what users reported: inconsistencies in interface design, unintuitive symbol use and unclear steps for correct use. Multiple locations had handwritten instructions over controls to clarify intention and had multiple signs inside and



"How safety is integrated into lifts does not instill trust in users."

out to direct users on how to use the device properly. Despite multiple signs, businesses report users getting stuck, being confused, and setting off alarms. It was unclear why the automatic safety features had locked them in place so they would panic.

Finally, the very design of the lift, in some cases, presents the need for a secondary user to operate the lift. They just do not have a wide enough lens to cover many disability needs.

4.3 Safety

How safety is integrated into lifts does not instill trust in users. Built-in locking mechanisms such as automatic safety lockouts, poor door swing timing, and door activations, are confusing. Users are often left concerned about becoming stuck between floors without adequate human support to get them out. If a lift stops because of a safety issue, it just stops; the user does not understand why and their immediate response is to start pressing buttons, which has created situations where emergency responders need to be called to get them out. On-site support people are broadly described to be uneducated on technology. Safety features such as keys call for on-site support, which is largely unavailable to users and impedes their use of the lift. These issues indicate that the current safeties designed into lifts are creating other safety risks.

Inclined lifts are generally considered dangerous to anyone outside of manual wheelchair users because they are lighter and can be lifted out should they become stuck. Overcoming safety flaps is a real concern for those with extra weight and power. This is further aggravated by small platforms that leave little room for error.

5 Recommendations

5.1 General

- Separate requirements for residential lifts so they are not constrained by minimums required for universal use in public spaces.
- Require inclusion of the disability community in the design and installation process.
- Greater harmonization of Provincial and National building codes to ensure that new buildings appropriately accommodate wheelchair lifts in their design.
- Include discussion concerning the US ASME process, which aligns with ADA standards and state building codes. This will require further investigation that was outside the scope of this research.

5.2 Space and Load

- Increase platform minimum size. Our survey results support the inclusion of space for larger devices and secondary users. Refer to [23] for guidance document.
- Increase weight minimums for public lifts to include a bariatric chair, obese user, a secondary user, and personal items.

- Our research recommends increasing the minimum rated loads for inclined lifts to match vertical ones. Minimum rated loads for inclined and vertical lifts are 180 and 250 kg, respectively. The current ASME 18.1 minimum standard is 250 kg for platform areas under 1.4 m^2. An SME recommended that this minimum be further increased to 455 kg, but these minimums require further investigation.
- Increase requirements for landing areas outside the lift to accommodate 90-degree turns on egress. See CSA B651, section 5.2.2 Maneuvering Area at Doors.

5.3 Safety

- Use transparent walls to reduce claustrophobia and allow the user to see the space around them and for others to see the user should they become stuck or have a health issue.
- Do not allow for moving walls to reduce the risk of catching, pulling and trapping personal items or secondary users such as children.
- Review the effectiveness and consequences of safety features, e.g.:
  - Holding down buttons supporting the motion of the lift;
  - Lift stopping/locking when close to a moving wall;
  - Door locking mechanisms;
  - Key for activation; and
  - Beeping in motion.
- Standardize signage to communicate lift location, safe use, and what to do in the case of an emergency.
- Standardize how help can be accessed from the lift, particularly where lifts are in isolated areas.
- The following ADA Guidelines are a baseline upon which additional engineering and design research may be carried out, including:
  - Maximum gap clearance, e.g., ADA 2010, section 410.4, *Platform to Runway Clearance:* 32 mm between the platform sill and the edge of any runway landing [8], or ASME 18.1, section 2.1.1.3: 20 mm [7].
  - Maximum vertical changes between platform and landing. Refer to ADA 2010, section 405 [8].
  - Door closing speed. Refer to ADA 2010, section 404.2.8: door closing speed should move from 90 degrees to 12 degrees in no less than five seconds, and doors with spring hinges should move from 70 degrees to full close in no less than 1.5 seconds [8].

5.4 Design

- Conduct an ergonomic study to inform the standardization of lift controls that:
  - Support for left- or right-hand use and limited hand function;
  - Limit users' need to reach across their body; and
  - Support ease of maneuverability when entering the lift.
- Define the sequence of use of lifts to improve maneuverability and reduce hand use demands.
- Define the interaction between lift controls, doors, ingress, and egress as a system.
- Control reach area should be unobstructed. For example, CSA B651-18 ranges are [9]:
  - Highest side reach is 1400 mm
  - Lowest side reach is 230 mm
  - Highest forward reach is 1200 mm
  - Lowest forward reach is 400 mm
- If maintaining button use:
  - Interior buttons should mirror the operation and symbol conventions of elevator buttons.
  - Removal of the continual button press requirement.
- Hands-free automation replacing exterior buttons, folding open of stair lifts, door activation and flap motion.
- Automate door opening upon exit.
- Within the standard, specify the location, symbols, labels, and procedures for controls that consider the location in which they have been placed (i.e., proximity to a wall which may limit maneuverability, facilitate entry and exit in a scooter, etc.)
- Consider the symbols and button layouts to increase the learnability and ease of use of lifts, including the size of buttons and forms that support people with limited hand function. This may require further research.

- Conduct further research regarding new minimums regarding the protective nature of safety flaps, with consideration for engineering requirements that support safe and effective containment of power, speed and weight maximums described in this report.
- Design public lifts for bariatric users with limited hand and/or cognitive function in a tilt-in-space wheelchair as a baseline, or "persona," to encompass a broader cross-section of the disability community in all designs.
- Reduce minimum door weight.
- Standardize the travel rate of doors to allow for entry without hitting the wheelchair, while allowing sufficient time to maneuver from exterior controls.
- Standardize access handle forms to support people with low hand function.
- Aesthetic: Reduce stigma by limiting the industrial/ medical appearance of lifts by following architectural trends for public spaces.
- Reduce alarms and beeps. Refer to ASME 18.1-2020, section 2.11 for guidelines [7].
- Maintenance was a key complaint. This is a complex issue that is not under CSA control. Working with Provincial and Federal building code administrators could allow CSA B355 to inform space requirements of buildings that facilitate more public access to lifts. Further, critical maintenance requirements could be mandated of building owners, such as regular maintenance to ensure the lift:
  - Continues to come to flush with transitions upon stop;
  - Is free of barriers and clear of refuse; and
  - Is in working order.
- Install curved mirrors at entry and exit to assist in reverse maneuvers and increase environmental visibility.

6 Limitations and Future Directions

The findings of this report are limited to wheelchair platform lifts, mobility devices and the people who use them. It does not apply to vehicle lifts or include these wheelchair types:

- center wheel drive (which are much more maneuverable and stable in both front and rear)
- complex rehab power chair
- portable chairs, foldable power chairs (lighter, people travel with them)
- sports equipment (basketball/lacrosse/rugby chair, hand cycle/racer, etc. An everyday chair might have three degrees of camber versus a basketball chair with 12 degrees of camber)

A complete evaluation of all available mobility devices was beyond the project's scope. This review includes the most common mobility devices but anticipates rapid changes in emerging technology such as front-end attachments, which are not yet standardized. Further research is recommended to understand projections for changes in mobility device parameters (dimensions, size, power, and weight), e.g., front-end attachments.

Most study participants were from urban areas of British Columbia. While the survey did capture perspectives from most provinces and rural areas, a larger study is recommended to gain strength in responses from these areas and for more input on weather-related issues. Other interest groups should actively be considered, including:

- secondary users and parents with strollers
- users of other mobility devices, such as walkers & canes
  - building managers and property developers (new and old buildings)

The study did not apply limitations for responders to the focus groups or survey. They need only be experienced wheelchair and platform lift users. That being said, for diverse inclusion, it may be necessary to actively recruit participants from some communities to ensure all voices are heard. Other opportunities for further investigation include:

- An ergonomic assessment of lifts, which was out of scope for this research. Understanding the sequence of effective and safe use of wheelchair lifts (function and form) for a range of disabilities will provide quantitative and qualitative data to support new minimums for design.

- Participants in all aspects of the study indicated that shifts in the centre of gravity of the mobility device/user system while accessing the lifts posed a significant safety problem. Emerging research in this area could inform the design requirements of lifts and/or mobility devices.
- Wayfinding - This report does not include labels and signs for the location of the devices, which proved difficult to locate in field studies. They should be included in public wayfinding maps and signage placed outside the doors where they are located as per the BC Office of Housing and Construction Standards' *Building Accessibility Handbook* [28].
- Further research is needed to improve various aspects of wheelchair design, including adding backup cameras to aid reverse movements, adaptations for dexterity issues and improved chair control, and effects of changing the wheelbase size (i.e.,) stability versus lift access.
- There is a need to address the poor maintenance of these devices. Further research is needed to make improvements in this area.
- Weather-related environmental considerations for lift design and maintenance could be explored in future research.

7 Conclusions

This research aimed to provide information from a broad range of resources to assist in reviewing and updating CSA B355. Several issues were identified that demonstrated a need to revise the CSA B355 standard for power mobility device/user access. The most notable issue was the need for larger platforms, stronger safety flaps, separation of public and residential requirements and requests for the elimination of the need for an access key. Revisions to the standard should accommodate the broad range of mobility devices and users, reflecting their size, shape, and functional abilities. The standard does not directly address maintenance issues. However, SMEs and users both expressed the need for building codes and all levels of government to prioritize the maintenance of accessibility lifts, with corresponding mandated and enforceable regulations.

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Appendix A – Interview Questions

To familiarize interviewees and users with the project, BCIT will provide a presentation to them similar to the outline provided in the Dec 10th BCIT/AP meeting. The following are questions and notes from a brainstorming session that will be used to formulate the specific questions for interviewees and users. Final questions will be developed and tailored from these notes specifically to approach lift device manufacturers, mobility device manufacturers, usability experts and device users.

1. Are you aware of existing mobility devices, including advanced wheelchairs or add-ons that would impact current wheelchair lift standards – or - What areas of the CSA B355 Standard should be reviewed in consideration of the increased prevalence of power chairs?
2. Based on the presentation you have just seen, are you aware of any other categories of mobility devices/add-ons we should consider?
3. Similar to Q2, are you aware of mobility devices, including advanced wheelchairs or add-ons that may be in development that would impact current wheelchair lift standards?
4. As a lift manufacturer, what are the various categories of wheelchair lift devices your company has considered in the design of your lifts?
5. For the various categories of lift devices and types of mobility devices, how do you think the following features would affect chair maneuverability in a lift:
   - Control input
   - Load capacity
   - Weight
   - Max footprint (wheelchair + add-on)
   - Turning radius
   - Height of COG
   - Seat elevation/stand capabilities (max height)
   - Protrusions/ hazards (that could damage vertical boundaries)
   - Power
   - Max speed
   - Do you feel there is a need to change the requirements in any of the following B355 standard sections (if so, please explain):
   - Protection against hazards
   - Protection against falling from the platform at landings
   - Obstructions and projections
   - Vertical clearance
   - Travel, limits of travel, landings and inclination
   - Rated speed

- Capacity, rated load, size
- Safety factors (currently 5)
- Lighting
- Runway requirements
- Landing doors and gates: strength, vision, fire rating, dimensions
- Power-assisted swing doors or gates
- Lift dimensions
- Endurance tests
- Current interruption
- Operation without lubricant
- Passage of tests in a damp atmosphere, misalignment of doors, electrical insulation, force and movement
- Mechanical limits at the top and bottom end of travel
- Horizontal clearances
- Guide rails

6. Do you feel there is a need to add to or remove sections of the B355 standard?
7. Are there other aspects that we need to be thinking about?
8. Is there anybody else you recommend we should talk to?
   - Futureproofing: What advances in device design do you anticipate might impact recommendations arising from this report?
   - Are you aware of any incidents or existing incident statistics related to the use of power chairs, including their use in wheelchair lifts (CSA B355 devices)?
   - What is the average power wheelchair weight sold in Canada?
   - What is the average user weight?
   - How do you think would mobility device users do if they were using a lift device that has been built only to current minimum standards?
   - Have you ever had issues where protrusions from your chair hit surrounding obstacles in the lift?
   - Have you ever had a situation where you lost control of your input device, causing you to speed up/change position unexpectedly/fall from the chair/tip over?
   - Have you ever had problems with the gate height or safety flap or using the lift control buttons?
   - Add a question about demographics e.g., rural vs urban?

Appendix B – Summary of Studied Wheelchairs

Power Assist Wheels

Motor and battery are integrated into a quick-release wheel hub. The footprint increase is very small (up to 5 cm). A remote control, joystick, or Smartphone app is used as a control input. The total weight of the powered wheel is 27 kg and the maximum weight of the person is 200 kg. Motor power is 300 W and can increase the speed by up to 10km/h.

Potential issue of concern: power, control

Integrated Power Assist

The unit is not an add-on system. The system is integral and propels the chair using a small power source and a microprocessor that senses the user's input and provides the right amount of assistance and glide to supplement users' effort. Power is 180 W and can assist propelling movement up to 10.08 km/h. Overall weight varies from 25 to 62 kg, and load capacity is 135 kg.

Potential issue of concern: control

Rear-End Attachments

Rear-end attachments provide auxiliary power to manual wheelchairs to reduce the pushing power needed by their users. It is controlled with a joystick/steering handle, Bluetooth wristband, or double tap to start ramping up the speed. They do not add additional width to the chair as they tuck underneath the wheelchair, only adding about 3" (7.6 cm) in length. Motor power is 640 W, and the maximum speed is 10 km/h. Total weight varies from 7 to 37 kg and load capacity is 200 kg.

Potential issue of concern: control

Front-End Attachments

The front-end attachment system transforms a wheelchair into a 3-wheeler and back again. A powered front wheel attaches to the front of a manual wheelchair to provide motorized power. It lifts the smaller front castors off the ground and is steered and controlled with one or two hands. The total weight of the attachment is 24 kg, including the battery, and the maximum load capacity is 110 kg. They add up to a 107 cm increase in length. They have a motor power of 1620 W and a max speed of 30 km/h. There are no protrusion hazards that could damage vertical boundaries. Specs did not provide a turning radius.

Potential issue of concern: control input, maximum footprint, maximum speed, turning radius, motor power

Passive Front End

Front-end attachments lift wheelchair castors off the ground, turning the chair into a 3-wheeler. Chair height increases by 5 cm, and overall length increases by 42 cm. The centre of gravity is shifted rearwards due to the change in seating geometry. Overall length necessitated wide turns. The turning circle changes from 106 to 224 cm (42" to 88").

Potential issue of concern: Turning radius

Stand Up Chairs

Indoors/outdoors wheeled robotic devices provide upright and seated mobility with a maximum speed of 6 km/h. The total weight without load is 170 kg, and the max load capacity is 120 kg which makes a total weight of 300 kg. It has a small footprint (68 cm wide, 121 cm long). A turning radius of 600 mm to 810 mm allows for a smooth direction transition. The maximum height in an upright position is 164 cm (64.56"). UP'n'Ride features an auto-balancing and unchanged center of gravity. However, driving downhill can shift the user's center of gravity forward, hence prefer moving in a sitting mode. A raised seat changes the center of gravity and increases the risk of tipping. Tek RMD can be easily maneuvered up and down ramps for easy loading and unloading.

Potential issue of concern: weight, maximum height, shift in COG if driving in standing

Segway Chairs

The total weight of the Segway chair is about 115.7 kg and has a load capacity of 100 kg. This type of chair has a high motor power of 3 kW, and a maximum speed of 20 km/h can be reached. The turning radius is 759 mm. The Ogo model has built-in safety features that will shut it down when it comes up against a high curb or obstruction it cannot traverse. Therefore, it is very unlikely to tip backwards.

Potential issue of concern: motor power, control, speed

Stair Climbing Chairs

Stair climbing chairs have a total weight of 300 kg, including user weight. They are equipped with a control console with a joystick and can move at a maximum speed of 10.9 km/h. The turning radius is 1150 mm. The seat raises up to 90.9 cm; raising the seat height raises COG. The overall length is 1090 mm, and the overall width is 685 mm. The minimum transport dimensions are 1130 x 695 x 790 mm (L x W x H), and the maximum height of the chair is 126 cm. In some configurations, headrest adjustment links may protrude behind the assist handle and hit surrounding obstacles.

Potential issue of concern: height of COG/ tipping hazard, protrusion hazard, seat elevation

Bariatric Wheelchairs

These types of wheelchairs have a maximum weight of 470 kg (including user weight). The turning radius is 940 mm for powered wheelchairs. They have a power of 419 W and a max speed of 7.24 km/h. Overall length and maximum widths are 97 cm and 75 cm.

Potential issue of concern: maximum load capacity

Tilt-in-space Wheelchairs

Tilt-in-space wheelchair allows the whole chair to tilt and enables users to optimize their repositioning, functional reach and power drive positions for greater freedom of movement. High-performance motors enable a top speed of 10km/h. These chairs have a load capacity of 204 kg and a maximum weight of 203 kg. The turning radius is 1676 mm, and the seat can be elevated up to 35 cm. They have a length of 146 cm and a width of 71 cm. Operating the seat lift and seat tilt/ backrest recline changes the center of gravity and increases the risk of tipping over. It is recommended to use those seat functions on level ground and not on hills, ramps, slopes or other inclines. Using those seat functions while driving on inclines can lead to personal injury and property damage.

Potential issue of concern: change of COG height/ tipping hazard, turning radius, maximum footprint (chair dimensions), weight

Mobility Scooters

Mobility scooters have a maximum length of 122 cm, and their weight without a battery is 89 kg. The turning radius varies by model (e.g., there is a turning radius of 1555 mm for [redacted]). Mobility scooters have a maximum speed of 13.84 km/h and a maximum load capacity of 226 kg.

Potential issue of concern: load capacity and turning radius

Appendix C – Summary of Wheelchairs and Add-ons

	Control input	Load Capacity	Weight	Total Weight (Load capacity+ device weight)	Max footprint (wheelchair + addon)	Turning radius	Height of COG	Seat elevation/ stand capabilities? (max. height)	Protrusions/ hazards (that could damage vertical boundaries)	Power	Max speed	Notes	Extra
Power assist wheels													
	Remote-control, joystick, Smartphone app	200 kg	27 kg	Wheelchair weight + 227 kg	Wheelchair width + 5 cm		No significant change	No	No	300 W	10 km/h	Can include power assist wheels + battery + joystick	
Wheelchairs with integrated power assist													
		135 kg	62 kg	197 kg			No significant change	No	No	180 W	10.08 km/h	Speed on slop of 3°: 11 km/h. integral system (not add on); propels the chair using a small power source and a microprocessor; supplements users' effort.	
Rear-end attachments													
	Smart Drive: wristband/ Bluetooth (double tap to ramp up speed, tap to stay at current speed; double tap to stop); ZX- 1: Joystick; Benoit Light Drive- joystick + steering handle	200 kg	37 kg	Wheelchair weight + 237 kg	Wheelchair length + 7.6 cm		No significant change	No		640 W	10 km/h	Smart drive: no additional size to the chair	
Front-end attachments													
	Five power assist levels with fingertip control of brakes and gear shifter	110 kg	23.9 kg	Wheelchair weight + 133.9 kg	Wheelchair length + 107 cm	not available	No significant change	No	No	1620 W	30 km/h	See Illustration 1A	*See Illustration 1B*
Passive front-end													
	NA	127 kg	2.2 kg	Wheelchair weight + 129.2 kg	Wheelchair length + 42 cm	1115 mm	No significant change	No		NA	NA	Overall length necessitated wide turns. E.g.: Turning Circle 42″ vs 88″	
Stand-up chairs													
	Joystick	120 kg	170 kg	290 kg	68 X121 cm (w X l)	810 mm	UPnRide: Auto- balancing and unchanged center of gravity	164 cm			6 km/h	Indoors/outdoors wheeled robotic devices, provide upright and seated mobil-ity. Tek RMD can be easily maneuvered up and down ramps for easy loading and unloading.	Height (upright position): 164 cm (64.56") maximum
Segway/self balancing chairs													
	Dynamic seat control system	100 kg	115.7 kg	215.7 kg		711 mm				3000 W	20 km/h	Ogo has in built safety fea-tures that will shut it down when it comes up against a high kerb or obstruction that cannot traverse.	The user is able to move by simply leaning in the direction they want to travel.
Stair climbing chairs													
	Control console with joystick	136 kg	162 kg	298 kg		1150 mm	iBot: Raising the seat height raises COG. A sudden change in COG reported when user tried to catch a falling object.	90.9 cm	In some configurations, headrest adjustment links may protrude behind the assist handle & cause hitting surrounding obstacles.		10.9 km/h	Parking mode: Total length: 1050 mm; width: 688 mm; height seat platform: 630 mm Min. Transport dimen-sions 1130 x 695 x 790 mm (Crawler mode with backrest folded down)	iBot: Ground clearance of main chassis: 243 mm; SCEWO: Hight seat platform 890 mm; iBot Height: 126 cm

Illustration 1A

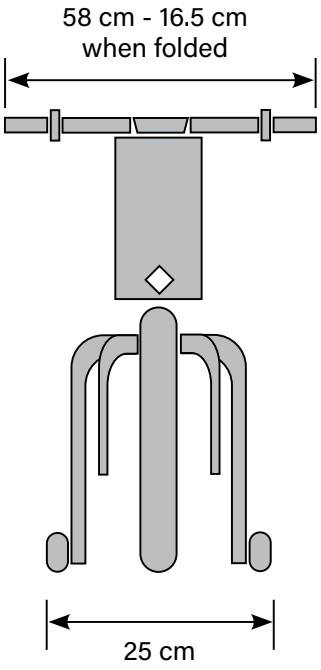
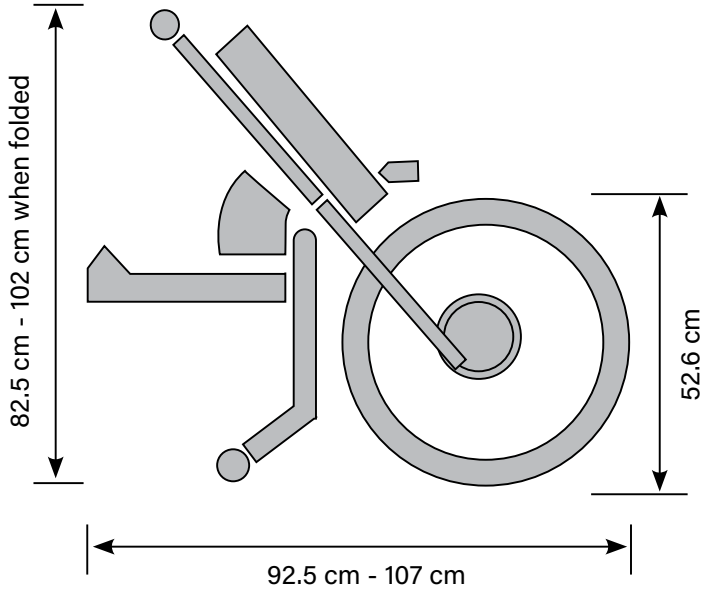


Illustration 1B



Appendix D – List of Relevant Standards

Focus: CSA B355-19 EN Platform Lifts for Barrier-Free Access

- Specifies minimum requirements for the design, construction, installation, and operation of platform lifts and stair lifts that provide barrier-free access.
- Addresses requirements for enclosed/unenclosed vertical platform and incline lifts.
- Provides recommendations for the inspection, testing, and maintenance of platform lifts and stair lifts for barrier-free access.
- Provides non-mandatory guidelines for relocatable lifts.

ADA 2010-410, *Platform Lifts* (US) – Rule 410 covers platform lifts specifically and references other ADA 2010 Standards that platform lift requirements should comply with. These platform lifts shall comply with ASME A18.1. Platform lifts shall not be attendant-operated and shall provide unassisted entry and exit from the lift.

ASME A17.1-2019/CSA B44:19, *Safety code for elevators and escalators* – Has become the accepted guide throughout North America for the design, construction, installation, operation, inspection, testing, maintenance, alteration, and repair of elevators, escalators and related conveyances.

ASME A18.1-2020, *Safety standard for platform lifts and stairway chairlifts* (US) – Presents specific guides for the design, construction, installation, operation, inspection, testing, maintenance, and repair of inclined stairway chairlifts inclined and vertical platform lifts.

CAN/CSA B613-00 (R2012) (Withdrawn), *Private residence lifts for persons with physical disabilities* – Intended to fulfill a similar need for facilities in private residences. However, it does not specify all of the safety requirements that are in CSA Standard B355.

CSA B651-18, *Accessible design for the built environment* – Requirements for making buildings and other facilities accessible to persons with a range of physical, sensory, or cognitive disabilities including but not limited to mobility impairments, reaching or manipulation disabilities, hearing impairments, visual impairments, etc.

CSA B44.1-19/ASME A17.5-2019, *Elevator and escalator electrical equipment* – Safety Standard for the design and construction of equipment to be used in conformity with the rules of the applicable elevator and electrical codes. Its purpose is to reduce the risk of injury to persons and damage to property from fire and electrical shock and arose from the need to have identical Canadian and U.S. requirements for this equipment.

ISO 9386-2:2000, *Power-operated lifting platforms for persons with impaired mobility — Rules for safety, dimensions and functional operation — Part 2: Powered stair lifts for seated, standing and wheelchair users moving in an inclined plane* – Safety rules, dimensions and functional operation for permanently installed power-operated stairlifts. Intended for use by persons with impaired mobility, for seated, standing and wheelchair users moving in a substantially inclined plane. It is restricted to stairlifts:

- that travel between fixed levels over a staircase or an accessible inclined surface;
- whose rated speed does not exceed 0.15 m/s;
- whose rail inclination does not exceed 75° from the horizontal; and
- whose carriage is directly retained and guided by a rail or rails.

SS-EN 81-40:2020, *Safety rules for the construction and installation of lifts – Special lifts for the transport of persons and goods – Part 40: Stairlifts and inclined lifting platforms intended for persons with impaired mobility* (Sweden) – This standard covers the safety requirements for construction, manufacturing, installation, maintenance and dismantling of electrically operated stairlifts (chair, standing platform and wheelchair platform) affixed to a building structure, moving in an inclined plane and intended for use by persons with impaired mobility

GB 24806-2009, *Stairlifts for persons with impaired mobility* (China) – This standard is written in Chinese. While not included in this document, it is worth noting for inclusion in future research.

AS 3695.2:2019, *Wheelchairs Requirements and test methods for electrically powered wheelchairs* (including mobility scooters) (Australia) – The objective of this Standard is to specify test requirements and minimum performance; safety and durability requirements for electrically powered wheelchairs, scooters and their battery chargers. It's a useful reference for understanding international requirements for power chairs.

CSA Z10535.2:2017, *Lifts for the transfer of persons – Installation, use, and maintenance* (Canada) – This standard applies to lifts and accessories that are used to transfer persons from one resting place to another, sit to stand or stand to sit.

BS 8300:2018, *Part 1 and 2* (UK) – This revised code of practice aims to give the information needed to create an inclusive environment from the outset of a project. Part 1 primarily covers access in and around the external environment and the approaches to buildings. Part 2 provides guidance on access within buildings, including the facilities that should be provided inside buildings. Both parts of BS 8300 supersede the 2009 version of this standard, which has been withdrawn.

CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.

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