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Safe Securement and Containment of Mobility Aids in the Cargo Compartment (Phase 2)

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FLIGHT RESEARCH LABORATORY

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List of Abbreviations

Abbreviation	Definition
ANSI	American National Standards Institute
ATPDR	*Accessible Transportation for Persons with Disabilities Regulations*
CTA	Canadian Transportation Agency
FAA	Federal Aviation Administration
IATA	International Air Transport Association
ISO	International Organization on Standardization
IWG	International Working Group
NRC	National Research Council Canada
OEM	Original Equipment Manufacturer
PAX	Passenger
PTR	*Personnel Training for the Assistance of Persons with Disabilities Regulations*
PWD	Persons with disabilities
RESNA	Rehabilitation Engineering and Assistive Technology Society of North America
TC	Transport Canada
TNA	Training needs analysis

Executive Summary

Passengers travelling with a powered mobility aid face many challenges as they travel by air, including the potential of being separated from their only mode of transportation, leaving themselves in full trust of the airlines and airports. To be proactive in addressing the issues surrounding the transportation and safe storage of wheelchairs, the Canadian Transportation Agency (CTA) mobilized an International Working Group (IWG) in 2018. One major outcome of this initiative, and of this current study, was the identification of functional and performance guidelines as well as best practices for the airlines and other stakeholders on the securement or containment of mobility aids in the cargo compartment.

The CTA, Transport Canada (TC) and the National Research Council (NRC) collaborated on this study to complete the objectives of the initiative. The NRC interviewed stakeholders from all sides of the accessible air travel experience including ground services, wheelchair manufacturers, aircraft manufacturers, airlines, and travellers. To efficiently address the stated concerns, the NRC completed an in-depth investigation resulting in best practices and recommendations regarding mobility aid handling and transport.

Through interviews and observations, we identified the current pain points faced during securement and containment of mobility aids in the cargo hold. The collected data helped us understand the needs of handlers and ramp personnel when they are interacting with a traveller's powered mobility aid. Based on the observations and analysis, we were able to identify a total of 9 significant pain points and critical handler tasks.

Following this, 22 interviews were conducted across 7 stakeholder groups. The results of the task analysis and interviews revealed that the process for safe securement and containment of mobility aids extends beyond the cargo hold.

At a high level, our study recommends and provides the following elements related to handling powered mobility aids;

- 9 functional guidelines for the safe securement and containment of powered mobility aids;
- functional job aid guidance that includes clearly defined high-level steps for securement and containment, written in lay language, with visuals for quick reference;
- a detailed training needs analysis (TNA) that can identify gaps in skills and knowledge for handlers with respect to securing wheelchairs.

In addition to recommendations related to handling mobility aids, our study also provides recommendations related to handling powered mobility aids at a systems level:

- that mobility aid original equipment manufacturers (OEMs) provide a brief document with visuals and clearly defined steps for safely disassembling and reassembling the mobility aid;
- that mobility aid OEMs include securement brackets as part of their design, and that the brackets themselves be designed to be more visible;
- that communication between travellers and airlines be improved by further developing the Mobility Aid Passport and Mobility Aid Handling Checklist, identified as short-term recommendations within the *Mobility Aids and Air Travel Final Report* (Hunter-Zaworski, 2019);
- that training regulations continue to require recurrent training to prevent errors associated with skill fade;
- that current training be adjusted, whether through regulation or through recommendations to airlines, as there is a gap between the current training content and the knowledge that handlers possess and are able to effectively apply on the job; 8 training-related recommendations are provided to this effect.

1. Introduction

1.1 Overview of the Project

The CTA is Canada's federal independent, expert tribunal and regulator that oversees the Canadian transportation system, which is essential to the economic and social well-being of Canadians.[1] One of its core mandates is to ensure that transportation services are accessible to persons with disabilities. As part of its regulatory modernization initiative, the CTA consulted with persons with disabilities and relevant industry to understand where the CTA could help make the transportation system more accessible for persons with disabilities. Issues related to the storage and transportation of mobility aids on aircraft were identified as needing further examination as mobility devices have grown in size and complexity. According to data extracted from the U.S., at least 7,747 wheelchairs were mishandled between January and September 2019, which is an average of 29 times per day.[2] Although Canada does not have the same reporting requirements for Canadian carriers, it is clear that this is also an issue in Canada.

To be proactive about the issues surrounding the transportation and safe storage of wheelchairs, the CTA mobilized an IWG in 2018. The IWG reviewed materials, held a workshop and multiple working group meetings to discuss the issues regarding the transport and safe storage of mobility aids. The IWG generated an in-depth report containing short, medium and long-term recommendations and goals. TC, the CTA, and the NRC joined together to review the IWG's recommendations and collaborate on a way forward. It was decided that this team would continue with the medium-term recommendation listed in the report: a detailed investigation and analysis regarding the safe securement and containment of mobility aids in the cargo hold. The outcome of this initiative is the development of functional and performance guidelines, as well as best practices for the airlines and other stakeholders on the securement or containment

1 https://www.otc-cta.gc.ca/eng/acts-and-regulations

2 https://www.usatoday.com/story/news/nation/2019/11/22/airlines-department-transportation-report-damage-wheelchairs/4270695002/

of mobility aids in the cargo compartment.

The IWG also noted that there are inconsistent policies across the airline industry regarding the requirements for securement or containment of mobility aids in the cargo compartment. To understand the holistic nature of the issue, stakeholders from various sides of the accessible air travel experience were included, such as ground services, wheelchair manufacturers, aircraft manufacturers, airlines, and travellers. In order to efficiently address the stated concerns, this collaborative project between CTA, TC, and NRC was organized into two phases. Phase 1 included a background review of the current state of mobility aids during transport, and was submitted in 2020 (Kelsey et al., 2020). Phase 2, the focus of this report, consists of an in-depth investigation resulting in best practices and recommendations regarding mobility aid handling and transport.

This study includes an analysis of the current securement and containment tasks, constraints, limitations, and pain points experienced by a wide variety of stakeholders. The data collection protocol was reviewed and approved by NRC's Research Ethics Board, and involved observations of handling onsite at a Canadian airport, structured interviews with wheelchair OEMs, end-users (i.e., persons with disabilities), and other stakeholder groups. Together, these methods of data collection resulted in the identification of factors that contribute to mobility aid damage, and in a series of recommendations and best practices associated with the securement of powered mobility aids that would reduce damage to powered mobility aids.

This document contains the following sections:

- Section 1: Overview of the Project
- Section 2: Background and Project Goals
- Section 3: Methodology
- Section 4: Results and Analysis
- Section 5: Recommended Performance Guidelines and Best Practices
- Section 6: Final Statement
- Section 7: References
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2. Background

> *"The risk of [my chair] being damaged or broken, the risk of losing my chair, and the risk to me… I decided not to fly anymore. I don't feel that air travel is accessible for me".*

This quote, from one of the participants interviewed for this project, highlights the many challenges and feelings that travellers who use mobility aids face. Air travel is more difficult than other types of transportation as it is the only mode where the traveller is consistently required to be separated from their mobility aid. For those who use mobility aids, their chair is a part of them; it is their physical support system and is required for them to move through the world. Understanding this concept is crucial for the accessibility of air travel to improve. The United States government passed the *FAA* [Federal Aviation Administration] *Reauthorization Act of 2018*, H.R. 302, Cong., 2018, which included in section 432 the requirement to complete a feasibility study on in-cabin wheelchair restraint systems by the Architectural and Transportation Barriers Compliance Board, in consultation with the Secretary of Transportation, aircraft manufacturers, air carriers, and disability advocates. While there is a possible future where travellers will be able to remain in their mobility aid onboard the aircraft, testing mobility aids and related systems for airworthiness will take time, requiring the development of standards by recognized agencies and regulators.

In 2017, the American National Standards Institute and the Rehabilitation Engineering and Assistive Technology Society of North America (ANSI/RESNA) published a revised and updated version of wheelchair standards that included developing a WC-19 label that can be affixed to a mobility aid, indicating that it has been properly tested for vehicle transport (RESNA, 2017). The International Standards Organization (ISO) also has documents that indicate how to properly secure mobility aids for ground transport (ISO 10542-1:2012, 2012; ISO 10865-1:2012, 2012). Although the work completed by ANSI and RESNA was designed for ground transport, RESNA, together with other

organizations such as All Wheels Up[3], are actively working towards enhancing air travel for travellers with a mobility aid, including airworthiness tests for mobility aids onboard aircraft (Erwin, 2018).

While travelling with one's mobility aid is within sight for future travellers, current travellers face an uneasy feeling of separation from their mobility aid during the air travel experience and run the risk of damage to their mobility aid during the flight. The travel experience for mobility aid users can result in significant emotional, medical and sometimes financial consequences for the traveller. Recent changes in reporting requirements within the U.S. highlight the frequency of damage claims submitted by passengers with mobility aids. For the first time, the *FAA Reauthorization Act of 2018,* H.R. 302, Cong., 2018, requires U.S. airlines to report the number of damaged mobility aid claims to the Department of Transportation, as well as the number of travellers with a mobility aid. According to data extracted from the initial report, at least 7,747 wheelchairs were mishandled between January and September of 2019, which is an average of 29 times per day (Fraser, 2019). While the total number of wheelchairs damaged compared to those that travelled is approximately 2%, it is likely that the number of damaged mobility aids is underreported (Fraser, 2019; Morris, 2019).

To address improvements to accessible air travel with a mobility aid, the CTA mobilized an IWG in 2018 to develop recommendations for future action to address the challenges experienced by persons living with disabilities (PWD) who use powered mobility aids during the air travel experience. The IWG report recognized a need for additional discussion and development including "issues related to the cargo compartment, ramp equipment, functional guidelines for securement and containment, and transportable mobility aid design" (Hunter-Zaworski, 2019). Table 1 summarizes the key areas of interest that were identified within the report that came out of a 2-day forum held in Toronto in June 2018.

3 *All Wheels Up, Inc.* (AWU) was created with the intent of proving wheelchair tie-downs can pass and withstand the FAA standards for safety.

Table 1. Key Areas of Interest Defined by the CTA IWG

Recommendation	Description
Mobility Aid Passport	The development of a Mobility Aid Passport that contains technical information on the mobility aid such as dimensions and any special instructions for safe handling. Key users would be ramp personnel.
Creation of a Standard Mobility Aid Handling Checklist	An International Standard Mobility Aid Handling Checklist to identify the required steps in the proper handling of mobility aids at the origin and destination airport. Simple design that uses pictograms wherever possible.
Communication	The development of more communication materials in multiple formats to improve communication at reservation, pre-trip and day of travel between passengers, airlines and airport ramp operations on the needs of the passenger with disabilities and the handling of their mobility aids.
Training	The development of additional training materials for reservation agents, airlines and airport staff including ground handlers, on providing appropriate assistance to passengers with disabilities and understanding the information contained in the Mobility Aid Passport and the Mobility Aid Handling Checklist. The training must include trainers with disabilities.

Recommendation	Description
Cargo compartment design	There are no plans for aircraft manufacturers to change the size of the cargo compartment doors on existing certified aircraft. However, the manufacturers are more aware of design changes that could be incorporated in new types of single aisle aircraft to accommodate larger mobility aids.
Ramp equipment	It is recommended that a feasibility study be conducted on ramp equipment and include an economic evaluation, and consider the options for lifts and other devices to board heavy mobility aids from the tarmac to the belt loader or directly into the cargo compartment of the aircraft. This study could also include consideration of the European practice of using a special vehicle that assists with boarding of passengers with disabilities and the safe movement of the mobility aids into the aircraft.
Functional guidelines for securement/containment	The development of new functional guidelines and/or performance standards for the securement and/or containment of mobility aids in the cargo compartment.
Transportable mobility aid design	Encourage further development and marketing of air transport friendly mobility aids that meet the needs for people with reduced mobility.

Powered mobility aids are stored in the aircraft's cargo hold during transport, while smaller devices such as walkers, canes, and some manual wheelchairs are stored in the passenger cabin (*Accessible Transportation for Persons with Disabilities Regulations*, SOR/2019-244; *Canada Transportation Act,* SC 1996, c 10*; Air Transportation Regulations*, SOR*/*88-58). Preliminary findings from Phase I revealed that enhanced communication, training, and clearly defined securement methods are key to providing a better service to those travelling with powered mobility aids. Key stakeholder groups from Phase 1 highlighted that it is crucial that handlers know how to safely operate, manipulate, and identify the ideal tie-down points on a powered mobility aid. Ensuring that passengers have access to information prior to their flight was also identified as an area for improvement as a result of Phase 1 and, in turn, handlers should be provided with adequate information (e.g., dimensions, weight, and battery type) to ensure the safe transport of the passenger's mobility aid. Although the results from the IWG included general recommendations regarding the communication and information, results from Phase 1 of the current study revealed some further pain points and weaknesses in the holistic process that will enable further improvements.

2.1 Project Goals

In Phase 1 of this project, we completed background research, identified stakeholders to be interviewed in Phase 2, had informal discussions with a few selected stakeholders, and provided a detailed plan for Phase 2. The work and report for Phase 1 was completed and submitted on March 31, 2020, laboratory report number LTR-FRL-2020-0033 (Kelsey et al., 2020). Phase 2 is the focus of this current report. To further understand the issues revealed from the IWG work, we collected data from stakeholders, observed ramp handlers, analyzed the interviews, categorized and prioritized the data, and provided recommendations for best practices, performance guidelines and novel methods that we hope will improve the current containment process. This report (LTR-FRL-2021-0030) includes an overview of the method, data, and results of Phase 2.

The specific goals for this project were to:

1. Identify, through interviews, observation, and user feedback, the current pain points faced during securement and containment of mobility aids in the cargo hold.
2. Understand the needs of handlers/ramp personnel when they are interacting with a traveller's powered mobility aid.
3. Using the Key Areas of Interest from the CTA IWG, identify the top 3 highest priorities based on our analysis.

3. Methodology

Throughout this project, two methods of data collection were used to gain an understanding of the current state of handling powered mobility aids:

1. Task analysis of handling powered mobility aids; and
2. Structured interviews with key stakeholders.

Unfortunately, the COVID-19 pandemic affected the ability to conduct in-person methods. The team was to observe ramp handlers across smaller regional airports and larger international ones within Canada to understand how the size of the operations may have an impact on wheelchair handling. However, given the COVID-19 pandemic, only one day of on-site observations at a Canadian international airport was approved for data collection. (Note: The NRC complied with all Canadian, airport, and NRC social distancing and safety protocols.) In addition, the cargo door tool user testing (Method 3) that was to take place in person was conducted remotely. The following sections explain two primary methods used: structured interviews and the task analysis.

3.1 Task Analysis of Handling Powered Mobility Aids

Researchers conducted a task analysis of mobility aid handling tasks, training, equipment, and information that handlers and airline staff need to perform their job. Task analyses are used to refine the functional requirements of a system in order to describe the tasks that people will perform (Annett & Stanton, 2004). To perform a proper task analysis, on-site observations at a Canadian international airport were

completed using a shadowing technique. Shadowing is an observational method that involves tracking users (i.e., ramp handlers) in their context of work to collect first-hand details about their activities and decision patterns (Hanington & Martin, 2012). Observations were documented with photographs, audio-visual recordings, detailed notes, and sketches.

3.2 Structured Interviews

Structured interviews were conducted with seven stakeholder groups: travellers, mobility aid manufacturers, ramp handlers and air carrier staff, mobility aid damage repair services, airline representatives, subject matter experts, and travel agents. Interviews were conducted remotely via Microsoft Teams, and lasted approximately 60 minutes. Phase 1 of our research highlighted the importance of obtaining a holistic picture when approaching the challenge of reducing powered mobility aid damage during air travel. By including OEMs in this stage, we were able to gain an understanding of their design approach, their considerations with respect to air travel, and how they envision a safer transport of mobility aids in the cargo hold. Interviews with handlers and airport staff were designed to supplement the task analysis of handling, providing a more detailed exploration of their thoughts throughout the process of handling a mobility aid.

4. Results and Analysis

Twenty-two individual stakeholders participated in this project across the two methods of data collection. Information from the interviews was categorized using content analysis based on four themes: positives, pain points, issues, and recommendations. The task analysis includes identification of critical tasks and pain points. Critical tasks are major decision points or tasks made by ramp handlers throughout the process of handling a powered mobility aid that if not done or done correctly will lead to potential mobility aid damage. Pain points are considered to be bottlenecks within the current decision-making process that result in a failure, which can lead to an incomplete task, missing information, or jeopardizing the safety of the traveller, handlers, or the mobility aid.

4.1 Handling Mobility Aids – Task Analysis

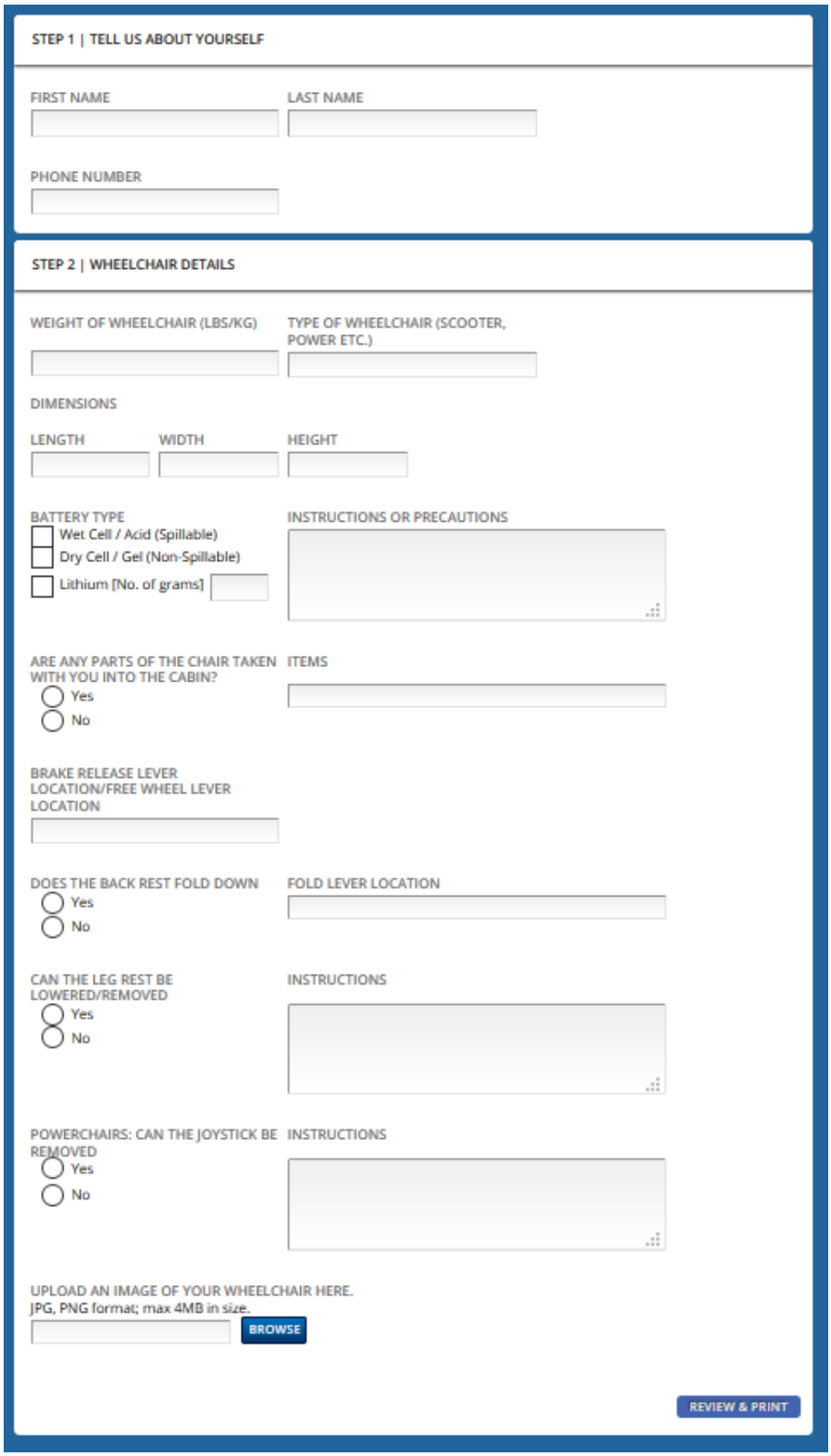
A total of 8 hours were spent onsite at a Canadian international airport in November 2020. During that time, two researchers were accompanied by an experienced ramp handler, who led them through the processes completed when a traveller arrives onsite with a powered mobility aid. Although the researchers did not have access to a powered mobility aid, a manual wheelchair was used to simulate tasks that would be completed with a powered mobility aid. The results of the task analysis include critical paths, gaps, and other pain points that exist within the system of securing and containing mobility aids in the cargo hold. Although the focus is on the securement and containment of mobility aids, it is crucial to acknowledge how the entire system functions. Researchers interacted with many different airline employees, such as check-in agents, health and safety employees, handlers, damage claims representatives, systems operations employees, and training managers to capture a holistic picture of the process.

4.1.1 Task Analysis Observations

According to subsection 32(1) of the *Accessible Transportation for Persons with Disabilities Regulations*, SOR/2019-244 (ATPDR), if a person with a disability informs the carrier that they will be traveling with a powered mobility aid at least 48 hours before the scheduled time of departure, the carrier must provide accessibility services associated with travelling with a powered mobility aid. Ideally, this information is captured and shared at the time of booking in advance of the 48 hours. This would afford the carrier the opportunity to determine whether the mobility aid will fit within the cargo hold door frame by requesting the dimensions of the mobility aid and cross-referencing it with the aircraft that the traveller will be on. If the mobility aid is too large to fit through the cargo door, the carrier is required to make every reasonable effort to provide accommodations, as stated in subsection 32 of the ATPDR, but can also refuse transportation as stated in paragraph 44(a), as a last resort.

Many airlines encourage travellers to fill out a powered mobility aid information form (examples are provided in Figure 1 and Figure 2). The information and layout of these forms is not standardized across airlines, creating variability in both content, look and feel. Some airlines request that the traveller fill out the mobility aid form electronically,

while some require that the traveller print and fill out the form prior to check-in, and bring it with them when they travel. Handlers want to be able to rely on these forms, but because there is no common look and feel on how information is being provided and disseminated, the information requested from travellers is not always what the handlers require. For both Example 1 (Figure 1) and Example 2 (Figure 2), the traveller provides basic information such as the weight, type of mobility aid, dimensions, as well as the battery type. However, Example 1 requests information regarding the location of the brake release, whether the backrest can be folded down, if the leg rests can be lowered or removed, and whether the joystick can be removed. Example 1 also asks the traveller to upload a photo of their mobility aid. In Example 2, although there is a section that highlights the different parts of the chair, no direction regarding disassembly or reassembly is highlighted. In the bottom left hand corner of Example 2, there is a section for additional instructions, but the writing space is limited, and does not ask targeted questions that would be useful for handlers.



STEP 1 | TELL US ABOUT YOURSELF

FIRST NAME

LAST NAME

PHONE NUMBER

STEP 2 | WHEELCHAIR DETAILS

WEIGHT OF WHEELCHAIR (LBS/KG)

TYPE OF WHEELCHAIR (SCOOTER, POWER ETC.)

DIMENSIONS

LENGTH

WIDTH

HEIGHT

BATTERY TYPE

- Wet Cell / Acid (Spillable)
- Dry Cell / Gel (Non-Spillable)
- Lithium [No. of grams]

INSTRUCTIONS OR PRECAUTIONS

ARE ANY PARTS OF THE CHAIR TAKEN WITH YOU INTO THE CABIN?

- Yes
- No

ITEMS

BRAKE RELEASE LEVER LOCATION/FREE WHEEL LEVER LOCATION

DOES THE BACK REST FOLD DOWN

- Yes
- No

FOLD LEVER LOCATION

CAN THE LEG REST BE LOWERED/REMOVED

- Yes
- No

INSTRUCTIONS

POWERCHAIRS: CAN THE JOYSTICK BE REMOVED

- Yes
- No

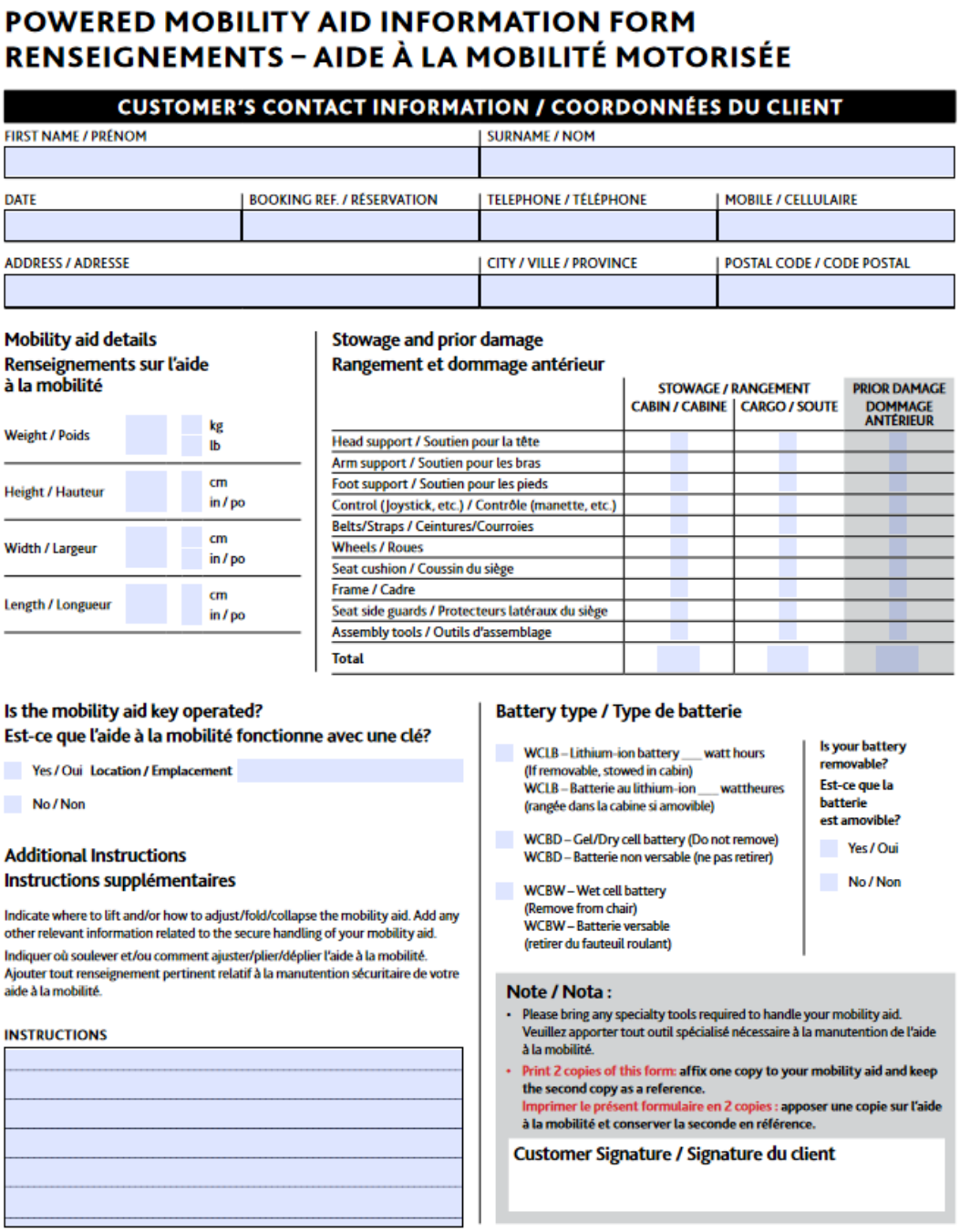
INSTRUCTIONS

UPLOAD AN IMAGE OF YOUR WHEELCHAIR HERE.
JPG, PNG format; max 4MB in size.

BROWSE

REVIEW & PRINT

Figure 1. Example 1 of an electronic mobility aid information sheet



POWERED MOBILITY AID INFORMATION FORM
RENSEIGNEMENTS – AIDE À LA MOBILITÉ MOTORISÉE

CUSTOMER'S CONTACT INFORMATION / COORDONNÉES DU CLIENT

FIRST NAME / PRÉNOM	SURNAME / NOM		
DATE	**BOOKING REF. / RÉSERVATION**	**TELEPHONE / TÉLÉPHONE**	**MOBILE / CELLULAIRE**
ADDRESS / ADRESSE		**CITY / VILLE / PROVINCE**	**POSTAL CODE / CODE POSTAL**

Mobility aid details
Renseignements sur l'aide à la mobilité

Weight / Poids		kg / lb
Height / Hauteur		cm / in / po
Width / Largeur		cm / in / po
Length / Longueur		cm / in / po

Stowage and prior damage
Rangement et dommage antérieur

	STOWAGE / RANGEMENT CABIN / CABINE	STOWAGE / RANGEMENT CARGO / SOUTE	PRIOR DAMAGE DOMMAGE ANTÉRIEUR
Head support / Soutien pour la tête			
Arm support / Soutien pour les bras			
Foot support / Soutien pour les pieds			
Control (Joystick, etc.) / Contrôle (manette, etc.)			
Belts/Straps / Ceintures/Courroies			
Wheels / Roues			
Seat cushion / Coussin du siège			
Frame / Cadre			
Seat side guards / Protecteurs latéraux du siège			
Assembly tools / Outils d'assemblage			
Total			

Is the mobility aid key operated?
Est-ce que l'aide à la mobilité fonctionne avec une clé?

- Yes / Oui **Location / Emplacement**
- No / Non

Additional Instructions
Instructions supplémentaires

Indicate where to lift and/or how to adjust/fold/collapse the mobility aid. Add any other relevant information related to the secure handling of your mobility aid.

Indiquer où soulever et/ou comment ajuster/plier/déplier l'aide à la mobilité. Ajouter tout renseignement pertinent relatif à la manutention sécuritaire de votre aide à la mobilité.

INSTRUCTIONS

Battery type / Type de batterie

- WCLB – Lithium-ion battery ___ watt hours (If removable, stowed in cabin) / WCLB – Batterie au lithium-ion ___ wattheures (rangée dans la cabine si amovible)
- WCBD – Gel/Dry cell battery (Do not remove) / WCBD – Batterie non versable (ne pas retirer)
- WCBW – Wet cell battery (Remove from chair) / WCBW – Batterie versable (retirer du fauteuil roulant)

Is your battery removable?
Est-ce que la batterie est amovible?

- Yes / Oui
- No / Non

Note / Nota :

- Please bring any specialty tools required to handle your mobility aid. Veuillez apporter tout outil spécialisé nécessaire à la manutention de l'aide à la mobilité.
- Print 2 copies of this form: affix one copy to your mobility aid and keep the second copy as a reference. Imprimer le présent formulaire en 2 copies : apposer une copie sur l'aide à la mobilité et conserver la seconde en référence.

Customer Signature / Signature du client

Figure 2. Example 2 of a paper mobility aid information sheet

Handlers are afforded an advantage if the traveller fills out the information form prior to passenger arrival as they will have time to prepare for the mobility aid handling. However, if the traveller does not fill out this form, or the information required is not shared with the handlers, then the handlers receive all of this information when the traveller arrives at the gate. If this is the situation, handlers may not have had adequate

time to prepare the mobility aid for transport once they transfer the traveller into the aisle chair, creating additional time pressure for the handlers.

Prior to transferring the traveller, depending on experience, some handlers might recognize that they need additional information from the traveller about their mobility aid and ask these questions at this time. The more experienced handler that participated stated that they rely heavily on soft skills to communicate effectively with travellers, and will do everything they can to keep their mobility aid safe. However, they relied on experience and not specific training. Knowing the types of questions to ask was mentioned as coming with experience (e.g., where is the brake release? How do I disengage the drive mechanism? Can the back rest or leg rests be folded in? Is the joystick removable?). Once the handler has acquired the right information, they transfer the traveller into the aisle chair (i.e., Washington chair, Figure 3).

Figure 3. Typical aisle chair (i.e., Washington chair) that travellers with powered mobility aids have to sit in while boarding the aircraft

In Canada, assisting passengers with boarding is the responsibility of air carriers. Access to specialized equipment to assist with handling powered mobility aids and transfers, as well as other adaptive equipment, may be the responsibility of the airline or the airport, depending on the equipment. Access to hoist equipment for passenger transfers varies across airlines across the country. Travellers are often physically lifted by handlers and/or flight attendants. Once the traveller has been transferred, the handlers relocate the powered mobility aid to the tarmac. During this time, there is a significant amount of pressure on the handlers to load the aircraft quickly so that flight delays do not occur. Handlers must take the mobility aid to the nearest elevator (which is often not in close proximity), and bring it down to ground level. To do this, handlers are often pushing the mobility aid through the airport, which requires that the mobility aid be on "freewheel" mode.

Once the handler and the mobility aid are on the ground level, the handler has the opportunity (if they asked questions, or received an information form) to reduce the overall size of the mobility aid (if required) to ensure that it fits through the cargo door. With their expertise, the experienced handler has an intuition about the relative size of the cargo doors for each of the aircraft in their airline's fleet, and is able to extrapolate whether a mobility aid will fit or not based on the type of aircraft and looking at a mobility aid. There is a risk that the handlers will realize that the mobility aid will not fit within the cargo door as they are trying to load it if dimensions are not communicated early on or if they are inaccurate, and the handler is less experienced. A major pain point for the traveller and other stakeholders is a delay in takeoff or inability to travel because of this type of miscommunication. Currently, there is no tool or list of compiled information for handlers or other stakeholders to be able to make this "fit" decision.

After the mobility aid has been prepared for loading (e.g., reduced in size if required/possible, and battery is handled according to dangerous goods regulations), there are two options:

1. If the aircraft is a wide-body aircraft, then the mobility aid can be loaded into a container.
2. If the aircraft is a narrow-body aircraft, then the mobility aid is loaded onto the belt loader.

Under both of these circumstances, the handler that participated in this study revealed that transporting powered mobility aids from the ground level into a container was extremely difficult and as such they created a tool to ensure safer transport. Specifically, they repurposed a luggage cart and ramp to lift the mobility aid from the ground into the container, or onto the belt loader (see Figure 4). With the front end acting as a ramp, the handler is able to push (or drive) the mobility aid onto the cart without having to manually lift it, which helps to avoid injuries. Powered mobility aids can weigh over 300 lbs and require anywhere from 2-4 handlers to lift, depending on the weight and size of the mobility aid. Using this cart increases their safety and reduces the time it takes to load the mobility aid into the cargo container or onto the belt loader. However, they acknowledged that not all staff use the cart, and other airlines do not rely on the same equipment. In fact, they see many handlers manually lifting powered mobility aids from the ground onto the belt loader, which introduces a level of risk to both the handler from an ergonomics and safety perspective, and the traveller, with an increased likelihood that their mobility aid is dropped.

Figure 4. Repurposed luggage cart to assist in handling powered mobility aids

The researchers completed the remaining tasks in the task analysis as if the aircraft was narrow bodied, which resulted in a focus on the most difficult airframe to contain wheelchairs. When the handler places the mobility aid onto the belt loader, it is crucial that they remember to lock the wheels. Locking the wheels is labeled a “critical” task because, if the mobility aid rolls off the belt loader, this could cause irreversible damage. Training and previous best practice documents state that mobility aids should only be loaded right side up and never turned on their side. Handlers confirmed that this is not always the case in reality and there are numerous reasons for this outcome. Ramp handlers stated that there is significant time pressure associated with departure, as well as the feeling that they need to meet the needs of the traveller. The dimensions of cargo doors is a factor in that, if the handlers are not able to reduce the size of the mobility aid (or they do not know how), it is possible that by turning the mobility aid, it will fit through the cargo door, which can result in damage to the mobility aid. The variability in the design of cargo doors also influences the decisions made by handlers. Some cargo doors open inwards, some doors are slightly blocked by the engine (Figure 5), creating a smaller opening than what may be stated in any documents. Therefore, ramp handlers will place the mobility aid on its side to enable fit through the cargo door, or if doing so will reduce time taken to load the cargo. In addition, not all ramp handlers are aware that the mobility aid wheels have a locking mechanism, and will therefore turn the aid onto its side to stop it from rolling. Belt loaders are also quite narrow in comparison to many mobility aids, and therefore handlers feel that the aid will be “safer” on its side.

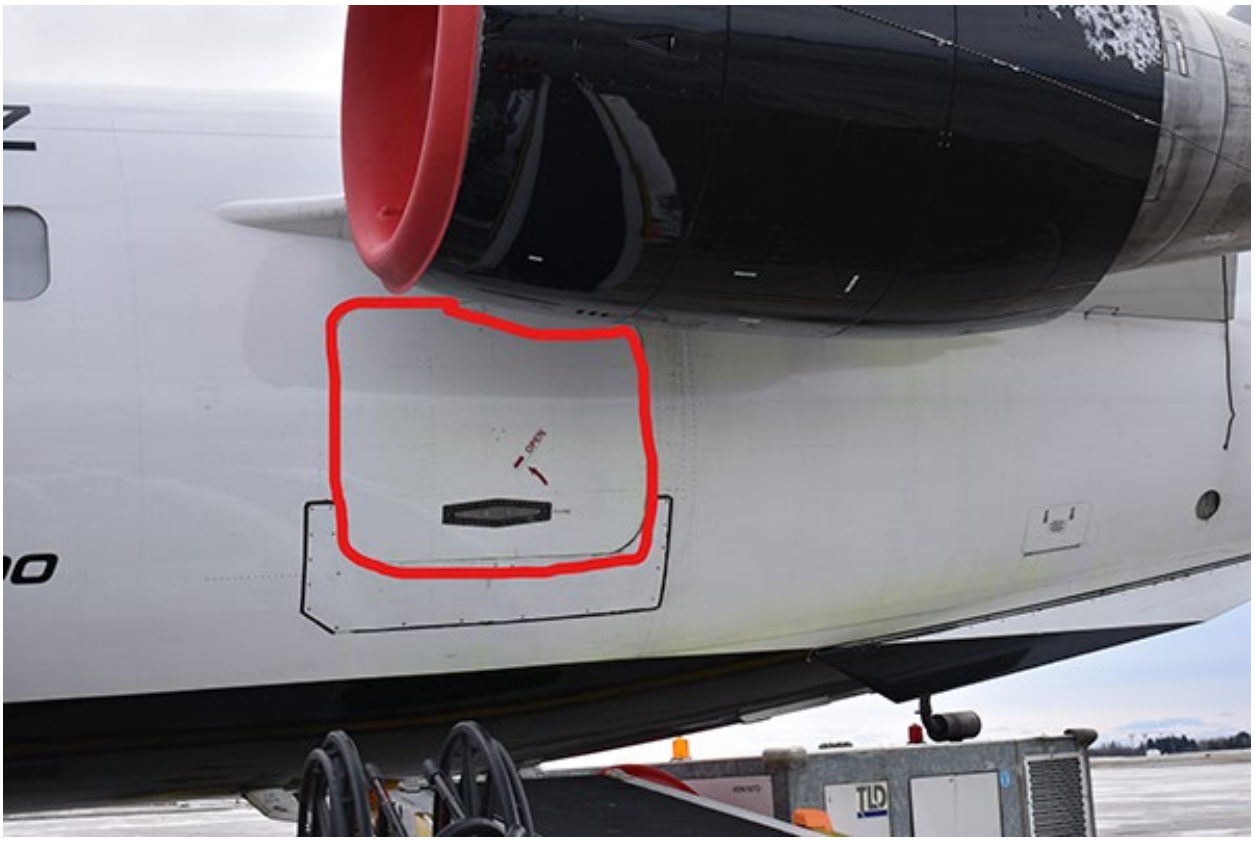


Figure 5. Example of a cargo door, with the engine slightly blocking access to full cargo door dimension, as shown in red outline

Cargo holds can be extremely restrictive in terms of size, making them difficult to maneuver within. Having to adjust, slide, push, or otherwise move an extremely heavy powered mobility aid is challenging for the handlers from an ergonomics perspective. Once inside the cargo hold, they highlighted that they have to line up the mobility aid with associated tie-down points on the floor (i.e., floor anchorages). The handlers transport the mobility aid into the cargo hold, and then use securement (i.e., ratchet) straps to tie down the mobility aid (Figure 6). Ideally, the mobility aids are loaded into the cargo hold prior to any other luggage. One handler we spoke with reflected that they have heard of instances where handlers did not secure the mobility aid to the floor, and they had to unload unsecured mobility aids from incoming flights. They stressed that this is absolutely “unacceptable”. They stressed that the tie-down and securement process is the same, regardless of whether it is occurring in the cargo hold or the cargo container that would be loaded into the wide-body aircraft.

Figure 6. An example of a common securement strap used by handlers

During the time onsite at the airport, the researchers had the opportunity to have two handlers demonstrate how they would secure the mobility aid to the floor of a cargo container. The researchers asked the two handlers to demonstrate how they would secure the mobility aid to the floor, and asked them to talk through their steps, highlighting any differences in how they would approach securing the mobility aid if it was powered and not manual. Interestingly, the two handlers took two very different approaches. Handler 1 first provided an example of what they would do, and then what they would not do (Figure 7). Handler 1 also completed the task before Handler 2 saw what they did, so that Handler 2 was in no way influenced by Handler 1. On the left hand side of Figure 7, they demonstrated how they would place the strap over the metal bar below the armrest, and not thread it through and over the plastic barrier, which is demonstrated on the right side of the figure (closest to the handler's hand). They highlighted that placing the strap over fragile components or areas (i.e., plastic pieces, removable parts) increases the likelihood of damage; when the handler goes to tighten the strap, the additional pressure is likely to break fragile components. Handler 1 also highlighted that they would never place the strap over armrests either (Figure 8), or wrap the strap around any removable parts like a leg or footrest, joystick, or headrest.

Figure 7. Handler 1 demonstrating their securement technique

Figure 8. Handler 1 demonstrating that straps should not be placed over armrests

Handler 2 took an entirely different approach, and mentioned that they remembered hearing in training that they should try and secure the mobility aid at the base of the

frame. Handler 2 wrapped the straps around the frame of the mobility aid (Figure 9). Although this may appear secure, wrapping the strap rather than laying it across the two points presents problems when the strap is tightened, causing unequal distribution of tension across the two contact points. If this happens, portions of the strap length will be slack, which would allow the mobility aid to slide during transit, therefore increasing the risk of damage.

Figure 9. Handler 2 demonstrating their securement technique

Handler 1 then demonstrated how this process would be done within the cargo hold of two different airframes, with the manual wheelchair acting as a substitute for a powered mobility aid (Figure 11). Cargo holds vary in the size, layout, and door dimensions. Regardless of door dimension, the same belt loader is always used, and was highlighted by the handler as being narrow in comparison to the majority of mobility aids (Figure 12). Once the mobility aid was loaded, the handler pointed out that an obstacle they encounter is that the floor anchorages for the straps are often dirty, making it difficult to anchor the strap into the floor properly. As seen in the left of Figure 10, the amount of debris initially prevented the handler from properly securing the strap. An L-track system is shown on the right of Figure 10, and is another example of a

type of floor anchorage seen in the cargo hold.

Figure 10. Examples of floor anchorages in the cargo hold

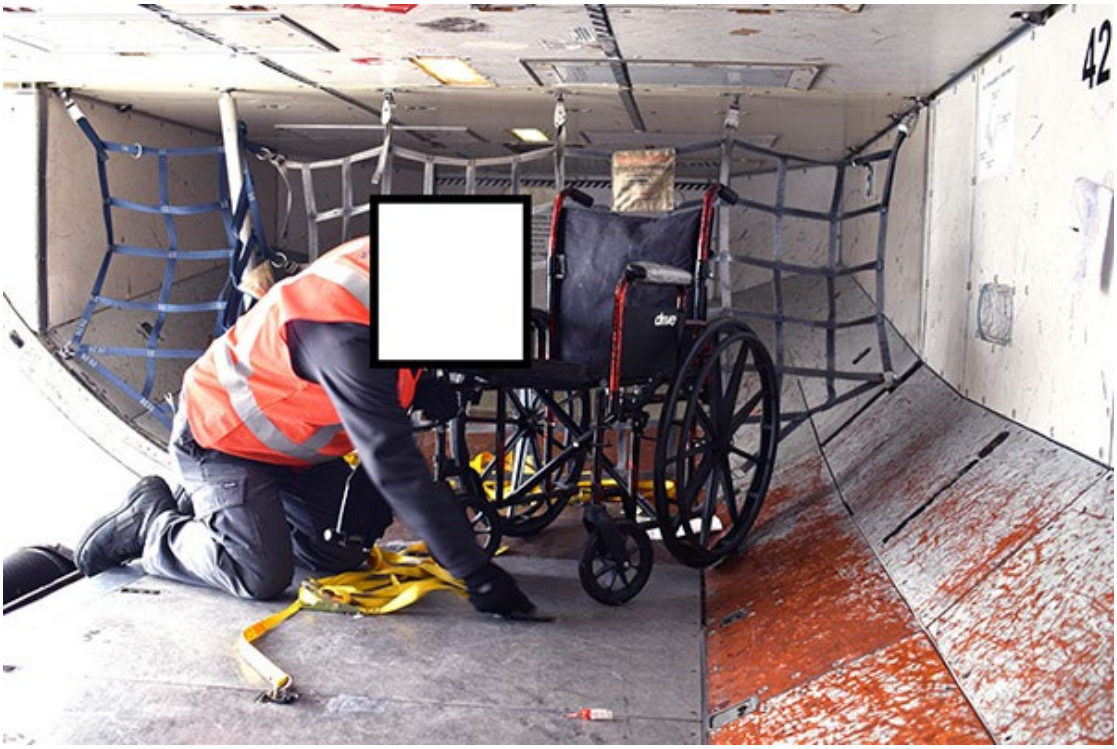


Figure 11. Handler 1 in the cargo hold of an A319, securing a mobility aid

Figure 12. Handler 1 highlighting the width of the belt loader compared to the wheelchair for loading

Once the mobility aid has been loaded and secured, the handler's job is effectively complete. If the handler is receiving an incoming flight with a powered mobility aid, there is currently no tracking or communication system in place for visibility regarding how to reassemble any components. The handlers at the arrivals airport are often left guessing as to how to put the mobility aid back together. If the arrivals handlers notice that the mobility aid has been damaged, they report it to their supervisor so that the correct next steps can be taken with the traveller. Depending on the severity of the damage, this might render the traveller without a mobility aid that meets their needs for an extended amount of time if an appropriate mobility aid is not available for them at the airport. In Canada, it is currently the responsibility of the airline to process claims and pay for any damage done to a traveller's mobility aid, in addition to providing a temporary replacement (ATPDR, section 61).

4.1.2 Critical Tasks and Pain Points Identified

This section provides a hierarchical task analysis that tracks the chronological listing of the tasks completed by handlers once a traveller arrives onsite with a powered mobility aid. Within each high-level task (1-11), there are numerous subtasks. In Table 2, subtasks are shown for Task 9, as an example. The detailed task analysis that highlights the high-level tasks, subtasks, and pain points across all tasks can be found in Appendix 1. The ID column lists the task number, with a total of 11 high-level tasks, and 45 associated subtasks. Task Description provides the name of the task. The column Category highlights whether the task is associated with communication, is time sensitive (i.e., temporal), relies on training, or maintenance of the aircraft. We recognize that the whole experience of air travel is time sensitive, but in the case of the task analysis, we wanted to point out where time pressure was a predominant factor impacting the required tasks.

Table 2. Hierarchical Task Analysis of Handling Powered Mobility Aids

Tasks that contain a pain point are highlighted with a blue background and an asterisk on the ID number.

ID	Task Description	Category	Notes
ID 1*	Handlers are notified of presence of powered mobility aid by air carrier staff.	Communication	Advance notice is required for all travellers, with a minimum of 48 hours ahead of time.
ID 2*	Receive specific information regarding powered mobility aid.	Communication	Powered mobility aid information form not adopted by travellers or airline employees. This form is rarely used, if ever.

ID	Task Description	Category	Notes
ID 3	Receive powered mobility aid at the gate.	Training	Includes transferring traveller into the aisle chair.
ID 4*	Prepare mobility aid at gate with PWD.	Training, Communication	PWD may complete some tasks in 4, otherwise handlers need to know how to complete these tasks. "Experience" and "common sense" is depended on by handlers, rather than training.
ID 5	Transport mobility aid to tarmac.	Training, Temporal	Handlers are under time pressure once the mobility aid is in their hands.
ID 6*	Decide if mobility aid will fit through aircraft cargo hold door.	Communication, Training	Decisions are usually made earlier in the process, but last-minute airframe decisions have a significant impact, or if information was not communicated during booking.

ID	Task Description	Category	Notes
ID 7*	Transport mobility aid to cargo hold.	Training, Temporal	Includes placing mobility aid onto the belt loader.
ID 8	Place mobility aid into the cargo hold of narrow-body aircraft.	Training	Assuming mobility aid will fit.
ID 9*	Secure mobility aid.	Training, Temporal	"Experience" and "common sense" is depended on by handlers, rather than training.
ID 9.1	Locate securement straps and floor anchorages (e.g., L-tracks).	Training	Ensure they have the equipment they need.
ID 9.1.1	Ensure the floor anchorage is clean.	Maintenance	
ID 9.2*	Locate tie-down points on the mobility aid.	Training	Should be completed prior to loading the mobility aid as room is restricted.
ID 9.2.1	Find sturdy places on the mobility aid (e.g., not plastic or fragile parts). Examples are securement brackets, hooks, or welded frame components.	Training	This was inconsistent across handlers that we interviewed.

ID	Task Description	Category	Notes
ID 9.3*	Place securement straps on mobility aid.	Training	If handlers incorrectly complete task 9.2, then damage is likely to occur during task 9.3.
ID 9.3.1	Lay straps across the base of the frame of the mobility aid, and not over top of armrests or wheels.	Training	Do not wrap the straps around the chair.
ID 9.3.2	Place the hook of the strap into the securement bracket/hook, or securely around a welded component of the mobility aid.	Training	
ID 9.4	Secure mobility aid in place by tightening the straps.	Training	
ID 10	Unload mobility aid.	Training	
ID 11*	Reassemble mobility aid.	Training, Communication	There is no information hand-off between departure and arrival handlers.

This analysis helped to identify areas of improvement and pain points, therefore not all high-levels tasks are included in this discussion. Below is a summary of the identified high-level tasks and associated pain points. Section 5.1 highlights these issues and provides recommendations.

Task 1 – Handlers are notified of presence of mobility aid by air carrier staff: This can currently occur in two ways, with the handlers either being notified prior to the arrival of the passenger, or once the passenger arrives at the airport. In the majority of cases, the handlers we spoke with are notified when the passenger arrives at the airport, even if the passenger has called ahead of time to notify the airline that they will be travelling with a powered mobility aid. Because of this, Task 1.2 – Receiving notification once the passenger arrives at the airport, was identified as a pain point. Handlers require as much notice as possible in order to ensure that they have any equipment available and allow for additional time to load and contain the mobility aid.

Task 2 - Receive specific information regarding powered mobility aid: According to the ATPDR, subsection 32(1), if a person with a disability informs the carrier that they will be traveling with a powered mobility aid at least 48 hours before the scheduled time of departure, the carrier must provide the service. However, this does not provide the carrier with any protection if the passenger does not provide the carrier with accurate information ahead of check-in. Fortunately, this is not the standard behaviour, and the majority of passengers do call ahead of time and provide mobility aid information. However, handlers are still frequently exposed to scenarios where travellers arrive at the airport with a powered mobility aid and the staff including handlers are not made aware until check-in, because information was not transmitted in an efficient way or is inaccurate. This makes any preparation required very difficult, stressful and time-consuming for all parties involved. To expand on this, there are four potential challenges with communication of mobility aid information at this stage: 1) from the traveller to booking agent or airline, 2) from the booking agent to airline, 3) within the airline itself, and/or 4) airline to sub-contracted handlers.If the traveller provides mobility aid information, the airline should be entering this into their electronic database. However, where this likely breaks down is that the handlers do not have efficient access to Passenger Name Records (PNRs) or medical records associated with each traveller, leaving them without important information that they need. The information provided on the information form required by the handlers is not specific enough in some circumstances, and too detailed in others. Interviews revealed that they would like information presented in a more systematic and visual way.

Task 3 - Receive powered mobility aid at gate: Handlers feel that the most stressful time for them is between transferring the passenger to the aisle chair, and loading and securing the mobility aid into the cargo hold. A lack of information received earlier in the process exacerbates this stress and increases the potential for missing critical tasks in securing the mobility aid.

Task 4 – Prepare mobility aid at the gate with PWD: Within this task, Task 4.1 – Locate important electronic and battery information, and Task 4.2 – Determine how to safely remove any components as needed, are considered pain points as there is little to no consistency in how the handlers complete these two tasks.

Task 6 - Decide if mobility aid will fit through aircraft cargo hold door: Upon discussion, it is clear that the cargo door dimensions are acting as a bottleneck within the process, and this is therefore identified as a pain point. Mobility aid dimensions should ideally be obtained at the time of booking, but also communicated to all stakeholders, including handlers. If mobility aid dimensions are unknown, or inaccurate, and the chair dimensions are too big to fit through the door, this results in an extremely stressful situation and may result in chairs having to be laid on their side to fit, a delay in departure, or denial or re-routing of travel for the passenger if possible.

Task 7 - Transport mobility aid to cargo hold: Mobility aids can be heavy and airlines may not have the equipment to support handlers in lifting and manoeuvring heavier mobility aids. For instance, most belt loaders are small in width, and handlers often rely on tilting mobility aids on their sides to fit them in, all while trying to not hurt themselves with the heavy chair. In addition, forgetting to lock the wheels, as identified in Task 7.1.1, could result in the mobility aid rolling off the belt loader, causing serious damage to the mobility aid. The safety manager revealed that injuries experienced by handlers most often occur during manual lifts of either the powered mobility aid or the passengers. During discussions with handlers and the safety manager, it was clear that this is a pain point for disability claims (i.e., Workers Compensation claims). In fact, the manager suggested that it would be very interesting to evaluate the number of claims, hours lost, or money lost related directly to loading wheelchairs. A specialized lift that would reduce or eliminate the need to manually lift any powered wheelchair could benefit the handlers and reduce disability claims, as well as damage to mobility aids, in the future.

Task 9 - Secure mobility aid: The powered mobility aid is to be tied down securely in the cargo hold or container. Observations and interviews revealed a lack of consistent methods, skill, and knowledge regarding this critical task. Instead, common sense and experience seem to be what handlers are relying upon. When asked about training, they were not aware of any specific powered mobility aid training related to tie-down methods, or the training was not recent enough to remember the proper methods. Because of these findings, Task 9.2 – Locate tie-down points on the mobility aid, and Task 9.3 – Place securement straps on mobility aid, are considered to be pain points during the holistic process of handling mobility aids.

Task 11 - Reassemble mobility aid: A pain point for handlers can sometimes be a disassembled mobility aid received upon arrival. As mentioned in Task 11.2, the handlers at the arrivals airport attempt to reassemble prior to any contact with the passenger and in the absence of any information form, or reliable instructions. Lack of information and experience can lead to errors during reassembly, which is why this task is identified as a pain point.

In summary, a total of 9 pain points were uncovered with this analysis, and are as follows:

- Task 1.2 – Receive notification once traveller arrives at the airport
- Task 2.1 – Receive powered mobility information form (if available)
- Task 4.1 – Locate important electronic and battery information
- Task 4.2 – Determine how to safely remove any components as needed
- Task 6 – Decide if mobility aid will fit through aircraft cargo hold door
- Task 7.1.1 – Lock powered mobility aid wheels
- Task 9.2 – Locate tie-down points on the mobilty aid
- Task 9.3 – Place securement straps on mobility aid
- Task 11.2 – Attach or adjust any parts that were modified by departure handlers

The pain points identified within this task analysis inspired many of the questions that were asked of the stakeholders during the interview process. By understanding the perspective of the handlers, we can better address the systemic challenges across the air travel industry when it comes to handling powered mobility aids.

4.2 Stakeholder Interviews

Interviews conducted within a 6-month timeframe between September 2020 and February 2021, included 7 stakeholder groups for a total of 22 participants. The stakeholder groups included;

- Travellers
- Mobility aid manufacturers
- Handlers and airline staff
- Damage repair services
- Airlines
- Travel agents
- Subject Matter Experts (Academic)

Researchers created a question script that contained targeted questions related to each stakeholder's field of expertise, as well as final open-ended question that were common across all interviews (Appendix 2). Researchers then completed a content analysis to analyse and categorize the responses within each interview. A quadrant structure consisting of positives, pain points, issues, and recommendations is listed for each stakeholder group. Note that the recommendations provided are ideas from the interviewees, and not from the researchers.

4.2.1 The Travellers

A total of four travellers were interviewed who had varying degrees of travel expertise. Two of the individuals were novice travellers, meaning that they travelled on occasion but not regularly. The novice travellers were born with a disability and have used powered mobility aids their entire lives. The third participant was an expert traveller who travelled a few times a week. The expert traveller used a mobility aid because of an accident that was experienced later in life. Lastly, a family member whose spouse regularly travels with a mobility aid was also included in the interviews. See Table 3 for a summary of the interview analysis with travellers.

The travellers typically notify airlines before arriving at an airport about their needs. However, even though they contact the airline, they still feel as though the air travel industry in general does not make it easy for those travelling with powered mobility aids. One individual discussed how they no longer fly as frequently as they used to because it is too stressful for them. Prior to returning to air travel, they need to see significant changes in the industry.

The issue of damaged mobility aids during flight travels is a common concern, according to the interviewees. Damage occurs often and in a variety of severities. One traveller offered to share a picture of damage experienced (see Figure 13 and Figure 14). Other examples of issues pertaining to mobility aids included no longer being able to charge properly, damaged headrests, and arriving at the wrong destination. The risk for these travellers is significant and alters their independence and ability to travel. One individual expressed that there is a risk of losing their chair, having it be broken or damaged, and the risk is such that they decided not to fly anymore. They stated that they don't feel that air travel is accessible for them." Another individual stated, "[They] would never travel by air by themselves again". They could not imagine feeling safe without a companion flying alongside them.

Figure 13. Photo of a damaged powered mobility aid that fell off a belt loader

Figure 14. Photo of a mobility aid, damaged beyond repair due to a cracked frame (note securement point sticker)

When asked if they have ever previously used an airline-specified information form for their mobility aid, all of the travellers said they have, but feel that the sheet does not capture the details of their chair and that the airlines do not use the forms properly. One novice traveller said that the form was “a waste of time”, and that they “filled out the form…for [her] partner and I” and that, when she gave the airline the forms, they asked “what is this?” and did not want the form. Instead, she was asked to provide pictures, and they gave her back the information forms. One of the other novice travellers said that they always call and provide information that way, rather than filling out a form. Our expert traveller said they filled out a form once, but “found that the handling form wasn’t sufficient in terms of the information”. They instead created and “laminated a list of instructions for what the handlers should do to manipulate the chair”. They also said that not all airlines have a form to fill out, and that the inconsistency in use and design of forms across airlines is frustrating. They also suggested including questions on the form such as “where is the brake release mechanism, rather than a blank [text box] because the customer might not know what instructions to provide” to the handlers so that they handlers have a better idea of how

to manipulate the chair beyond the minimum information of weight, dimensions, and battery type.

Previous negative experiences leave travellers feeling that the airlines are unable to meet their needs. For instance, when explaining how to handle their mobility aids (e.g., items to remove), they feel that the handlers and check-in agents brush aside their instructions. They feel that most likely the handlers are rushed to transfer their chair to the cargo hold and do not have time to have an informative conversation about how to handle their mobility aid. The participants noted that removing parts correctly, and with the right tools, is sometimes difficult and time consuming, but damage can occur when done incorrectly. These participants rely on travel companions to disassemble their chairs correctly. These issues create a sense of unease in passengers when booking a flight, as they do not want to be worried that they will not have a chair when they arrive at their destination.

Passengers also fear the scenario of a change in airframe, from a larger-bodied to a smaller-bodied airframe, with short notice. This means they may be denied a flight once they get to the airport, as their mobility aid may not fit into the cargo hold, even though they have done their part in calling ahead of time to book and provide details of their mobility aid. One traveller stated that this has happened to them in the past where the handling of their mobility aid resulted in a delayed departure for everyone. Once their mobility aid was loaded and the individual was in their aisle seat, the pilot reported to the passengers over the intercom that the reason for the delay was a traveller mobility aid. Rightfully so, the traveller felt that this was extremely insensitive.

A further concern for travellers with mobility aids is how airline staff will transfer them to the aisle chair and how adaptable these chairs are. Firstly, manual lifting can be dangerous and often times feels unsafe. The methods used are not always systematic and can lead to mishandling of the passenger. Moreover, aisle chairs as well as onboard seats do not support variability in physical statures and disabilities. For instance, one participant suffering from lordosis (curvature of the spine) stated that not having her headrest means they are in pain throughout the entire flight, and for days following.

It is clear that there is a need to create a system that allows passengers to remain in their own personal mobility aid during flight. The focus in the industry is starting to shift towards finding ways to secure mobility aids onboard (*FAA Reauthorization Act of 2018*, H.R. 302, Cong., 2018; Erwin, 2018). The data collected in these interviews support this shift. One positive outcome would be the reduction in the number of chairs incurring damage. Moreover, it would afford persons with disabilities the possibility of flying more comfortably and with confidence.

Table 3. Content Analysis Quadrant – The Travellers

Positives	Pain Points
• They have a strong desire to travel. • Some are creative when it comes to creating their own “travel kits”. • Use third-party travel agencies for booking to avoid frustration. • Know that they have to notify the airline ahead of time.	• Novice travellers may not know the process to follow. • Anxiety with air travel because of the requirement to part with their mobility aid. • Feeling that the airline staff cannot take the time to protect their mobility aid. • Damage to mobility aids is a regular occurrence in air travel. • Do not like the airline-provided mobility aid information form. • Some bring a custom information form, which requires a lot of effort but is often lost or damaged. • Physical lifting, manual transfers, into the aisle chairs are incredibly stressful, and sometimes painful. • Mobility aids reassembled incorrectly

Issues	Recommendations
• Mobility aids vary significantly. • Communication between traveller and handler regarding mobility aid. • Want to remain in their chair for as long as possible, but also want to give handlers more time to disassemble.	• Information about the mobility aid/passenger should be stored electronically (e.g., with their Passenger Name Record) if requested. • Reassurance that the airlines value accessibility. • Improved training for handlers. • Travellers allowed to remain in their mobility aid during flight.

4.2.2 Mobility Aid Manufacturer

Two representatives from a mobility aid manufacturer provided insight on the structure and design of powered mobility aids. In addition, they provided insight into the requirements gathering and procurement process for clients. Having basic securement points is not a matter of customization, but a standard for all wheelchairs. Although securement brackets as shown in Figure 15 are a company standard for this particular manufacturer, it is not a requirement for manufacturers to have them. International manufacturers may have different securement points, or not have specified brackets at all, which means the straps secure at durable points on the chair (i.e., the base or frame of the mobility aid). The mobility aid manufacturer highlighted that all of their mobility aids are equipped with securement brackets that allow for other ISO standard wheelchair tie-down and occupant restraint systems and securement methods to be used during vehicle transport (ISO 10542-1:2012, 2012). They also described how they do their best to ensure that the inner electrical workings and base-frame structures are as consistent as possible across their powered mobility aids. Consistency allows their employees to more easily address damage when needed, despite the high degree of customization across powered mobility aids.

Figure 15. Example of a standard securement point on a mobility aid

From their experience in repairing damaged mobility aids and through discussions with clients, the interviewed representatives know that travellers do not find the airline-specific mobility aid information forms to be useful. Instead, it was more common to see travellers make their own “travel kits”, describing how to handle their mobility aid once the traveller has been transferred into the aisle chair. For those with highly customized mobility aids, having to remove certain parts is required to ensure it fits through the cargo hold, and this presents a challenge for multiple individuals: the handlers, with respect to knowing how to properly disassemble and reassemble, and the traveller, with respect to having the peace of mind that this was done correctly. The overall lack of communication throughout the air travel process was highlighted as a major issue, which can leave both the handlers and the traveller wondering if they are safe. In their experience, clients seem to be very brand-loyal to airlines once they find one that they trust. The mobility aid manufacturing representatives stated “some [clients] don’t even know that [air] travel is an option”.

They also wondered what training for the handlers entails specifically for securing and

containing mobility aids, and how often that training occurs, highlighting that being able to identify securement points visually (or strong points on the mobility aid if securement points are not identified) takes practice, particularly for non WC-19 wheelchairs. WC-19 is a voluntary industry standard for designing, testing and labeling a wheelchair. A WC-19 wheelchair has four permanently attached and labeled securement points, highlighted with a standard label as seen in Figure 15. As WC-19 wheelchairs become more common, securement will become easier and more standardized. However, the current situation is that powered mobility aids are increasing in size, rarely designed to be transported, and increasingly difficult to properly secure (*ANSI/RESNA WC-4:2017, Section 19 - Wheelchairs Used as Seats in Motor Vehicles*, 2017; Rehabilitation Engineering Research Center (RERC) on Wheelchair Transportation Safety, n.d.).

When asked what one thing they would want to see changed going forward regarding the current securement and containment processes, one of the representatives of the mobility aid manufacturer brought up the challenge that is faced by a lot of airlines: staff turnover and third-party contractors. They stated that training the “boots on the ground” staff is a continual effort, and that the education piece of securement and containment is critical. Communication between all stakeholders needs improvement, as suggested by these participants. A lot of the time, when the mobility aid manufacturers are receiving a damaged mobility aid, they “don’t know what really happened”. In addition, the communication between those who load the mobility aid (i.e., departures) and the handlers who have to unload and sometimes reassemble (i.e., arrivals) is completely lacking. The representatives stressed that there should be a “protocol that all airlines follow” when it comes to handling mobility aids. Table 4 provides a summary of the content analysis for this interview.

Table 4. Content Analysis Quadrant – Mobility Aid Manufacturer

Positives	Pain Points
• High degree of customization to fit client needs. • One-on-one with each new client is completed to understand requirements. • ISO standard securement points already installed on all mobility aids (ISO 10542-1:2012, 2012). • Developed "how-to" guides for travelling with a mobility aid (posted as a blog). • Batteries used are pre-certified for air travel. • Inner electrical workings and frames are built around a company "standard"; similarities across models.	• Some [clients] don't even know that [air] travel is an option. • Lack of communication surrounding requirements for air travel. • Airlines and handlers need specific information on how to disassemble/reassemble, but it is not provided. • User manual is not "shareable", as it is long and wordy. • Travellers often make their own "travel kits" for handlers. • Training/recurrent training on how to tie down a powered mobility aid does not seem to be provided. • Customization could be challenging for handlers to work around.

Issues	Recommendations
• Communication between clients (i.e., the PWD) and the handlers is lacking.	• Manufacturers create a mobility aid quick guide that is permanently attached to the chair (e.g. slides out from under seat or backrest)

Issues	Recommendations
• Little to no communication between departure handlers and arrivals handlers regarding disassembly/reassembly of mobility aids. • Customized chairs result in a lot of parts and it is hard to standardize securement across custom chairs. • Handlers missing the securement points, and using a "best-guess" method.	that addresses customized mobility components. • Standardized training amongst carriers to create a baseline of knowledge for handlers and include manufacturers as stakeholders. • Manufacturers ensure that during requirements-gathering stage, air travel is addressed.

4.2.3 Handlers and Airline Staff

The NRC met handlers and airline staff either in person or virtually, and included two ramp handlers, two airline damage claims employees, two systems operations control employees, one training manager, and three check-in agents for interviews (for a total of 10 employees). These different types of professionals were grouped together in this category of stakeholders, as their professions require that they handle and manage any assistive technologies or critical information pertaining to the safe handling of these devices and are a part of the holistic handling process. For instance, booking agents, check-in agents, damage claim employees and training managers manage information regarding clients' requests, training for staff, and resolution, among other information. Behind-the-scenes systems operations managers and ramp handlers deal with the securement and containment procedures of the physical mobility aids. All stakeholders listed in this group push or pull information from each other and therefore play an essential role in the discussion of the communication and training needs. Interviews focused on the discussion of the technical processes that a mobility aid and its information undergo from when a client books a flight to when they arrive back from their flight.

One main topic in these interviews was about whether airlines provide clients with

information forms to fill out before their trip, and how handlers receive this information. Many airlines do provide these types of forms, but participants discussed how, at times, passengers bring their own. Moreover, the forms provided by the airlines are normally in paper format, and this was discussed as being an issue as the paper can be lost before getting to handlers or inefficient for handlers who normally work manually with gloves or many objects in their hands at the same time.

Training was a significant focus of discussion with the handlers. Within the ATPDR there is a requirement in paragraph 18 titled “Handling mobility aids”. This provision state the following:

> If a member of personnel may be required to handle mobility aids in the course of carrying out their functions, they must receive training that provides an adequate level of knowledge and skills to carry out those functions, including training including with respect to:
>
> a) the different types of mobility aids; and
> b) the requirements and appropriate methods for transporting and storing mobility aids, including the disassembling, packaging, unpackaging and reassembling of mobility aids.

When questions arose about training, handlers stated that they have to rely on common sense or intuition when handling a mobility aid. They could not recall their mobility aid-related training, nor specific mobility aid-related skills or knowledge acquired through training. Most handlers do not interact with a PWD and mobility aid frequently, and therefore handlers have not been given the time to acquire a mental model of how to handle a mobility aid safely. They emphasized the need for more specific, interactive and frequent training on the subject matter. There needs to be a way to address the fact that they may experience skill fade. (Skill fade is the gradual decline in abilities or adaptiveness towards a skill that is utilized infrequently. Skill fade may occur if the training provided is provided once across the career of the handler and/or they infrequently interact with mobility aids, such as in a small regional airport.) In addition to the physical handling of a mobility aid, handlers also noted that they did not recall soft skills as being a part of their training for handling mobility aids. Soft skills are certainly required throughout the process, and staff need a level of interpersonal skills,

even if they do not deal directly with passengers often in every shift. Lastly, they mentioned that this should be consistent across all handlers, regardless of carrier or contractor, otherwise the inconsistencies will lead to further damage if they rely on one another in any way.

Access and procurement of equipment was highlighted as an issue as well, with the representatives mentioning that handlers often injure themselves trying to manually lift powered mobility aids, which can weigh upwards of 300 lbs. With specialized equipment to lift the mobility aids from the ground to the height of the cargo door, handlers would not have to manually lift, and the mobility aid also wouldn't have to be placed on the belt loader. Belt loaders are too narrow for many powered mobility aids, which increases the likelihood that they will fall off, potentially causing irreversible damage. Table 5 provides a summary of the key findings.

Table 5. Content Analysis Quadrant – Handlers and Airline Staff

Positives	Pain Points
• Very invested in safely handling mobility aids. • Creative problem solving to try to improve the process (e.g., making a cart specifically for mobility aid transport). • Finding custom information sheets travellers bring that are laminated sheets, or booklets, describing how to interact with their mobility aid. Interested in this idea as a standard, but would like it simple and visual.	• Multiple stakeholders responsible for sharing information. • Paper mobility aid information sheets are not useful. • Reliance on manual methods of handling due to lack of equipment. • Experience and "common sense" are relied upon more than training when securing mobility aids. • Third-party contractors do not have access to the same airline-specific training that airline employees do. • Significant stress is experienced due to time restrictions at the gate once the traveller is transferred.

Positives	**Pain Points**
	• Cargo doors are small, and mobility aids are heavy and big. • Disassembly and reassembly occur at two different places by different people and sometimes different airlines. • Training is inconsistent
Issues	**Recommendations**
• Communication of information needs improvement. • Experience and "common sense" used over and above training. • Time pressure. • Safety of handlers.	• Efficient, interactive and repetitive training on securement and containment. • A quick guide for mobility aid securement. • Specific information from travellers regarding disassembly and reassembly. • Better tracking of traveller information. • Cargo door dimension database for handlers, travellers, and staff.

4.2.4 Damage Repair Services

We thought it important to interview participants that deal with the damage to mobility aids incurred from air travel. We interviewed two representatives from a company that specializes in rentals, replacement, and damage repair for mobility aids. This company also assists travellers in filing damage claims for damaged mobility aids resulting from their air travel experience. Finally, they also provide mobility aid handling training for airline staff. With operations across North America and points of contact at major

airports, they estimated (pre-pandemic, January 2020) that they were filing between 500 and 600 damage claims a month. It was our hope that data obtained from this interview could help pinpoint where the most frequent damage was occurring so that we could recommend performance guidelines that would have the highest impact at reducing damage to mobility aids. Although we were unable to obtain quantitative data regarding the frequency and type of damage, insight into the types of damage overall was possible.

During a discussion around the current processes of securement and containment, participants stressed the safety of the handlers as being incredibly important, and that the wellbeing of the traveller and their mobility aid should not fall solely on the handlers. Consistent with previous interviews, how information about the traveller's mobility aid is shared is unpredictable, and often lacking beyond the minimum of dimensions, weight, and battery type. Specific instructions on how to disassemble (if needed) to fit the mobility aid through a cargo hold door are often missed, unless the handler asks the traveller verbally during transfer at the gate, or the traveller brings their own custom information form. Many of the travellers that this company works with do not find that the airline-provided information forms capture the complexity of the mobility aids, and therefore do not use them. Because of their training program, they know that it often comes down to simply not knowing the kinds of questions that need to be asked (e.g., Can the backrest fold down? How do I disengage the drive mechanism? Can the joystick be removed?). Mobility aids can look extremely complex, but once the handlers know what to look for, their job becomes easier, and the frequency of damage decreases. These issues highlight the need for efficient communication (right information at the right time) across all individuals involved in handling the mobility aid during the air travel experience.

The training this service provides also highlights soft skills required throughout the process. They understand that staff members need a level of interpersonal skills, especially important, as they do not deal directly with passengers often. People who manage information and handle mobility aid devices need to be empathetic and have a level of patience for the issues they encounter. Issues or needs identified by PWD need to be taken seriously, and meticulous attention must be made to ensure not only the passenger's satisfaction, but also their safety. If the mobility aid is not transported

properly, it can be damaged; the passenger is then left without a functional chair and may not have it returned for a significant amount of time. This is a consistent finding with the handlers interviewed as well.

Overall, when asked what they would like to see changed within the current processes, they highlighted better training for handlers as the number one priority, and ensuring that they have access to knowledge and equipment to do their job safely. They also mentioned that improving the way that information about the traveller and their mobility aid is shared needs to be improved.

When asked what types of damage they see occurring most often with powered mobility aids, they mentioned fragile components like the joystick, armrests, leg and foot rests, and cushion damage. Although not occurring as often as damage to individual components, they also mentioned significant damage to the frame, to the point of being beyond repair. Cracked or bent frames, or damage to the electrical components, impact the structural integrity and functionality of the mobility aid, leaving the traveller without their mobility aid. Extreme damage like this would require the traveller to go through the process of getting a new mobility aid, which is the responsibility of the airline. Cracked frames typically happen if the mobility aid falls off the belt loader, which can occur for two reasons: not locking the wheels of the mobility aid, and/or an error on the part of the handler. Based on our task analysis, we also know that the width of most belt loaders is generally too small to accommodate a lot of larger mobility aids, which increases the likelihood that they will fall off. Damage to the frame or wheels can also occur because of improper securement, such as incorrectly placing straps on the mobility aid. First, if the straps are placed on non-welded components, those components are likely to crack or bend. Secondly, if the straps are placed at welded components of the frame, but are wrapped around the frame rather than hooked into securement brackets or laid across the frame, this prevents the strap from tightening evenly. A loose strap means the mobility aid can move and slide within the cargo hold, which has the potential to cause damage. Overall, the source of damage during transport is difficult to pinpoint, beyond falling off the belt loader. General aesthetic wear-and-tear was also mentioned, but they recognize that this is not of the same level of concern as the previously mentioned areas of damage.

Overall, when asked what the service provider would like to see changed within the current process, they highlighted better training for handlers as the number one priority, and ensuring that they have access to knowledge and equipment to do their job safely. They also mentioned that improving the way that information about the traveller and their mobility aid is shared needs to be improved. Table 6 includes a summary of findings related to damage repair services interviews.

Table 6. Content Analysis Quadrant – Damage Repair Services

Positives	Pain Points
• Track frequency and type of damage that occurs. • Integrated with airlines and travel agents. • Travellers can rent mobility aids, rather than take their own (only applicable to some). • Airlines organize contracting of the repair service for the passenger. • Airlines do provide training for handlers.	• Many individuals can be handling a mobility aid; “this is not all on the handlers.” • Safety of the handlers – having proper ergonomic training on how to lift, if mechanical lifts are not available. • Lack of use, or misuse, of airline-provided powered mobility aids information forms. • Handlers are not provided with a strong baseline of knowledge or awareness of the kinds of questions to ask. • Cargo doors (and belt loaders) are small, and mobility aids are big and heavy.

Issues	Recommendations
• Access to proper equipment (handlers) (e.g., mechanical lifts). • Procurement of equipment. • Safety of handlers. • Safety of the mobility aid. • Inconsistent training/practice handling mobility aids. • Communication of mobility aid information is lacking and inconsistent. • Handlers do not have informative training.	• Hands-on training for handlers when possible. • Recurrent training programs that address the needs of the handlers and travellers. • Better equipment for handlers. • Improvement on information sharing.

4.2.5 The Airlines

To gain an understanding from the airlines' perspective, a major Canadian airline was interviewed for this study. The airline representative currently works within the dangerous goods department of their airline, and had 15 years of experience in working with mobility aids in air travel. When asked to reflect back on their experience with handling mobility aids, they said that “information transfer is key”, and highlighted how important communication and cooperation are, on all fronts, when transporting powered mobility aids. When a traveller arrives at the check-in counter, they have ideally provided advance notice (i.e., at least 48 hours is required, but at the time of booking is preferred) that they are travelling with a powered mobility aid. With this specific airline, travellers with mobility aids are also encouraged to fill out a paper-based information sheet that contains various pieces of information about the mobility aid (e.g., weight, dimensions, battery type, where various parts are being stowed, any prior damage). However, in their experience, some travellers also bring their own personalized information sheets that they have made themselves and that contain similar information, but also go above and beyond to included pictures and disassembly instructions. This representative recalled one instance where a traveller arrived at the

airport, and had filled in the airline specific information form, and had their own sheets with "all the right information…[and] how to handle their mobility aid", but that this does not happen as often as they would like.

The airline representative stressed that, in order for the handlers to do their jobs, handlers need specific information about how to properly handle powered mobility aids but that the onus for providing this information should not fall entirely on the traveller; they suggested that the mobility aid manufacturers provide a "quick set-up sheet" for any traveller's mobility aid that they can use for air travel, rather than having the traveller compile the information. They said that this "kit" should be "graphic-[based] and very clear" so that it is easily interpreted regardless of language. For example, they reflect back on an instance when a traveller was taking a flight, arrived at their destination, only to realize that their mobility aid wasn't charging because "when it got put back together…they didn't attach an extra wire that had to go in which would have let [the mobility aid] charge". When asked about handler training on loading powered mobility aids, they said that all handlers receive proper training, highlighting that mobility aids should never be turned on their side during the loading process. However, in speaking directly with handlers, this isn't always the case; handlers reported that they feel pressure to load quickly and ensure that they do everything they can to make sure that the traveller is able to take the flight they booked, which has previously included turning the mobility aid on an angle.

Powered mobility aids can have highly customized components, and no one mobility aid is exactly like another. When discussing the complexity of mobility aids, the representative mentioned that handlers, and occasionally the travellers themselves, do not know the inner mechanical workings of the mobility aid (e.g., how to remove components, or safely disable the battery) because, beyond air travel, there isn't any other mode of travel where the traveller and their mobility aid are not together. They mentioned that they see a wide variety of experiences in travellers, with some travelling frequently through the airport, and others who are preparing for their first flight. Experienced travellers know what to bring and how to prepare, while newer travellers might not. When discussing the mobility aid information sheets, they mentioned that although the idea of sheets is helpful, in practice, they don't provide information in a transferable way, highlighting the challenges between departure and arrival handlers as

well as language barriers.

In addition to the complexity of mobility aids, they also mentioned that both the handlers and the airline are under significant time pressure when preparing an aircraft for a flight. Once the traveller is at the gate, the handlers only have a short amount of time to get the mobility aid down to the tarmac, load it into the cargo hold, and secure it for travel. Given time pressure, in addition to having to complete a potentially unfamiliar task (i.e., disassemble, or reassemble, a mobility aid), there is a chance that the handlers could miss a step if they do not have the information clearly presented to them. In addition to time pressure, the aircraft type could also change at the last minute and, if the traveller is taking multiple flights, they might be on more than one type of aircraft. The time pressure to take off, combined with the potential for last minute changes in the type of aircraft, means that there is the chance that the available aircraft's cargo door is too small for the traveller's mobility aid and that the traveller will have to wait for the next available flight. When discussing cargo door dimensions, the representative stated that they think the reporting of "accessible dimensions…should be up to the airline itself". They also recognize that the inherent cost of damage, both emotionally and physically for the traveller as well as the monetary cost and reputation of the airline, is a risk that the handlers take when handling powered mobility aids. When prompted to reflect on the training that handlers receive on mobility aids, they stated that the handlers do receive training in compliance with the regulations, but they were unsure how often training occurred. In addition, they said that the traveller and the handlers should work together, in that "it is not the customer's [job] to say "you should strap [the mobility aid] down here"…that should be training that comes from the manuals of the airline".

When asked to reflect on any recommendations for improving the current processes of securement and containment, they highly recommended that a general guide on mobility aid practices be developed, in addition to a specific "how-to" guide from each traveller that mentions key details about how to safely handle their mobility aid. Ideally, this would be developed by the mobility aid OEMs themselves, so that the onus for compiling information from the user manual does not fall entirely on the traveller. They also stressed the importance of pre-notification and that although a 48-hour notice is required, notification at the time of booking is preferred so that both the traveller and

the airline ensure they have any required materials or staff ready when the traveller arrives. Pre-notification and arriving early at the airport ensures that the handlers have as much time as they can in order to do their job safely for everyone. In conclusion, they mentioned that, when considering these challenges, “there isn’t one answer” to solve everything, “there’s multiple answers depending on the situation, but information transfer is key”. They noted that all employees “think of this [mobility aid] as a passenger [does], and this is their legs”. Table 7 summarizes the ideas from the interview with the airline.

Table 7. Content Analysis Quadrant – Airlines

Positives	Pain Points
• Developed information sheets for mobility aids. • Claim that training needs are met (for handlers). • All mobility aids need to be loaded right-side up.	• Disassembly and reassembly happen at two different locations. • “Information transfer is key”. • Handlers are often in a rush. • Changing aircraft last minute can present major issues. • Differences between expert and novice travellers. • Not all passengers understand the “inner workings” of their mobility aid. • Bare minimum = need dimensions of the mobility aid, weight, and battery type. • Cost is high for everyone if damage occurs. • Language barriers.

Issues	Recommendations
• Communication between departure and arrival handlers. • Time pressure. • Handlers getting the information they need, when they need it.	• A general quick guide for handlers. • Specific information from travellers regarding how to disassemble and reassemble removable parts. • OEMs should provide a guide for handling (user manual). • Relieving time pressure.

4.2.6 Travel Agents

We interviewed travel agents from two different agencies. These professionals were specialized in booking trips for individuals with disabilities and therefore provided fruitful information for this project. Their job consists of meeting accessibility needs during the booking process of the travel journey for people who have accessibility concerns. Having travel agents that specialize in accessibility is essential in the industry as airline websites can be difficult to navigate for the general population. It can be even more difficult to use when a client has specific needs, but information is either unavailable, inaccessible or not presented in a user-friendly manner. Their clients usually return to them for future bookings, knowing that they have someone that they can trust and rely on to get the job done.

One topic discussed was the use of the Global Distribution System to book clients. This is a system that agents use, which contains detailed information regarding the flights for each airline. Although this system is what they work with every day, it contains no information about cargo door dimensions. Agents are required to call the airline every time they book a PWD traveling with a mobility aid to obtain information regarding the cargo door dimensions. Moreover, not all travellers know the details of their wheelchairs well enough to know how to answer the agents' questions regarding the properties and dimensions needed of the mobility aids. This means that the traveller has to either call them back once they are informed, or the agent books with uncertain

measurements. These issues can create a time-consuming booking process, reduces the chance that clients can book in short notice, or profit from last minute travel deals. Even though an agent can look up many of the aircraft cargo door dimensions online from various sources, flight information is constantly changing. Therefore, the agents need the airlines to be aware that there is a PWD flying with a mobility aid so that, when changes to the airframe occur on the flight, the airlines can inform them about the changes and help reduce possible issues at check-in.

Agents discussed how there is a need for all staff involved in the process of transporting the mobility aid to truly understand that the mobility aid is the passenger's “legs”. Therefore, the mobility aids need to be cared for with the same level of integrity or intentionality you would treat a passenger because, if the mobility aid is damaged, the traveller will be at a disadvantage and this can seriously impact their travel and post-travel experience. There was a discussion about how damaging a wheelchair can affect more than just the traveller. The airline has a reputation to uphold and, if wheelchairs are not transported safely, there is negative backlash by many clients.

Recommendations that came out of these discussions revolved around training for handlers. The emphasis was both on how to work with mobility aids, but also on how to work with the traveller. They need to be able to listen to a traveller’s requests with a perspective that is intentional and empathetic to their needs. Moreover, they need to understand the securement process. Training on how to recognize key features of mobility aids is essential. Another recommendation was to enhance the accessibility of airline websites. This can allow for a greater number of individuals to get involved and interested in booking more flights. It also allows them some sense of autonomy that they rightfully deserve from the airlines. In addition, airlines should provide cargo door sizes in their booking information. It should appear with flight numbers during the booking process so that passengers do not have to go through a lengthy process to find the information necessary to them. Table 8 contains a summary of the interviews held with travel agents that specialize in accessible air travel.

Table 8. Content Analysis Quadrant – Travel Agents

Positives	**Pain Points**
• Travellers rely on agents to help with the booking process. • Agents act as a mediator between the traveller and the airline to ensure accessibility needs are met. • Need dimensions, weight, battery type, make and model of the mobility aid from the traveller.	• Damage to powered mobility aids is frequent • Airline websites are an accessibility challenge. • Training for handlers does not meet their needs. • "Viral" photos and videos on social media are costly for the airline and the traveller. • Airlines can change airframe at the last minute (cargo door sizes). • Requesting information from travellers.
Issues	**Recommendations**
• Training for handlers. • Cost for everyone. • Communication of mobility aid information.	• Cargo door dimension information readily available. • Better tracking of mobility aid information. • More empathy, understanding from the airlines. • Better training for handlers. • Enhancing accessibility of airline websites.

4.2.7 Subject Matter Expert (Academic)

We interviewed one subject matter expert (SME) who provided insight into the holistic process and its pain points. This SME has an engineering background and expertise in accessible transportation. Overall, the SME noted issues with handler training and support, mobility aid design, time pressure in air travel, and transparency and communication between stakeholders. See Table 9 for a summary of the analysis of this interview.

The SME stated that handlers lack the soft and hard “tools” they require for successful mobility aids handling. Training for handlers is most often online and not interactive. However, handling a mobility aid is an applied skill and, as such, the training needs to support this type of knowledge acquisition. In addition, handlers are subject to skill fade, as exposure to powered mobility aids is infrequent. This suggests that there would be a significant benefit in ensuring that recurrent training has a knowledge test component, and that useful and usable checklists are made available to handlers, as opposed to the currently available paper information forms. Although recurrent training is already required by the current ATPDR, there still seems to be a gap between the acquired knowledge and the applied skills. Language is also a barrier that handlers face while interacting with PWD and, therefore, checklists or tools need to be language independent, for example visual stickers to highlight tie-down points.

The design of mobility aids is a barrier to travel for PWD. The SME stated that current mobility aid design does not support air travel explicitly. A significant challenge within this area includes the size and shape of mobility aids. Fitting a square peg into a round hole is an analogy used to describe placing a larger mobility aid through cargo doors. In addition, once in the cargo hold, they are tight and difficult for handlers to move around. The tight quarters can make tying down the mobility aids within the cargo hold very difficult and not ergonomic. Lastly, handlers have to complete their tasks in a very short time frame so as not to delay the departure time. They feel rushed, and this frequent scenario leads to safety issues and damage to mobility aids.

Communication and transparency between stakeholders is key, according to the SME interviewed. From PWD's perspective, they need to know that they will be taken care of

safely. However, from the very first task of booking a flight, it is clear to the PWD that accessibility is not at the forefront of concern for the airlines. This is apparent in the airline websites as they are inaccessible to some, leaving the PWD relying on booking agents or phoning the air carrier directly. Finally, there is a requirement for accountability of damaged wheelchairs on an International level. When the US Congress passed the *FAA Reauthorization Act of 2018*, H.R. 302, Cong., 2018, they included a rule that requires airlines to report the total number of wheelchairs carried and mishandled each month. The Department of Transportation releases the data monthly in an Air Travel Consumer Report. This is a new requirement, and it will be interesting to see if it affects airline selection by PWD in the future. See Table 9 for a summary of the points discussed in the SME interview.

Table 9. Content Analysis Quadrant – SME

Positives	Pain Points
• The majority of high-end powered mobility aids will come with securement points for vehicle transport. • Desire to travel is strong, and needs should be met.	• Access to equipment for handlers (e.g., lifts, elevators, carts, etc.), and airport engagement. • Language barriers for information sheets rely heavier on visual cues and checklists. • Time pressure at the gate and maintaining flight schedules. • Mobility aid information sheets are not always accessible. • Training for handlers does not always reflect the practice; needs to be interactive and recurring. • Mobility aids are not designed for air travel.

Issues	Recommendations
• The majority of mobility aids already have tie-down points, but handlers do not recognize them. • Communication of mobility aid information. • Lack of accountability and understanding of risk.	• Mobility aid information recorded electronically (traveller profile). • Interactive training for handlers to provide a baseline of knowledge and understanding. • Visual guide sheet for handlers. • Transparency from the airlines.

4.3 Results and Analysis Summary

It is clear from the analyses contained within this report than the process for safe securement and containment of mobility aids extends beyond the cargo hold. Throughout the task analysis and stakeholder interviews, stakeholders identified challenges associated with communication, education and training. Approaching the challenge of safe securement and containment of powered mobility aids from a systemic, holistic perspective provides the opportunity for widespread improvement. To address the concerns raised by the stakeholder groups and task analyses, a multitude of recommendations are presented that address key areas of interest that were defined in previous work conducted by the CTA.

5. Recommendations and Discussion

The main objective for this project was to develop functional guidelines and performance standards for the airlines on the securement or containment of mobility aid in the cargo compartment. Therefore, the project goals were as follows:

1. Identify, through interviews, observation, and user feedback, the current pain points faced by stakeholders during securement and containment of mobility aids in the cargo hold;
2. Understand the needs of handlers/ramp personnel when they are interacting with a powered mobility aid; and
3. Using the Key Areas of Interest from the CTA IWG, identify the highest priority issues based on our analysis.

Researchers used a program called Miro to help analyse and categorize the issues raised by stakeholder groups, and key areas of interests identified by the IWG (Hunter-Zaworski, 2019). Miro is an online visual collaborative platform used for identifying common pathways and links across various items. Researchers grouped the pain points and recommendations raised by stakeholders by common theme. The analysis resulted in the extraction of recommendations that can be categorized as functional and of performance guidelines related to handling mobility aids, in addition to system-level recommendations. Therefore, researchers divided the recommendations into two sections; one dedicated to functional guidelines and performance standards, and a second that is dedicated to the system-level recommendations. Within the system-level recommendations, the focus was on the most frequently identified issues of communication and training. It is important to define the difference between a functional guideline and performance standard in reference to safe securement and containment of a mobility aid. A functional guideline enables the handler to complete the task in an easier or safer way, for example, “Handlers may benefit from recurrent and hands-on training”. In contrast, performance standards describe handler performance that is considered acceptable by their employers. These tasks are measurable and should relate to performance appraisals by management. Performance standards fit into one of four categories: quality, input, efficiency or outcome. Therefore, an example of a performance standard related to safe securement and

containment of a wheelchair may be “The mobility aid is secured using four points with four independent straps (2 front, 2 back) each secured at 45 degrees”. Section 5.1.2 provides a brief discussion on the important role of performance standards. Given the prescriptive nature of performance standards, the focus of this report will be on functional guidelines.

5.1 Functional Guidelines

Observations, albeit limited, strongly suggest that handlers do not have the skills or knowledge to secure a powered wheelchair properly. This is due to no fault of their own; the fault sits at a system level. Mobility aids can be extremely complex, are growing in dimension and weight, and are not designed with air transport in mind. To set up the handler for success, we recommend that exposure to informative handling and securing processes be included in recurrent training, that easy-to-use job aids be made available, and that accurate information about each mobility aid be shared in an informative way for the traveller, the airline, and the handlers.

The following functional guideline recommendations can support the success of the safe securement and containment of powered mobility aids:

1. Provide simple, usable and useful job aids presented in lay language with significant visual guidance. See 5.1.1.1 for specific details on recommended functional guidance documents.
2. Provide working knowledge regarding how to apply basic securement principles. These best practices, found through the Canadian Association of Occupational Therapists or similar, provide free, basic securement guides.
3. Share information that is customized to the specific mobility aid at the handler level as soon as possible to ensure safe and accurate securement, or risk delayed departure. This will relieve associated time pressure that the handlers and PWD feel at the time of transfer. The Mobility Aid Passport, under development by IATA, may feed into this recommendation.
4. Custom mobility aids can be difficult, if not impossible to secure. A possibility is to have a floor manager or other highly qualified handler thoroughly trained on

special securement knowledge who can help guide the handlers and confirm securement.

5. Perform a pre-departure check for debris in L-track. Debris in the cargo hold tracks acts as a barrier to proper securement and containment in the cargo hold floors.
6. Handlers need to be able to access securement straps at all times when needed.
7. Securement straps used by ramp handlers are seen as “prehistoric” in the mobility aid industry. The airlines or airports should replace them, where possible, with automatic or semi-automatic locking retractor straps that are compatible with L-track systems for ease of use and potentially less damage as they self-tighten and lock.
8. Ensure required ramp equipment is available for handlers. Many handlers manually lift powered mobility aids from the ground onto the belt loader, which introduces a level of risk to both the handler, from an ergonomics and safety perspective, and the traveller, with an increased likelihood that damage to the mobility aid will occur. Although special ramp equipment is expensive, the cost of disability claims directly caused by lifting may be an offset. A specialized lift that would reduce or eliminate the need to lift a powered wheelchair manually could benefit the handlers and reduce disability claims in the future. Airlines did not have this data available for this current study, but we recommend that airlines consider doing a cost-benefit analysis.
9. A hand-off of information between departure and arrival handlers.

5.1.1 Functional Guidance Job Aid

Based on the findings, we recommend the creation of a functional guidance job aid. This aid should be usable and as standardized as possible. It should contain clearly defined high-level steps for securement and containment, written in lay language and rely on visuals for quick reference.

The purpose of a job aid is to provide the handlers with a tool containing clear steps to follow when preparing a mobility aid for securement and containment in the cargo hold, should they have questions about securement. Job aids provide just the right amount of

guidance at the moment needed, for example a checklist. Reasons to include the job aid include: skill fade, low recurrence of training, training that is not applied (e.g. hands-on) and perhaps even non-compliance with training regulations.

It is recommended that this guidance document be developed in two formats: an extended version to have as a reference and used during training, and a job aid version that is posted at the workplace and potentially on mobility aid handling equipment such as mechanical lifts and/or carts, as well as the mobility aid itself.

Critical tasks identified in the task analysis should be included in the job aid; however, they require validation by subject matter experts. Graphics and lay language become the primary mode of communicating the validated tasks. Handlers complete critical steps and then verify the work done by the handler or an "expert" handler who is more qualified in handling powered mobility aids. Although in theory this would be implemented across all airports and carriers, we recognize that this may not be feasible for all operators. One alternative is making these major airport resources available on remote or virtual call for smaller bases as in-person assistance is much more useful and practical. We suggest these four steps as a starting point:

1. **Prepare** – The sub-steps are those observed during the task analysis, and include steps recommended by IATA as stated in (IATA, 2020) and the task analysis results:
    a) Check dimensions to ensure fit into cargo hold
    b) Turn off the on/off button
    c) Disconnect the system (take out the key, disconnect the joystick, disconnect the turn on lever)
    d) Confirm with the passenger if the battery is designed to be removed or not for transport
    e) Fold or remove foot/leg plates, headrest and backrest and store
    f) Engage freewheel mode and brake mode for battery-powered wheelchairs
2. **Identify securement points** – prior to loading the mobility aid onto the belt loader or mechanical lift, the handlers should visually identify the securement points they will use. This will afford the handler with adequate space to move around the mobility aid without being in a confined space of the cargo hold while

identifying securement points. Securement points can include brackets identified with a standardized sticker (WC-19), or sturdy points on the base of the mobility aid. The guide should include pictures of proper and improper securement. In addition, remind handlers that wrapping straps around armrests, wheels, foot/leg rests, or any removable part will result in damage.

3. **Load device** – prioritizing safety is crucial during this step. Handlers should use assistive equipment whenever possible and use good ergonomic techniques. They should not lean on fragile components of the mobility aid (e.g., joystick, control panel), and the mobility aid should be loaded right side up to prevent damage.
4. **Secure** – two options presented based on whether the mobility aid has specialized securement brackets or not. Both methods refer to a 4-point tie down, which is a standardized method for securing mobility aids (ISO 10542-1:2012). Any tie-down method must also comply with regulations in place for airworthiness of securement within the cargo hold. Securement straps have a direct path to securement point (See Figure 16 for examples of graphics and text).

Figure 16. Graphics and text to identify securement points and proper tie down

(from: https://www.qstraint.com/es-mx/securement-101/)

Throughout the job aid, there can be visual indications that highlight when the handler could refer to the Mobility Aid Passport or Mobility Aid Handling Checklist for more information about the mobility aid itself, provided by the traveller, and that are under development by IATA. A journey map, provided in Appendix 3, highlights a job aid integrated into the process as a whole. As previously stated, work completed with the CTA (Hunter-Zaworski, 2019) resulted in numerous recommendations. One of these recommendations was to create a Mobility Aid Passport. This Mobility Aid Passport is currently under development by IATA, and therefore will not be the subject of further recommendations within this report. Results from this study are consistent with the need for a Mobility Aid Passport.

Transport Canada (TC) created a similar job aid associated with securing child restraint seats (Hagen, L., Kelsey, S., Murray, JL. & Scipione, 2010; Rudin-Brown et al., 2004). Child restraint systems (CRS; car seats) are designed to prevent injuries in motor vehicle collisions. However, securement errors are very common and seriously reduce its safety benefits. TC conducted studies to understand what was contributing to safety errors and revealed that one major contributor to securement errors are poorly designed labels and instructions. CRS labels and instructions are not held to an evidence-based label design standard. TC redesigned the labels relying on a user-centered design (UCD) process for infant/child convertible CRS installation labels. The labels focused on two primary tasks: installing a CRS into a vehicle and securing a child into the CRS. The label design concepts were based on literature identifying primary areas for CRS misuse, human factors and UCD principles, product warning and label design standards, and current Canadian and US motor vehicle safety standards. The labels attach directly to the CRS so that they are always available to the user (see Figure 17).

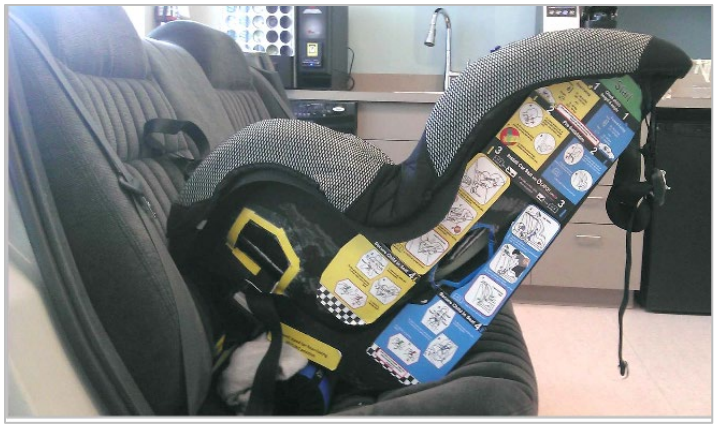


Figure 17. CRS label designed as a job aid for securement

A follow-up study evaluated the reduction of CRS installation errors based on the hypothesized enhanced label usability and effectiveness. There are similarities between securing a CRS and securing a powered mobility aid; but most particularly is that they are not secured frequently by the same person, and therefore it may be assumed that a job aid, such as the labels created for the CRS may provide great benefit to handlers in reducing damage caused by securement errors.

5.2 Performance Standards

Based on the data collected, it is clear that there is a gap in skills and knowledge for handlers related to securing wheelchairs. The gaps in knowledge and skill identified in this report may not be equivalent across all airlines and third-party subcontractors who employ handlers, and therefore we cannot assume that the same training needs are required for all handlers. What we can recommend is to conduct a detailed training needs analysis (TNA). A TNA will help employers to identify the specific training and development needs so that the handlers can do their job effectively. The TNA may need to include different needs based on whether it is intended for a new or an existing employee. For example, recurrent training may have different learning objectives than initial training. In addition to conducting a TNA, it would be very interesting to evaluate the number of claims, hours lost, or money lost related directly to loading wheelchairs. In turn, this data could be used to develop a set of metrics that could cue the airline to retrain employees or re-evaluate their processes.

Stakeholders included in this study were unaware of any existing performance

standards related to securement tasks. The TNA will provide a direct link between training and performance standards. Once employers identify gaps in current skills and knowledge, they can then link associated performance standards. Performance standards integrated into the system will lead to an improvement in mobility aid securement and containment. The standards can also close the feedback loop regarding future training and skills needed.

The training outcomes and performance standards are linked to the proposed job aid, which is in essence an outline of the critical steps identified in the TNA. This version of the job aid could contain detailed steps with photos of correct ways for handling mobility aids, including visual identification of safe securement points and brackets, and videos that reference current best practice standards such as WC-18 and WC-19. The extended training aid could also act as a template for airlines when they are developing training for their employees, rather than having to develop their own training modules from scratch.

5.3 System-level Recommendations

It is certain that there are various ways to reduce errors associated with mobility aid securement and containment; however, the overarching issue lies at the system level. For example, if functional guidelines are implemented and followed, errors may still occur because the system as a whole includes numerous stakeholders who rely on each other to provide the right information at the right time – no one stakeholder holds the key to success. Therefore, in this section, we discuss the issues from a system level and provide recommendations within two sub-themes: communication and training.

5.3.1 Communication

Communication is extremely important, especially when there is an element of risk involved. With many groups involved, either directly or indirectly, in the handling of powered mobility aids, researchers created a communication pathway diagram (Figure 18). The communication pathway diagram enabled researchers to understand communication occurring, or not occurring, between each stakeholder group. The solid lines represent a pathway that currently exists based on our analysis. Blue dashed lines

are pathways that exist, but are not clear, and often involve intermediate communication (e.g., the travel agents having to call the airline to confirm on behalf of the traveller). The dashed lines represent a pathway that does not currently exist based on our analysis, and we recommend that the stakeholders address this communication gap.

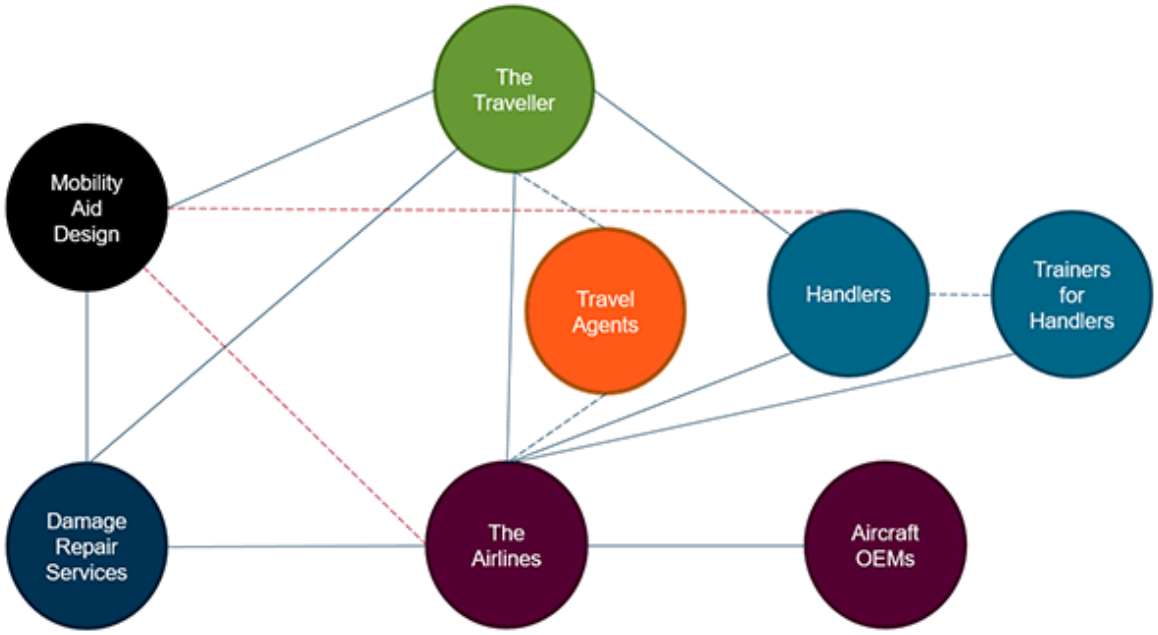


Figure 18. Communication pathway diagram for stakeholders involved

Lack of communication between mobility aid OEMs, airlines, and their handlers, means that travellers are solely responsible for providing information about their mobility aid. This currently occurs in the following three ways:

1. Provision of basic minimal information regarding dimensions, weight, and battery type;
2. Use of the airline-provided mobility aid information forms;
3. Traveller-made custom forms that describe how to safely handle their mobility aid (e.g., laminated do-it-yourself information sheets) based on the user manual for their mobility aid.

Although the mobility aid OEMs provide a user manual with each mobility aid, providing this entire document to a handler is not realistic.

Participants revealed that throughout the process of air travel with powered mobility aids, only minimal communication needs are met, and they tend to occur most often due to frustration with the current communication process (e.g., use of the information form, labour involved in making their own sheets). In addition, if the traveller is newer to the process and is not aware that they should include certain types of information, the handlers are then left guessing at all levels of handling the mobility aid (disassembly, transport, securement and reassembly). As a result of these challenges, we are recommending enhancing communication with mobility aid OEMs as a priority.

In addition to providing the mobility aid's user manual, we recommend that mobility aid manufacturers also provide a brief guide that travellers can attach to their Mobility Aid Passport, made available to handlers. Travelling by air with a mobility aid is currently the only mode of transportation where the traveller cannot remain in their mobility aid throughout the travel experience. It is also the only mode of transportation where the mobility aid may need disassembly to prevent damage of fragile components or to fit through the cargo hold door. If mobility aid OEMs provide a shorter document with visuals and clearly defined steps for safely disassembling and reassembling the mobility aid, this would have two obvious benefits:

1. The handlers would have detailed information about any nuances or additional complexities within the design of the chair, meaning they would not have to use a “best guess” when preparing the mobility aid for loading or comb through the larger user manual document.
2. The traveller would not be solely responsible for understanding the mechanical and electrical workings of their chair when preparing their Mobility Aid Passport, or any travel documents they may bring with them that relate to their mobility aid.

Beyond developing a condensed guide for mobility aids, we are also recommending that, for those mobility aid OEMs that include securement brackets as part of their design, the brackets themselves be made more eye catching, rather than black with a small sticker. Seeing as how they are a safety feature of the chair, we recommend that they be quick and easy to recognize. This could be done by adding colours such as yellow to indicate an important safety feature, similar to the ISO standards for use of

colour and symbols in safety signage (ISO 3864-1:2011) as well as their standards for design of graphical symbols for hazard and safety signage (ISO 7010:2019), or through textural differences (Rudin-Brown et al., 2004). We recognize that not all mobility aid OEMs attach securement brackets, and therefore handlers should follow the basic securement practices recommended; that is, securement straps placed on solid, or welded frame element.

There is a growing need to redesign safety features of mobility aids for transportation. Uptake of WC-19 and WC-18 safety standards is occurring, thanks to efforts by ANSI, RESNA, and the University of Michigan (*ANSI/RESNA WC-4_2017 S18*, n.d.). The development of these standards allows mobility aid OEMs to affix a WC-19 sticker (Figure 19) to the mobility aid if it meets the following safety standards:

- Have at least four permanently labeled securement points that can withstand forces of a 30 mph, 20 *g* impact;
- Have specific securement point geometry that can receive a securement end fitting hook of specified maximum dimensions;
- Be equipped with anchor points for a wheelchair-anchored pelvic belt and recommendations for purchasing a belt if not provided, such that the wheelchair and pelvic belt will withstand a 30 mph, 20 *g* impact;
- Provide a standard interface on the pelvic belt to connect to a vehicle-anchored shoulder belt.

Figure 19. WC-19 Wheelchair Transportation Safety (WTS) symbol

Although these standards currently only apply to ground transportation, ensuring these safety standards are met by the mobility aid OEMs means that proper securement points are indicated on the mobility aid itself.

Q-Straint, a world leader in the development of wheelchair securement systems, has also acknowledged the important work being done on WC-18 and WC-19, and has embraced the new standards by developing new products that comply with the WC-18 safety standards on securement. As of October 2020, 119 individual mobility aids (not limited to powered mobility aids) comply with the WC-19 standards; an updated list of WC-19 compliant wheelchairs can be found on their website (http://wc-transportation-safety.umtri.umich.edu/crash-tested-product-lists). As more airworthiness crash testing research is completed, mobility aid OEMs have the opportunity to develop "ready to fly" mobility aids for their customers.

Beyond enhancing communication with mobility aid OEMs, we recommend improving communication between travellers and the airline by further developing the Mobility Aid Passport and Mobility Aid Handling Checklist, identified as short-term recommendations within the *Mobility Aids and Air Travel Final Report* (Hunter-Zaworski,

2019). It is important that, when implementing these aids, airline staff and travellers are familiarized with them to ensure their proper use. The mobility aid passports are to contain "key instructions and information" such as "dimensions and any special instructions for safe handling" so that handlers would have the information they need to perform their job safely (Hunter-Zaworski, 2019). Types of information that are expected to be included within the Mobility Aid Passport are weight, dimensions, battery type, methods for safely disconnecting or powering off the battery, lifting and tie-down points (with photos), and instructions on safe disassembly and reassembly specific to the traveller's mobility aid. The Mobility Aid Handling Checklist was proposed as being a "simple, standardized generic handling form" that handlers can use when disassembling and reassembling the mobility aid (Hunter-Zaworski, 2019). With access to specific information from the traveller, as well as interactive training with practice on securing mobility aids, handlers would be better equipped to do their job safely for everyone. Therefore, further development of the short and medium-term recommendations for a Mobility Aid Passport and a Mobility Aid Handling Checklist are crucial. In addition, ensuring that handlers and airline employees have access to passenger information within a shared database is of great value.

5.3.2 Training

With respect to training, either the *Personnel Training for the Assistance of Persons with Disabilities Regulations* (PTR) or the ATPDR will apply depending on the size of the transportation service provider. The ATPDR covers large air carriers and the PTR covers smaller air carriers. Both regulations state that airlines are to provide training to all employees and contractors who handle mobility aids and, generally speaking, both require that training include methods of transporting and storing mobility aids including disassembling, packaging, unpackaging and reassembling aids.

Previously, the PTR applied to all air carriers regardless of size, and stated that carriers and terminal operators that fall under the regulations were required to ensure that staff "receive periodic refresher training sessions appropriate to the requirements of their function" (section 9). Although small air carriers still fall under the PTR, the introduction of the ATPDR now requires large air carriers to administer recurrent training at least once every three years (Part 1, section 21). It is clear, based on observations, that there

is a gap between the training content and the knowledge that handlers' possess and apply on the job.

Although the ATPDR requires that "transportation service provider…consult persons with disabilities in the development of each training program and the principal teaching methods" (Part 1, subsection 23(2)), the current regulations do not prescribe the format that mobility aid training takes (e.g., online training, in-person training, interactive training with mobility aids, etc.). In addition, to our knowledge, performance metrics and standards do not exist. The task of securing a mobility aid is interactive in practice, and we recommend adjusting current training, whether through regulations changes or simply recommendations to airlines. We also recommend that training regulations continue to require recurrent training to prevent errors associated with skill fade. Providing informative, efficient, and recurrent training to handlers and airline staff is crucial for reducing error due to skill fade, especially because those who travel with powered mobility aids are not as frequent as those who travel without one. Providing easy to remember steps, acronyms, photos, and practice scenarios would better equip handlers and airline staff in assisting those with powered mobility aids during the air travel experience, particularly as the securement process of their mobility aid is a major source of anxiety for travellers.

The following are recommendations to consider when developing training materials for handlers beyond the current regulatory requirements:

1. Include an applied knowledge and skill acquisition component with airworthiness-approved securement methods similar to a 4-point tie down used in ground vehicle transport.
2. Include knowledge regarding how to recognize securement points visually – all mobility aids are different, and some may or may not have designated securement brackets. Having practice with visually identifying bracket types, or other safe securement points on the frame of the mobility aid, is crucial. Handlers should also make every effort to do this prior to loading the mobility aid, as it will become challenging to maneuver once inside the cargo hold itself.
3. Include an applied knowledge and skill acquisition component for all equipment and tools used on the job including documentation and equipment.

4. Ensure handlers are familiar with the documentation they will be interacting with so that they know exactly where to look for information quickly when required.
5. Create a baseline of knowledge that handlers can transfer to more complex mobility aids – it is not crucial to know each mobility aid intimately, but more importantly to know the type of cues to look for and the key questions to ask.
6. Include soft-skill training as a mobility aid is an extension of the traveller's body, and needs to be handled with the utmost care and respect.
7. Training should include a walkthrough of the Mobility Aid Passport, the Mobility Aid Handling Checklist, and/or Functional Guidelines job aid so that the handlers and airline staff are familiar with the documents, and can integrate them into their current workflow.
8. The development of templates for what to include in training would ensure that information is more consistent and standard across Canadian airlines.

6. Final Statement

Passengers travelling with a powered mobility aid face many challenges as they face being separated from their only mode of transportation, leaving themselves in full trust of the airlines and airports. To be proactive about the issues surrounding the transportation and safe storage of wheelchairs, the CTA mobilized an IWG in 2018. One major outcome of this initiative, and the outcome of this current study, was to identify functional and performance guidelines as well as best practices for the airlines and other stakeholders on the securement or containment of mobility aids in the cargo compartment.

To ensure that the guidelines were holistic in nature, stakeholders from all sides of the accessible air travel experience were included: ground services, wheelchair manufacturers, aircraft manufacturers, airlines, and travellers. In order to efficiently address the stated concerns, this collaborative project between CTA, TC, and NRC, an in-depth investigation resulting in best practices and recommendations regarding mobility aid handling and transport, was completed.

In sum, we identified, through interviews, observation, and user feedback, the current pain points being faced during securement and containment of mobility aids in the cargo hold. The pain points helped us understand the needs of handlers and ramp personnel when they are interacting with a traveller's powered mobility aid. Based on the observations and analysis, we were able to identify a total of 9 significant pain points and critical tasks. Following this task, 22 interviews were conducted and included 7 stakeholder groups. The results of the task analysis and interviews revealed that the process for safe securement and containment of mobility aids extends beyond the cargo hold. At a high level, our study recommends and provides the following elements related to handling powered mobility aids;

- 9 functional guidelines for the safe securement and containment of powered mobility aids;
- functional job aid guidance that includes clearly defined high-level steps for securement and containment, written in lay language, with visuals for quick reference;

- a detailed training needs analysis (TNA) that can identify gaps in skills and knowledge for handlers with respect to securing wheelchairs.

In addition to recommendations related to handling mobility aids, our study also provides recommendations related to handling powered mobility aids at a system level:

- that mobility aid OEMs provide a brief document with visuals and clearly defined steps for safely disassembling and reassembling the mobility aid;
- that mobility aid OEMs include securement brackets as part of their design, and that the brackets themselves be designed to be more visible;
- that communication between travellers and airlines be improved by further developing the Mobility Aid Passport and Mobility Aid Handling Checklist, identified as short-term recommendations within the *Mobility Aids and Air Travel Final Report* (Hunter-Zaworski, 2019);
- that training regulations continue to require recurrent training to prevent errors associated with skill fade;
- that current training be adjusted, whether through regulation or through recommendations to airlines, as there is a gap between the current training content and the knowledge that handlers possess and are able to effectively apply on the job; 8 training-related recommendations are provided to this effect.

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Appendices

Appendix 1. Task Analysis Table (expanded)

ID	Task Description	Category	Notes
1	Notified of presence of powered mobility aid by air carrier staff	Communication	Advanced notice is required for all travellers with a powered mobility aid, with a minimum of 48 hours ahead of time.
1.1	Receive notification before PAX arrives at airport	Communication	
1.2	**Receive notification once PAX arrives at airport**	**Communication**	
2	Receive specific information regarding powered mobility aid	Communication	Powered mobility aid information form not adopted by travellers or airline employees. This form is rarely used, if ever.
2.1	**Receive powered mobility aid information form (if available)**	**Communication**	**Some airlines have their own, while some travellers bring their own sheets, and some bring no additional documentation.**

ID	Task Description	Category	Notes
2.1.1	Receive powered mobility aid information form at check-in time	Communication	This is preferred over 2.1.2 as this provides more time for ramp handlers to prepare.
2.1.2	Receive powered mobility aid information form at gate	Communication	This occurs more often than 2.1.1 and not preferred.
2.2	Request specific information about mobility aid (i.e., dimensions, battery type, weight)	Communication	
3	Receive powered mobility aid at gate	Training	Includes transferring traveller into the aisle chair.
3.1	Transfer traveller into the aisle chair	Training	At this point in time, the mobility aid is the responsibility of the handler and the airline.
3.1.1	Transfer PAX using manual lift	Training	This was highlighted as being the norm for handlers.
3.1.2	Transfer PAX using Eagle lift	Training	Occurs less often compared to Task 3.1.1 because the equipment is not readily available when they need it.

ID	Task Description	Category	Notes
4	Prepare mobility aid at gate with PWD	Training, Communication	Some tasks in 4 may have been done by PWD. But if not, they need to know how to complete these tasks. Knowing what to do was highlighted as being dependent on "experience" and "common sense" for the majority of handlers, rather than training.
4.1	**Locate important electronic and battery information**	Training, Communication	**Exactly how the handlers receive this information is not standard - sometimes this information is on the airline-specific information form or the passenger-provided do-it-yourself sheets, and other times the handlers must have a conversation to get this information.**
4.1.1	Turn off the on/off button	Training, Communication	

ID	Task Description	Category	Notes
4.1.2	Disconnect the system (take out the key, disconnect the joystick, disconnect the turn on the lever)	Training, Communication	
4.1.3	Confirm with the passenger if the battery is designed to be removed or not for transport	Training, Communication	
4.1.4	Engage freewheel mode and brake mode for battery-powered wheelchairs so that chair can be pushed to the nearest elevator	Training, Communication	
4.2	**Determine how to safely remove any components as needed**	Training, Communication	See note for Task 4.1.
4.2.1	Ensure that all the detachable parts (e.g. joysticks, seat cushions, pillows, backrests, footrests, headrests, armrests, etc.) are removed from the mobility device and are carried by the PWD on board the aircraft	Training, Communication	
4.2.2	Fold down, or remove backrest and store as needed	Training, Communication	
4.2.3	Fold in or remove foot/leg rests and store as needed	Training, Communication	
4.2.4	Remove or disengage battery according to regulations on dangerous goods	Training, Communication	
4.2.5	Disengage the drive mechanism	Training, Communication	If not completed in Task 4.1.

ID	Task Description	Category	Notes
5	**Transport mobility aid to tarmac**		**Handlers are under time pressure once the mobility aid is in their hands.**
5.1	Disengage drive mechanism for "freewheel" mode	Training, Communication	This allows the mobility aid to be pushed or, if the traveller permits, the handler can control the mobility aid.
5.2	Transport mobility aid to the tarmac	Training	This may require elevators, wagons or other equipment
6	**Decide if mobility aid will fit through aircraft cargo hold door**	**Communication, Training**	**This is currently occurring when the passenger is already at the airport to account for last-minute flight changes, or if information wasn't communicated during booking.**
6.1	Mobility aid will fit within the cargo hold		Clear to proceed to Task 7.
6.2	Mobility aid will not fit within the cargo hold	Training, Communication	PAX runs the risk of not being able to fly.

ID	Task Description	Category	Notes
7	Transport mobility aid to cargo hold		
7.1	Load mobility aid onto the belt loader if narrow-bodied airframe	Training	Includes placing mobility aid onto belt loader.
7.1.1	**Lock powered mobility aid wheels**	**Training**	**If not completed, runs the risk of the mobility aid rolling off the belt loader.**
7.1.2	Raise mobility aid onto belt	Training	Common.
7.1.2.1	Manually lift the mobility aid onto the belt	Training	
7.1.2.2	Use equipment to raise mobility aid from the ground to belt loader.	Training	
7.2	Load mobility aid into cargo container if wide-bodied	Training	In this situation, the mobility aid is better protected by the container.
7.2.1	Place mobility aid onto cargo cart	Training	
7.2.2	Move mobility aid into container	Training	
7.2.3	Secure mobility aid in container	Training	Same securement processes apply as for narrow-bodied frame (see Task 9).
7.2.4	Load container into the aircraft		

ID	Task Description	Category	Notes
8	Place mobility aid into the cargo hold of narrow-body aircraft	Training	Applies if completing Task 7.1, and assumes mobility aid will fit.
9	Secure mobility aid	Training	Handlers not relying on training for this step, but on “experience” and “common sense”.
9.1	Locate securement straps and locate floor anchorages (e.g., L-tracks)	Training	Ensure they have the equipment they need.
9.1.1	Ensure that floor anchorage is clean	Training	
9.2	**Locate tie-down points on the mobility aid**	**Training**	**Ideally, this would be done before they load the mobility aid - there is not much room to move once inside the hold itself.**
9.2.1	Find sturdy places on the mobility aid (i.e., not plastic or fragile parts); examples are securement brackets, hooks, or welded frame components	Training	Not all mobility aids have securement brackets, so straps might have to be placed around frame parts.
9.3	**Place securement straps on mobility aid**	**Training**	**If handlers incorrectly complete Task 9.2, then damage is likely**

ID	Task Description	Category	Notes
			to occur during Task 9.3.
9.3.1	Lay straps across the base of the frame of the mobility aid, and not over top of arm rests or through wheels	Training	Do not wrap the straps in any way.
9.3.2	Place the hook of the strap into the securement bracket/hook, or securely around a welded component of the mobility aid	Training	
9.4	Secure the mobility aid by attaching the strap to the floor and tightening it	Training	
10	Unload mobility aid	Training	
11	Reassemble mobility aid	Training	No note-tracking system in place.
11.1	Connect battery	Training	
11.2	**Attach or adjust any parts that were modified by departure handlers**	**Training**	**Arrivals handlers are left guessing at reassembly.**
11.3	Report damage (if applicable)	Communication	

Appendix 2. Interview Questions for Stakeholders

Mobility Aid Design –

- When designing a new mobility aid, is air travel a consideration? What are your limitations?
- Can you think of potential reasons why mobility aids are frequently damaged during air travel?
- Which components of mobility aids do you see damaged most often? Why?
- Do mobility aids have specific tie-down points?
- Do you provide your clients or airlines with information on the proper preparation and handling of mobility aids for air travel?
- Could a mobility aid be designed to be more durable?
- If you could change one thing about the current state (e.g., regulations, handling of mobility aids, design of mobility aids, etc.), what would that be?

Handlers and Airline Staff –

- How do you typically receive notification that there will be a passenger travelling with a mobility aid?
- Who interacts with the mobility aid itself, across the entire process of air travel?
- What types of information are exchanged between airline staff and ramp staff?
- What types of equipment are available for you to use for handling mobility aids (e.g., lifts, transfer equipment at the gate, straps for securement)?
- Where (around other baggage or separate) and when (first, last) are mobility aids stored in the cargo hold?
- What would you do if you damaged, or you noticed damage, on a passenger's mobility aid?
- Do handlers and/or staff receive training on how to properly secure mobility aids in the cargo hold?
    - What does this training look like?
- What would make your job easier when handling powered mobility aids?
- Do you experience any challenges between carriers, terminals, or airports?

- If you could change one thing about the current state (e.g., regulations, handling of mobility aids, design of mobility aids, etc.), what would that be?

Damage Repair Services –

- What information do handlers receive training on in your program, and how is the program different from traditional airline-provided training?
- How often do you receive damage claims?
    - What kinds of damage do you see most frequently?
    - What is the most severe type of damage?
- How do passengers access information regarding your services?
    - Can you walk us through the process of submitting a damage claim?
    - What if the passenger needs an entirely new mobility aid?
- If you could change one thing about the current state (e.g., regulations, handling of mobility aids, design of mobility aids, etc.), what would that be?

The Airlines –

- How often does training occur for handlers when it comes to handling mobility aids?
    - What does training look like?
    - What are the handlers taught to do/not to do?
- How do the airline-provided information forms assist employees when a traveller has a mobility aid?
    - How are these used in practice?
    - Do you see travellers coming through with their own information forms instead?
- How do travellers with accessibility needs get the information they need?
- What is your biggest challenge when a traveller has a powered mobility aid?
- How does mobility aid design impact the handlers?
- What kinds of damage do you see?
    - Why do you think this damage happens?

- If you could change one thing about the current state (e.g., regulations, handling of mobility aids, design of mobility aids, etc.), what would that be?

Travel Agents –

- What is your role in the travel process for persons with disabilities?
- What information do you need from travellers when booking a flight for them?
    - Do they typically have this information at-the-ready?
    - How do you then share this information with the airline?
- In your experience, what is the general feeling that you get from travellers regarding travel with a mobility aid?
- Has there been a situation where a client's wheelchair did not fit through the cargo hold?
- Has a client's wheelchair ever been broken or damaged during air travel?
- Do you have any insight into how handlers are handling mobility aids?

The Traveller –

- Reflect back on your experience with air travel – what would you like us to know?
- Before a flight, how to you prepare?
    - Do you typically consider whether your mobility aid will fit through the cargo door?
    - Do you bring any tools or information?
    - How do you share information with the airline?
    - How do you get information about your mobility aid, and do you know the dimensions and battery type?
    - Have you ever used an airline-provided information form for your mobility aid?
    - Do you inform air carriers how to disassemble and reassemble your mobility aid?
- What challenges have you experienced as a traveller with a mobility aid?
- Has your mobility aid ever been damaged? How, and do you know what happened?

Subject Matter Expert –

- What do you see as major gaps within the current processes of handling mobility aids?
- What do you see as the major concerns for passengers who travel with powered mobility aids?
- Any thoughts on the content and use of airline-provided information forms?
    - What about passengers bringing their own information forms?
    - What are the pros and cons for both options?
- In your experience, where do you see damage most often occurring on mobility aids during air travel?
- Where does the process of accessible travel start?
- How can healthcare providers and/or mobility aid manufacturers be more involved?
- If you could change one thing about the current state (e.g., regulations, handling of mobility aids, design of mobility aids, etc.), what would that be?