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ORIGINAL PAPER

Proposal of an Accessible Cabin Concept on Regional Aviation for Passengers with Disabilities

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Abstract

Despite a global increase in the number of passengers with disabilities on regional aviation, most aircraft cabins are still not adequately equipped to provide sufficient comfort to this public, making the travel experience much less attractive. In order to investigate how airlines and aircraft manufacturers could improve the cabin's accessibility, this study aims to investigate solutions and systems available in the market to propose an accessible cabin concept for regional aviation. This research is part 2 of a two-part series that aims to apply a methodology inspired by Design Thinking Tools such as persona mapping to suggest improvements for the experience of passengers with disabilities. To this end, potential systems were evaluated and a cabin concept was proposed. It was noted that for passengers with sensory impairments, it is possible to improve their experience without major cabin modifications. However, research on their needs is limited and there are few solutions on the market targeting this audience. Conversely, passengers with mobility restrictions pose more complex challenges. Finally, the proposed accessible cabin concept demonstrates the potential to enhance the flight experience for passengers with special needs, potentially increasing their market share and overall satisfaction.

Keywords: Aircraft interiors; Human factors engineering; Systems engineering.

INTRODUCTION

The article 13 of the Universal Declaration of Human Rights asserts freedom of movement, and, as such, tourism and travel as a universal right. In April 2010, the European Union (EU) declared that one's ability to travel and the way people spend their holidays is a great indicator of quality of life (THE TIMES 2010). However, as presented on "Traveling with a disability: more than an access issue" (Yau *et al.* 2004), people with disabilities sacrifice their right to travel as they feel there are too many challenges that need to be overcome.

As new rules and standards are established for commercial aviation, safety and comfort for the passengers has been put in high regard for legislators. Along with the establishment of these rules, passengers with disabilities have been demanding that the

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industry adequate itself to their needs, allowing them to fulfill their universal right for tourism and travel. One of the main reasons that discourages people with disabilities from traveling is simply the physical inaccessibility of facilities used by passengers, such as airports and aircraft (Avis *et al.* 2005).

When it comes to the facilities to be used by passengers with special needs, there are usually fewer services offered in the aircraft environment than in airports. Today, most aircraft have seats with movable armrests to facilitate the transfer of a passenger to and from the wheelchair. Transporting passengers to the lavatory is done with an on-board wheelchair, but most lavatories are not accessible. Depending on the airline, services such as braille safety instructions, trunk restraint belts, and stretchers are offered for passengers in need (Vega 2016).

According to the literature, current legislation in several countries defines few or no criteria that aircraft must meet to ensure the accessibility of their facilities. Aircraft are mostly equipped to comply with Part 382, part of the U.S. legislation, however, even meeting these stipulations still does not seem to be enough to leave passengers with special needs on an equal footing with able-bodied passengers (Vega 2016).

The existing legislation aims to ensure equal treatment for passengers with special needs, but is not sufficient to ensure their satisfaction with the services offered by air transport. Numeral studies have been reviewed and have shown that, for the most part, passengers with reduced mobility or sensory disabilities have less than ideal satisfaction with these services.

Amid the ongoing transformation in aviation, there is a discernible trend towards the modernization of airplane cabins through the integration of smart devices (Silva *et al*. 2023a; b). This ongoing transformation seeks to enhance the overall passenger experience by introducing innovative technologies and amenities. Notably, this trend is not only revolutionizing the way passengers interact with the cabin environment, but also holds the potential to bring about significant benefits for individuals with disabilities. By leveraging these smart technologies, airlines can tailor services to better meet the diverse needs of passengers, including those with reduced mobility or sensory disabilities. These aspects are also considered in this study.

This article aims to present a concept for an accessible cabin concept for regional aviation, with systems aimed at improving the experience of people with disabilities. This study is based on a list of user needs mapped by previous studies using a methodology based on Design Thinking.

Based on these needs, a list of requirements related to the needs of passengers with disabilities was created. This list was then used to select systems available in the market that could enhance accessibility. Using these systems, an accessible cabin layout was proposed using AutoCAD to demonstrate how these systems could alter the cabin layout. Thus, this study highlights that, to better fulfill their roles as providers of traveling and tourism services, aircraft manufacturers cab design passenger cabins that adequately meet the needs of passengers with disabilities, informed by user research insights.

METHODOLOGY

This study is part 2 of a two-part series of articles regarding the definition of an accessible cabin. The cabin proposal that will be presented here is based on the list of needs outlined in "Definition of Needs and Requirements for an Accessible Cabin in Regional Aviation", obtained through a methodology inspired by Design Thinking (do Nascimento Filho *et al.* 2023). A similar methodology was applied in the study by Silva *et al.* (2023a; b), utilizing Design Thinking was employed for the development of smart cabin design in regional aviation.

The first step in properly assessing the needs is to use them to create High-Level Requirements (HLRs) that can be properly assessed and measured. For that, a new table containing the HLRs was created, associating each need with one or more requirement, employing a methodology inspired by the NASA (2016) Systems Engineering Handbook.

Based on the requirements, a survey of potential solutions and systems available in the market was conducted. The most promising solutions were identified according to the requirements they are able to meet, and their technical feasibility of the solutions will be assessed.

To preliminary assess the technical feasibility and technological maturity of the proposed technologies, the Technology Readiness Level (TRL) was determined. The TRL is a methodology for assessing the maturity of technologies during the acquisition and development stages of a project. This method was developed by NASA and divides potential technologies and concepts as outlined by Table 1. For the cabin concept, only technologies with a TRL of 6 or higher will be considered, following the methodology outlined by Fahimian and Behdinan (2017).

Table 1. TRLs explained.

TRL	Maturity level	Technology phase
9	Actual system proven in operational environment	Deployment
8	System complete and qualified	
7	System prototype demonstration in operational environment	
6	Technology demonstrated in relevant environment	Development
5	Test and validate the technology in an environment similar to where it will be used	
4	The technology is thoroughly tested and proven effective in a controlled lab setting	
3	Experimental proof of concept	Research
2	A clear concept for the technology is developed	
1	Explore and understand the fundamental principles involved	

Source: Adapted from Fahimian and Behdinan (2017).

For this study, technologies with varying TRLs were identified. For technologies on the “deployment” stage, those that are already commercially available were assigned a TRL 9, while systems on the final stages of deployment (TRLs 8 and 7) were not found. For the “development” stage, technologies already available in other sectors or industries were assigned a TRL of 6. Finally, for the “research” stage, technologies that only presented virtual mockups, descriptions or concepts, were assigned a TRL of 2. Table 2 summarizes up potential technologies, the HLRs they assess, and their TRLs.

Finally, a virtual prototyping for an accessible cabin was performed, using the Computer Aided Drawing software (AutoCAD) and the list of selected technologies. This prototyping was essential to determinate the compatibility of the proposed solutions with regional aircraft cabins and their dimensions.

Table 2. Technology and HLR summary.

System name	HLRs assessed	TLR
Height-adjustable wheelchair	RM.2	9
ACCESS lavatory	RM.14	9
Onboard wheelchair storage	RM.12, RM.13	9
AudioBack	RS.2	9
In-flight entertainment with captions	RS.2	6
High contrast/visually accessible IFE	RS.12, RS.13	9
On-demand visual interpreting	RS.5, RS.6	6
Audio guidance	RS.5, RS.6	6
Passenger accessibility and services system (PASS)	RS.7, RM.11	9
Braille placards	RS.1, RS.7	9

Source: Elaborated by the authors.

HLRS

To define the solutions that will comprise the final concepts, the user needs were translated into HLR. These requirements are more generalizes than user needs and focus on the characteristics the cabin and the system must possess to satisfy the needs.

As previously stated, these requirements are based on needs that were mapped in "Definition of Needs and Requirements for an Accessible Cabin in Regional Aviation" (do Nascimento Filho *et al.* 2023). This list of needs can be seen in Table 3.The information is organized in the Table according to the aircraft system or flight stage related to the identified need. The solutions that will be proposed by this study may not necessarily address all the needs listed here.

Table 3. Needs of passengers with disabilities.

Needs	Requirements
Access to the aircraft	A.1 The steps of the access should be modified to improve accessibility
	A.2 The access stair handrail's height should be modified to improve accessibility
	A.3 The corridor should be larger to make it possible to circulate with a standard wheelchair
	A.4 The aircraft's door should be widened to allow access on a standard wheelchair
Access to the seat and seat usage	S.1 The seats should be larger to improve comfort of passengers with disabilities or reduced mobility
	S.2 The use of chairs with fixed armrests should be avoided, mainly on the first rows
	S.3 There should be a way for passengers with reduced mobility sat on the window seat to access the corridor
	S.4 Means for passengers with visual disabilities to locate their seats should be provided
	S.5 The seat controls location should be of easy access and the use should be secure
	S.6 Seat controls should be easier and safer to use through the use of levers for example
	S.7 More seat recline should be provided when possible for better comfort of passengers with mobility issues
	S.8 Optional seat cushions should be provided, or passengers should be allowed to use their own cushions to prevent pressure sores/ulcers
	S.9 Improve drink support for better stability for passengers with mobility issues
	S.10 Instead of floatable cushions, life vests should be provided for passengers with reduced mobility
Passenger control unit (PCU)	P.1 The PCU and PSU controls should be accessible to all seated passengers
	P.2 Avoid placing seat and PCU controls in areas of difficult access
Luggage and assistive equipment stowage	L.1 A stowage compartment in an accessible location should be provided (preferentially inside the aircraft cabin)
	L.2 The luggage stowage must be made so that it prevents damage to wheelchairs
	L.3 An individual compartment to stow hand luggage should be provided

Continue…

Table 3. Continuation.

Needs	Requirements
Crew announcements and cabin information	C.1 Subtitles for crew announcements on the IFE screen should be provided
	C.2 A better communication system should be provided for passengers with sensorial disabilities
	C.3 An aural indication should be combined with luminous sings (such as "fasten seat belts" "do not smoke" etc.) to facilitate recognition
	C.4 Improve contrast and size of visual signs
	C.5 Provide an aural indication for oxygen masks presence, as well as an audio description of how to use them
	C.6 Cabin audio description should be provided
	C.7 A briefing card with safety information with braille should be provided
	C.8 The "call flight attendant" button should be identified with braille or high relief
Passenger circulation and cabin space	CI.1 An appropriate and secure onboard wheelchair should be provided, or the use of conventional wheelchairs should be made possible
	CI.2 Aural and visual signs about lavatory occupation should be provided
	CI.3 A minimum space for guide dog accommodation should be provided
	CI.4 A solution that allows guide dog retention should be provided
Lavatory	LA.1 A secure and appropriate wheelchair for lavatory access and use should be provided, or the use of conventional wheelchairs should be made possible
	LA.2 Adequate space and conditions for the passenger to transfer between the onboard wheelchair and the toilet should be provided
	LA.3 Adequate space and conditions for passengers with reduced mobility to use the sink and other lavatory features should be provided
	LA.4 Adequate space and conditions for passengers to use the lavatory with a companion should be provided, if necessary
	LA.5 A door with adequate space for access with an onboard wheelchair should be provided
	LA.6 Toilet dimensions should be reassessed to improve accessibility
	LA.7 Means for passengers with visual disabilities to identify the location of the facilities of the lavatory, such as braille or high relief, should be provided
In-flight entertainment	IFE.1 Subtitles (closed-caption) should be provided in the IFE for crew announcements
	IFE.2 Flight information and entertainment content should be provided in sign language
	IFE.3 Voice software and high contrast layout should be available on the IFE device

Source: Adapted from do Nascimento Filho *et al.* 2023.

For this study, the Requirements Table will be divided into two categories, depending on the user who best relates to the requirements. This division aims to facilitate the subsequent mapping of solutions and identify the user who has stands to benefit the most from the satisfaction of each requirement. Thus, the Tables will be divided into Table 4 – Requirements derived from the needs of passengers with reduced mobility –, identified by the tag "RM.X", and Table 5 – "Requirements derived from the needs of passengers with sensory disabilities", identified by the tag "RS.X".

Table 4. Requirements derived from the needs of passengers with reduced mobility.

Req. ID	Requirement	User needs
RM.1	The access stair must be compliant with industry standards, such as NBR 9050	A.1 and A.2
RM.2	The aircraft's aisle must be at least 40 in wide, following ADA recommendations	A.3, CI.1, and LA.1
RM.3	The aircraft's doors must be at least 36 in wide, following ADA recommendations	A.4, LA.1, and LA.5
RM.4	Seat width must be at least 20 in wide	S.1
RM.5	Seats must allow for comfortable transfer of the passenger from and to the wheelchair	S.2 and S.3
RM.6	Seat controls must provide adequate grip and range of motion, as well as be located on accessible locations for passengers with restricted mobility	S.5, S.6, and P.2
RM.7	Adequate seat range of motion must be guaranteed to improve comfort for passengers with mobility issues	S.7
RM.8	Seats must be wide enough to accommodate for wheelchair seat cushions	S.8
RM.9	Food support must be firm enough to reduce vibration on normal aircraft operation	S.10
RM.10	Seats with movable armrest must offer life vests	S.11
RM.11	PCU and PSU controls must be positioned in range of passengers arm movement	P.1 and P.2
RM.12	Means to store wheelchairs and other medical assistive equipment inside the cabin must be provided	L.1
RM.13	Adequate fixation for wheelchairs and medical assistive equipment and their components must be provided	L.2
RM.14	Lavatory dimensions must follow industry standards and recommendations	LA.2, LA.3, LA.4, LA.5, LA.6, and LA.7

Source: Elaborated by the authors. ADA = Americans with Disabilities Act.

Table 5. Requirements derived from the needs of passengers with sensory disabilities.

Req. ID	Requirement	User needs
RS.1	The cabin must provide high relief or braille placards for ease of seat access	S.4
RS.2	The system must provide means for comprehension of crew announcement for passengers with hearing impairment	C.1, C.2, and IFE.1
RS.3	Aural indications must be provided to signify specific indications for passengers	C.3 and C.5
RS.4	Visual signs must have adequate contrast and size for comprehension of passengers with low vision	C.4
RS.5	Means for the passenger to receive information about cabin disposition in audio format must be provided	C.6
RS.6	Safety information available for passengers with visual disabilities must be provided	C.7
RS.7	Buttons, indications and commands must be identified with braille and/or high relief	C.8 and LA.6
RS.8	Means for passengers with visual disabilities to identify lavatory occupation status must be provided	CI.2
RS.9	Adequate space for presence of guide dog must be provided for at least one seat	CI.3
RS.10	Means for adequate and safe retention of guide dogs must be provided	CI.4
RS.11	On-board lavatory must provide means for passengers with visual disabilities to locate the amenities	LA.7
RS.12	Accessible content must be provided on IFE system	IFE.2
RS.13	IFE device must offer option for high contrast layout adequate for passengers with low vision	IFE.3

Source: Elaborated by the authors.

With the HLRs derived from the user needs, it is possible to more clearly propose a cabin concept that meets the necessities of passengers with disabilities, by addressing points that are more closely aligned with their needs.

Technological prospection

The objective of this section is to produce a report that shows the options commercially available or those applied by aircraft manufacturers to enhance aircraft cabin accessibility, as well as concepts and designs studied in the industry and academia. Due to size constraints for this paper, only the technologies select as candidates for meeting the HLR and their maturity assessed are presented here.

The technologies identified in this section are organized according to the "class" of user need that they aim to fulfill, defined as follows:

Acc – Technologies Related to Aircraft and Seat Access;

Lav – Technologies Related to Lavatory Accessibility and Usage;

Lug – Technologies Related to Luggage and Assistive Equipment Storage;

Info – Technologies Related to Information and In-Flight Entertainment (IFE).

Since studies on accessibility, solutions specifically for aircraft are not very extensive; this section also aims to outline technologies, solutions, and ideas used to improve accessibility in other modes of transportation, as well as in buildings and other living spaces.

Acc

Acc.4 – Height-adjustable wheelchair

Depending on their height and width, passengers using wheelchairs inside the aircraft often hit the sides of the seats, making the transit inside the aisle uncomfortable. One potential solution is the adopting of wheelchairs that are capable of adjusting their height, making them taller or shorter as required. These wheelchairs could potentially replace those currently used by airlines for passenger transport inside the aircraft.

This solution is being studied by some groups, and manufacturers, such as Studio Rotors (2023), already have products available in the market. Figure 1 shows one such solution.

Source: Studio Rotors.

Figure 1. Studio Rotors' height-adjustable wheelchair.

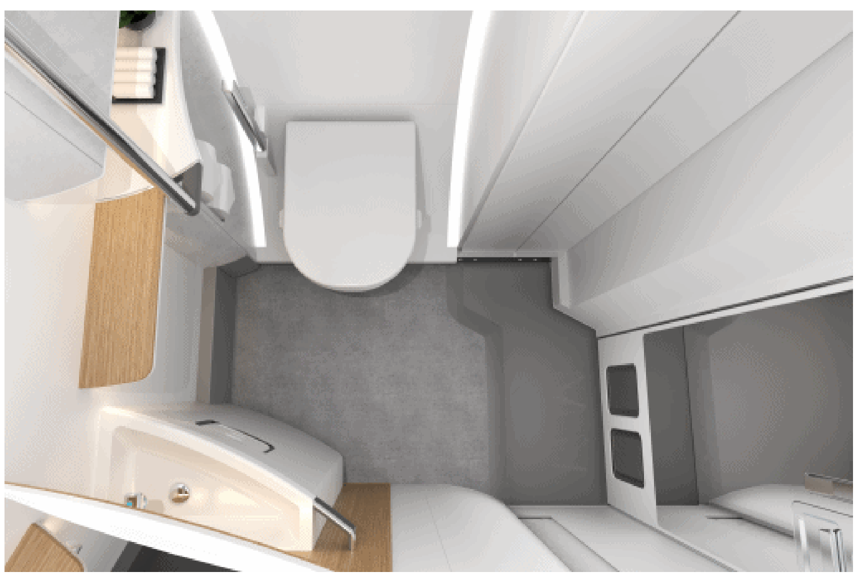
Lav

Lav.2 – ACCESS lavatory

ACCESS is an expanding aircraft lavatory concept developed by Acumen Design Associates and ST Engineering (2022). The system consists of a standard sized lavatory that is retrofittable into the Boeing 737 and Airbus 321 aircraft. The lavatory features a protractable wall that can be activated by cabin crew, expanding the bathroom temporarily into the galley area, changing its dimensions from 33 by 20 inches to 51 inches wide, with an entranceway of 24 inches, sufficient for wheelchair users. Figures 2 and 3 depict the bathroom in its Standard and Expanded configurations, respectively.

Source: Acumen Design Associates.

Figure 2. Standard ACCESS footprint.



Source: Acumen Design Associate.

Figure 3. Expanded ACCESS footprint.

Lug

Lug.1 – Onboard wheelchair storage

Some airlines and manufacturers are implementing onboard storage solutions for wheelchairs, which allow passengers to store their equipment inside the cabin during the flight. These storage compartments are designed to be easy to access and can help reduce the risk of damage to the wheelchair during transport. There are some models on the market and some regulators, such as FAA and TCCA, are already placing requisites for regional aircraft that include carrying this kind of storage. The Brazilian manufacturer Embraer recently publicized that they have delivered aircraft to the Canadian airliner Porter Airlines (2023) equipped with this system. Embraer's Wheelchair Storage can be seen in Fig. 4.

Source: Embraer.

Figure 4. Embraer's wheelchair storage system.

Info

Info.1 – AudioBack – ATR

AudioBack (ATR 2019) is a hearing loop concept that it delivers in-flight announcements to a hearing aid's telecoil even if it is switched off. It consists of an equipment that is placed on the seat's back, as seen in Fig. 5. The system functions with an inductive wire loop that sends sound signals from a microphone, speaker, or public address system directly to hearing aids or implants set up in telecoil mode. The telecoil functions as an antenna, relaying sounds directly into the ear, without background noise.

Source: ATR.

Figure 5. ATR's AudioBack system.

Info.2 – In-flight entertainment with captions

Some airlines offer closed captioning for a portion of their entertainment content, such as movies and TV shows already included in their in-flight entertainment, but captions are mostly unavailable for live content and television. Developing such a technology would also allow for closed captioning of crew announcements, which are already transmitted through the IFE system on some aircraft. There are some prototypes and studies for allowing such a system to operate on an aircraft, such as one developed by Panasonic Avionics Corporation (AFB 2008).

Info.3 – High contrast/visually accessible IFE

Some airlines (for example, Virgin Atlantic [Shimosakai 2019]) began providing IFE systems with accessible content options for blind and passengers and those with low vision. These modules include audio-description and high contrast modes, with larger fonts and more accessible colors, and may be included in the aircraft's own IFE or on an external tablet device.

Info.4 – On-demand visual interpreting

Some smartphone applications (for example, Aira [2023]) provide on-demand spatial visual interpretation for blind users, connecting them with volunteers who can provide them with description and guidance for their environment using the camera. Many airports, transit systems, museums, universities, and businesses subsidize the use of such apps for their customers, and alternatives could be developed for airlines. With the improvement of connectivity and networks on aircraft, such a solution could be adopted in the future, perhaps relying on artificial intelligence (AI) trained on aircraft interior pictures instead of other users to address concerns of cybersecurity and reliability.

Info.5 – Audio guidance

Other businesses, such as museums (MuseumNext 2023) and other transport systems, already use audio guidance extensively by providing pre-recorded audio content to blind users so that they can find their way more freely in these places. When required, the airline could provide audio guidance that would assist the passenger to find their seat and use the lavatory.

Info.6 – Passenger accessibility and services system (PASS) - InFlight Canada

PASS (InFlight Canada 2023) consists of a remote controller capable of interacting with the aircraft's passenger service unit (PSU). Currently, this system can operate existing PSUs from Boeing and Airbus aircraft. Figure 6 is an image provided by the manufacturer explaining the product's capabilities. According to the manufacturer, the system could be installed on only a few rows of the aircraft, potentially decreasing installation costs.

Source: InFlight Canada.

Figure 6. InFlight Canada's PASS information.

Info.7 – Braille placards

Braille placards for ease of seat access and location are an operational requirement for some certification authorities, such as Canada's TCCA and America's FAA. Manufacturers, such as J&C Aero, already offer braille placards for corridors, PSUs, and bathrooms. Embraer also recently publicized pictures of placards equipped on Porter's aircraft. Embraer's placards for seat location can be seen in Fig. 7.

Source: Embraer.

Figure 7. Braille signs for aircraft cabins on an Embraer cabin.

Technology summary

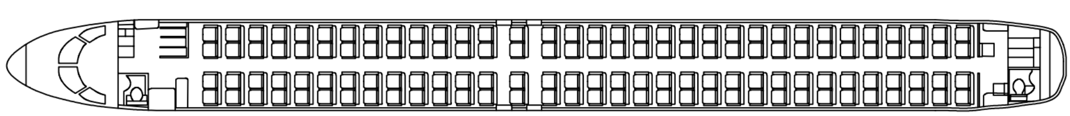
The next section summarizes the technologies chosen to meet the identified HLRs as shown in Table 2. These systems and concepts also had their TRL analyzed and documented, serving as a filter for the development of a cabin concept. Based on the Table 2, technologies will be selected and a general layout for the passenger cabin will be presented.

Accessible cabin layout suggestion

Using the selected systems, it is possible to design a cabin layout with those characteristics. In this section, a layout with the chosen systems will be presented, as well as a "standard" layout, for comparison in terms of number of seats and overall layout.

Standard cabin layout

For comparison, a standard layout for an Embraer 195-E2 aircraft was chosen. This layout was based on an information sheet provided by the original equipment manufacturer (OEM) (Embraer 2023) for a 132-seater configuration with a 31-inches pitch between seats. It can be seen in Fig. 8. This particular layout includes two standard bathrooms and no internal luggage compartment for wheelchairs.



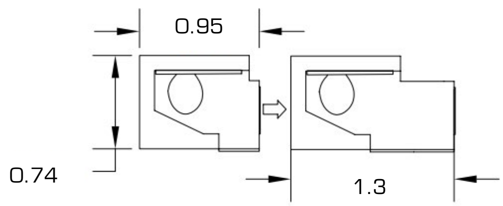
Source: Elaborated by the authors based on Embraer (2023).

Figure 8. Embraer 195-E2 standard LOPA.

Suggested cabin layout

The proposed cabin layout was loosely based on standard layouts proposed by the OƒEM, from the same information sheet. Due to space restrictions caused by the addition of an internal luggage compartment for wheelchairs, some seats had to be removed. To reconcile the number seats with requirements made by passengers with disabilities, a two-class configuration was chosen for the proposed layout of passenger accommodations (LOPA). The layout consists of an 84-seater economy class with a 31-inches pitch between seats and a 44-seater business class with a 34-inches pitch between seats. This layout is an initial estimate based on Embraer's proposed two-class configuration (Embraer 2023), as there is not much recent data on the number of passengers with disabilities needing more legroom. This improved pitch aims to meet passengers' HLRs involving legroom, as well as providing adequate space for guide dogs. Potentially, the airlines could charge more for these seats with improved legroom to passengers with no need for special assistance, but this would have to be assessed in further research focused on financial viability.

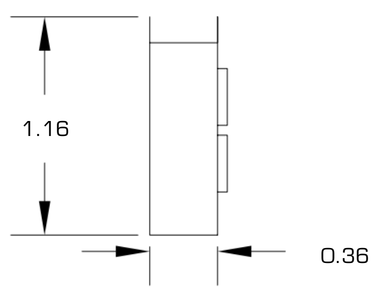
The main physical differences in this cabin layout include of a bathroom based on the ACCESS accessible bathroom, a luggage compartment for storage of wheelchairs and the inclusion of braille placards. Details for these solutions can be seen in Figs. 9-11, respectively.



Source: Elaborated by the authors.

Figure 9. Collapsible bathroom based on the ACCESS accessible bathroom.

The proposed bathroom system includes a collapsible wall that can be extended to increase the bathroom's dimensions temporarily. This change can be made on demand by cabin crew, and while the bathroom will temporarily occupy some of the space in the galley, this system is meant to transform a regular aircraft bathroom into an accessible bathroom, while a user who needs one is using it. In the proposed layout, it replaces the front bathroom, considering that passengers with mobility restrictions have priority in the front seats and would need to travel a shorter distance.



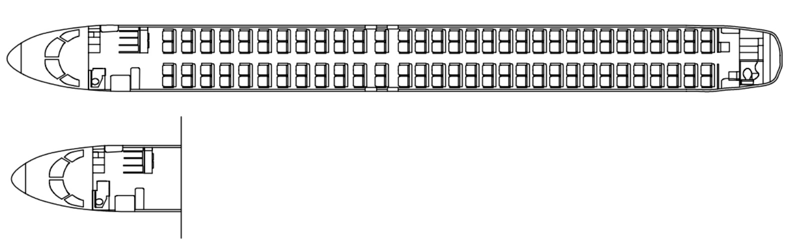
Source: Elaborated by the authors.

Figure 10. Luggage compartment for wheelchairs dimensions.

Source: Elaborated by the authors.

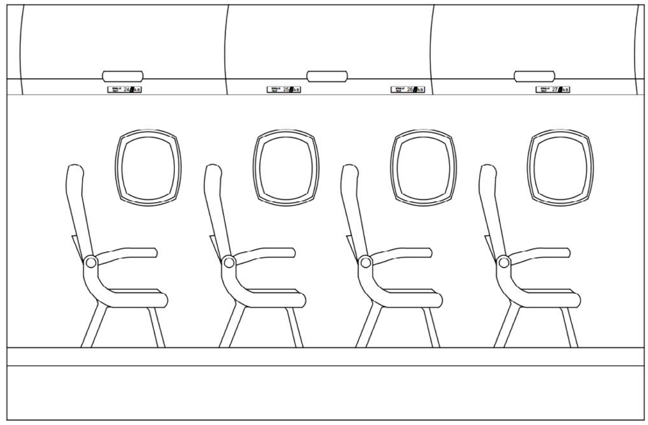
Figure 11. Braille placard detail.

The full-proposed layout, encompassing the proposed systems, can be seen in Fig. 12. A side view of the cabin, showing the placement of the braille placards, can be seen in Fig. 13.



Source: Elaborated by the authors.

Figure 12. Embraer 195-E2 Accessible LOPA.



Source: Elaborated by the authors.

Figure 13. Side view of the cabin layout.

Aside from the modifications required to accommodate for passengers with mobility issues and wheelchair users, some other systems could be implemented, which will be detailed in the following section.

Accessibility systems suggestions

In this section, we will detail other accessibility systems suggested in the architecture section. This separate section was created to better explain the functionality and limitations of the suggested systems that do not necessarily require major layout modifications.

Height-adjustable wheelchair

While adjustable wheelchair concepts found in the market may present challenges regarding stowage and system weight, they also offer the potential for increased comfort for larger passengers who require wheelchairs to transfer into their seats. By adjusting the height, this system allows the passenger to navigate narrow corridors without hitting the seats' shoulders.

AudioBack

As previously explained, the AudioBack system was initially proposed for aircraft cabin use by the European aircraft manufacturer ATR. It comprises of a hearing-aid loop, also known as an induction loop. It is a common assistive listening technology for visitors and travelers used in theaters, museums, and buses. It involves of physical loops of cable placed around a designated area, generating an electromagnetic field throughout the looped space, which can be picked up by hearing aids even when they are turned off.

The main issue for hearing aids users when traveling on aircraft is that the aids usually amplify ambient noise, making it so that the passenger cannot hear announcements or other relevant information. This makes it so that they usually turn off these devices to avoid being bothered by the noise. The main advantage of this system is that the aids do not need to be turned on for it to work, which makes it so that the passengers have access to the announcements while not having to tolerate the ambient noise.

One of the main challenges for implementing this system is that the only developed system for use on aircraft is property of ATR Aviation. Given the simplicity of the base system and the fact that it is already well demonstrated in other relevant scenarios, however, it is probably possible to develop a similar system.

Accessible in-flight entertainment

Another crucial system for designing an accessible cabin is an in-flight entertainment device with options for passengers with visual and hearing disabilities. Besides meeting these passenger requirements, this is also an operational requirement for some authorities, such as the Canadian Authority TCCA.

The key aspect for this system is to provide content equivalent to that provided for other passengers. There is a possibility, however, to also use the IFE for providing safety information for passengers with hearing disabilities by captioning crew announcements.

Audio guidance

For the audio guidance system, inspiration could also be drawn from museums, where visitors receive headphones guiding them through tours. A version of this system could be customized for an aircraft cabin, indicating seat locations and providing other safety information. Additionally, inspiration could also be drawn from other types of audio guidance, where a camera points to a location and another person or an AI model describes what the camera is pointing to. However, further development would be needed for this to be possible for implementation in aircraft.

PASS

This system could be implemented to allow for passengers with restricted mobility and those with visual disabilities to use the PSU and IFE in a safer and more comfortable manner. It consists of allowing the PSU and the IFE to be remotely controlled. Some airlines have already adopted similar systems, such as the Brazilian airline Azul.

CONCLUSION

The disabled and elderly population is growing and is becoming increasingly present in the air travel market. Through this research, it was possible to observe that many studies are underway to improve the experience of these passengers in these markets, with the development of new systems that aim to cater to their needs, while regulators are becoming stricter about the non-discrimination and the proper treatment of these groups.

When researching the solutions proposed in the market, it was noted that crash-worthiness certification and system airworthiness is still an important obstacle for some of them, especially those related to allowing the passengers to use their own wheelchairs. However, as was demonstrated previously, developing these concepts could fulfill a vast number of user requirements with minimal modifications to the cabin dimensions, greatly improving the user journey.

In the regional aviation market, passenger cabin dimensions are reduced compared to other aviation markets, which may pose a problem for some passengers with disabilities. It was noted that several proposals aim to improve these passengers' experience without modifying these aspects, but cost and weight could potentially be limiting factors, requiring further research. Proper evaluation or these proposed solutions with potential users is also essential.

Regarding passengers with sensory disabilities, it was noted that most of their requirements could be met without major modifications to the cabin. However, studies assessing the needs of these passengers are still somewhat sparse and warrant further investigated. The current research showed, however, that these passengers' needs may be simpler to address without drastic changes to the cabin layout, with the addition of better information systems, for example. Conversely, to properly assess the needs of passengers with mobility restrictions, changes in the cabin disposition were necessary.

Finally, the concept for an accessible cabin presented in this study aimed to improve the experience of passengers with special needs. Although the technical maturity of proposed solutions restricts the deployment of systems that would meet a higher number of the passengers' needs, this concept demonstrates that it is possible to make flights more accessible and satisfactory for these groups and potentially increasing their participation in this market. This, in turn, elevates the product's value for the OEMs and airlines and enhances customer satisfaction.

CONFLICT OF INTEREST

Nothing to declare.

AUTHORS' CONTRIBUTION

Conceptualization: Souza JBG; **Methodology:** Nascimento Filho SRO; **Validation:** Moraes AO, Souza JBG; **Formal analysis:** Nascimento Filho SRO; **Investigation:** Nascimento Filho SRO; **Writing - Original Draft:** Nascimento Filho SRO; **Writing - Review & Editing:** Nascimento Filho SRO, Moraes AO, Souza JBG; **Supervision:** Moraes AO, Souza JBG; **Final approval:** Nascimento Filho SRO.

DATA AVAILABILITY STATEMENT

The data will be available upon request.

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