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Smart Cabin Design Concept for Regional Aircraft: Challenges, Future Aspects & Requirements

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ABSTRACT

New technologies are increasingly being implemented in people's daily lives and with the growth of smart devices around the globe, the users' needs and demands have changed in favor of more technological cities, cars, houses, and airplanes. Therefore, it is important to define the stakeholder's needs and requirements to understand which technologies, smart or not, can be implemented on the cabin to support or even fulfill stakeholder needs. Consequently, those technologies enhance airplane operation and increase product competitiveness for airlines. This paper is the first of a two-part series where design thinking tools are applied to establish high-level requirements based on the concept of a "Smart Cabin" for regional airplanes from 60 to 120 seats. To achieve this goal, a series of methods such as stakeholders' studies, personas creation and user journey methods are used. The Smart Cabin concept aims to enhance the passenger experience by granting a new level of cabin comfort, customization and connectivity that allows the reduction of airplane time on ground because of the real-time monitoring of airplane cabin components that enables the prediction of maintenance procedures, creates new profits and revenues opportunities for services, provides a more sustainable airplane operation and derived services, and creates new business opportunities for all companies that integrate regional aviation ecosystem.

Keywords: Aircraft Compartments; Design thinking; Smart Devices; Passenger experience; High-Level Requirements; Stakeholder Analysis.

INTRODUCTION

Emerging technologies such as smart devices, Internet of Things systems and 5G services are increasingly becoming a reality for cities, cars, houses, and offices as presented by Madakam (2015), Gokhale (2018) and Van Kranenburg (2008). Thus, it is just a matter of time for its utilization on the interior of the commercial airplanes to become a priority for the Original Equipment Manufacturers (OEMs) as Embraer, Airbus, and Boeing. This trading leads to a new type of concept named "Smart Cabin".

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The "Smart Cabin Concepts" are examples of how technology can create a new line of customization for the passenger and crew as presented on Silva (2021). These projects are developed to be an airliner ally on aspects such as the operational routine of its airplanes and reduction of crew workload. Additionally, it also provides more efficient maintenance procedures that reduces the operational cost. Finally, flying on airplanes with a brand-new technological cabin will provide a more pleasant experience that results in more satisfied passengers as presented by Vink (2011; 2014).

Most of the current projects and concepts developed by OEMs of a Smart Cabin are focused on widebody long-haul airplanes. Although, regional aviation can also be benefited from those types of technology. Thus, this article is an assessment that aims the creation of a path for a new benchmarking on the "Smart Cabin Concept" to be implemented on regional airplanes. The following benefits are expected with the implementation of this concept on regional airplanes:

- Enhancement passenger experience by granting a new level of cabin comfort, customization and connectivity;
- Airplane reduction of time on ground because of the real-time monitoring of airplane cabin components that enables the prediction of maintenance procedures;
- Creation of opportunities for profit and revenue on services;
- A more sustainable airplane operation and derived services;
- Creation of new business opportunities for all companies that integrate the regional aviation ecosystem.

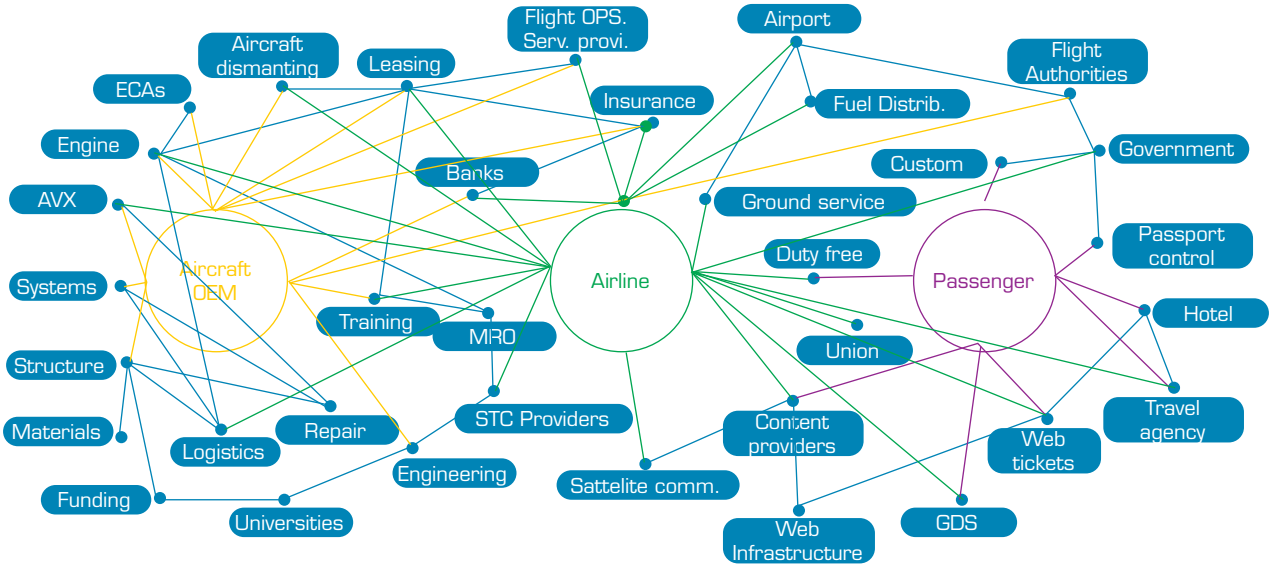
Thus, the first part series of this paper is focused on obtaining high-level requirements for the Smart Cabin concept. The methodology used in this article is based on the product development process presented in the NASA Systems Engineering Handbook (2016), this methodology is validated in several programs in the aerospace area, used worldwide, widely disseminated and known in the community. With the design phases and their respective outputs defined based on this handbook, design thinking tools are defined to assist in the search and definition of stakeholders needs and consequently the high-level requirements, a phase defined as Pre-Phase A (Mission Concept Review) and Phase A (System Requirements Review).

The next chapter identifies the possible stakeholders and their respective interaction with airplane cabin, recognizing the needs of each stakeholder. Following, a perspective of the requirements from the Personas method is presented. In the fourth section, the users' characteristics, necessities, activities and its problems in each determined journey are going to be determined. In the following section, the captured data of each respective persona is organized by means of the utilization of the necessity map. The sixth section provides the first version of the High-Level Requirements, and those requirements are going to be validated. After the validation of the requirements, the following section provides a method to identify which are the requirements with the higher potential opportunity. The last section defines the final High-Level Requirements table based on all the methods previously implemented. Finally, the Conclusion summarizes the contribution of this work regarding the requirements definition for a regional aircraft.

It is important to note that even the NASA Systems Engineering Handbook methodology, then the Smart Thinking tools, are methods that can be used on various areas of research, applications, and projects as presented by Hall (2013). However, in this article the focus will be on the application of a smart cabin concept aimed at regional aviation from 60 to 120 seats.

STAKEHOLDERS ANALYSIS

To identify possible stakeholders that interact with airplane cabin, different tools and methodologies of the Design Thinking are based on IDEO.org (2015). The goal is to identify what are the main problems and needs of each stakeholder. The Aviation Ecosystem Research can be seen in Fig. 1, this diagram shows all the possible stakeholders that, in some way, have an influence on a commercial airplane life cycle. This diagram is based on Stickdorn and Schneider (2011) and shows where exactly the stakeholders can have a connection or interaction among them, creating some sort of relationship. This diagram advises the understanding of the possible airplane's cabin stakeholders when analyzing the airplane and the relationship among them.



Source: Elaborated by the authors.

Figure 1. Aviation Ecosystem.

Based on the information from Commercial Aviation Ecosystem, one proposes the Cabin Life Cycle presented in Table 1.

Table 1. Cabin Life Cycle.

CABIN LIFE CYCLE				
PHASE	OEM	AIRLINE / LEASING		AFTER LIFE
Stakeholders	Engineering	Pilot	Ground Support and Servicing	Discard
	Manufacturing	Flight Attendant		
	Authorities	Passenger	Maintenance	

Source: Elaborated by the authors.

This table presents the phases of an airplane cabin and which are the major stakeholders that have interaction with the airplane cabin during each phase.

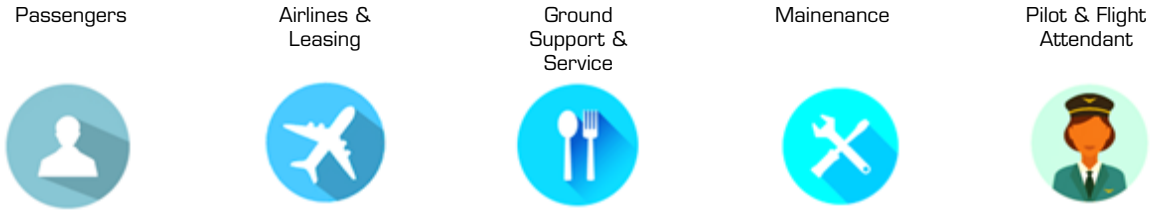
- Passengers: The passenger is the stakeholder that utilizes the airplane as transportation and pays the airline company for that. Three types of passengers are considered: First class, Economy and Passengers with permanent or temporary disabilities, such as reduced mobility, physical disabilities, sensorial disabilities, seniors with other disabilities.
- Ground Support and Servicing: The ground support servicing team do all the operations during the turnaround time and those operations that prepare the plane. For example: Fueling, Cabin cleaning, Catering, and other tasks.
- Maintenance: The maintenance team provides the necessary maintenance to enable the airplane to operate. Two types of maintenance teams are considered: Hangar Maintenance Team, which works in all airplanes during programmed maintenance, and second, the Line Maintenance Team, which is responsible to do some repairs during the turnaround time or through overnight maintenance.
- Airline Companies: The airline companies provide the passengers' air transportation and take care of all the bureaucratic matters. A bigger emphasis is given to airline companies that utilize planes from 60 to 120 passengers' seats.
- Flight Attendant: The flight attendant is the person that works inside the airplane and gives help to the passengers in case of an emergency. Occasionally, the flight attendant also has the responsibility of serving meals, giving information about the trip to the passengers and other secondary obligations.
- Pilot: The pilot is the person who flies the airplane for the airline companies, always respecting the airplane and air traffic safety procedures.
- Original Equipment Manufacturer (OEM) – Engineering: The OEM is the company that is responsible for the airplane concept development, certification, manufacturing and selling. For example, Embraer, Boeing, Airbus. The OEM engineering

corps provides a series of tasks during the entire airplane life cycle. Since the development of the project (Respecting regulators and their requirements), the analysis during airplane operation (the maintenance procedures for example), until the product discard. It is important to explain that the discard, on Table 1, is included as part of stakeholder OEM. The OEM must have in mind, during the project elaboration, ways to ease the product discard after the life cycle.

- Authorities: The Authorities stakeholder is composed by every governmental institution that supports many aviation activities and helps to formulate industry policy on critical aviation issues such as IATA, EASA and ANAC.

Stakeholders evaluation

With the stakeholders identified as shown in Fig. 2, it is necessary to study and understand the stakeholders' characteristics to be utilized on the next steps of the project.



Source: Elaborated by the authors.

Figure 2. Stakeholders chosen for Personas & User Journey methods.

Therefore, some stakeholders are clustered on groups that have something in common like the Pilot and the Flight Attendant. Other stakeholders like Engineering and Authorities are not considered here because both influence the development of the product, and the methods are focused on the users that influence the form of the final product when it is already developed and certificated.

Thus, to begin the application of the methods, research is done that aims on detailing each of the selected stakeholders to understand the main characteristics and the niches that comprise each stakeholder.

Stakeholders Prioritization

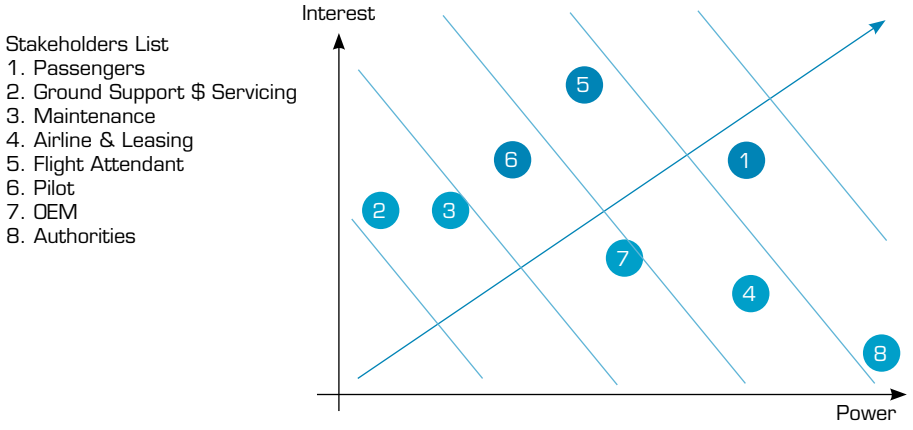
With the stakeholders' characteristics listed, the next step involves the establishment of an order of prioritization for the stakeholders to assist on the concept definition. Two main topics drive this prioritization. First, is the stakeholder with closer relation with the cabin, and second, is the market desire for a new Smart Cabin Concept. Therefore, two tools of understanding are used to sort the stakeholders' consideration order: the "Stakeholder Map" and "Interest vs. Power diagram". These tools are utilized along to the synthesize information to make it easier to visualize the importance of each stakeholder in a complete product life cycle.

Interest vs. Power & Stakeholder Map

The "Interest vs. Power – Diagram" has the objective to help the understanding of value for each respective stakeholder that possesses some level of interaction with the final product, which in this case is the Smart Cabin Concept. This tool is explained in Pandi-Perumal *et al.* (2015) that is utilized as a base for the study. With this diagram, it is possible to list and to observe visually the interest and the respective power that each stakeholder has on the final product characteristics. With this information, the concept is directed to a path that analyzes the market and the acceptability of the concept. First, to develop this diagram it is necessary to have a list of all the stakeholders, what is done in the previous section. Second, two axes must be drawn - one representing the interest and the other, the power:

- The bigger is the stakeholder power in changing product form and characteristics: more to the right its circle is located.
- The bigger is the stakeholder interest in changing product form and characteristics: more to the top its circle is located.

Then, with the research done before, the diagram is filled according to each stakeholder characteristic. Finally, the "Interest vs. Power – Diagram" is represented in Fig. 3, with its respective stakeholders list. The stakeholders which will buy the product are the airline and the leasing companies, and, because of that, this specific stakeholder has more power to change the product according to the companies' interests. However, all the stakeholders hold power to influence the airline interest depending on where the product will help in the final operation. For example, if the passenger prefers to fly on the product developed on this project, this can become a value for the airline company, and it can elevate the competitiveness.

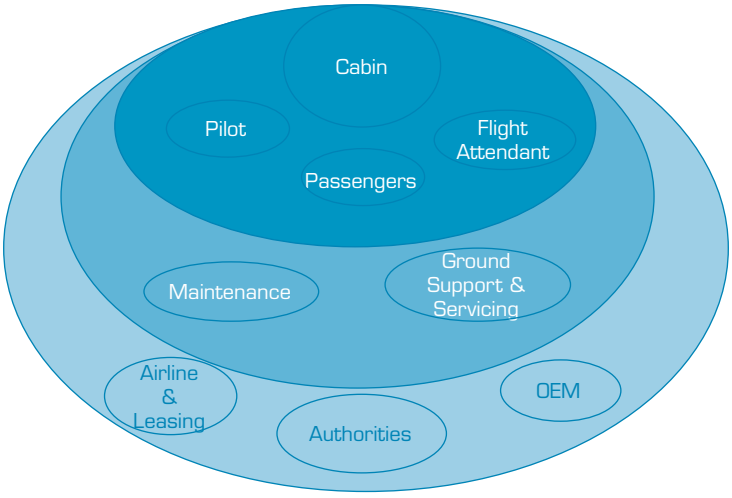


Source: Elaborated by the authors.

Figure 3. Interest vs Power Diagram.

Interest vs. Power & Stakeholder Map

To understand all these relations and interactions it is necessary to utilize another tool that can be called "Stakeholder Map" or "Onion Diagram" (because of its similarity with an onion) based on Olson (2013). This tool helps to understand the stakeholders' ecosystem interactions. The Stakeholder Map is built by putting the primary aspect treated by the project right in the middle, that, in this case, is the airplane Cabin;. therefore, this project is Cabin Centered. Then, in the second layer are allocated the stakeholders that have more interaction with the airplane cabin: the passengers, flight attendants and pilots. Following this, the same is done for the third and fourth layers, separating them by the level of interaction and time spent in contact with the cabin. Finally, the final Stakeholder Map of this research is shown in Fig. 4.



Source: Elaborated by the authors.

Figure 4. Stakeholder Map.

Consequently, putting together the results of "Interest vs. Power – Diagram" and "Stakeholder Map" it is possible to elaborate a list of stakeholders ordered by the project importance (List 1):

1. Passengers;
2. Flight Attendant;
3. Pilot;
4. Ground Support & Servicing Team;
5. Maintenance Teams;
6. Airline & Leasing;

7. OEM;
8. Authorities.

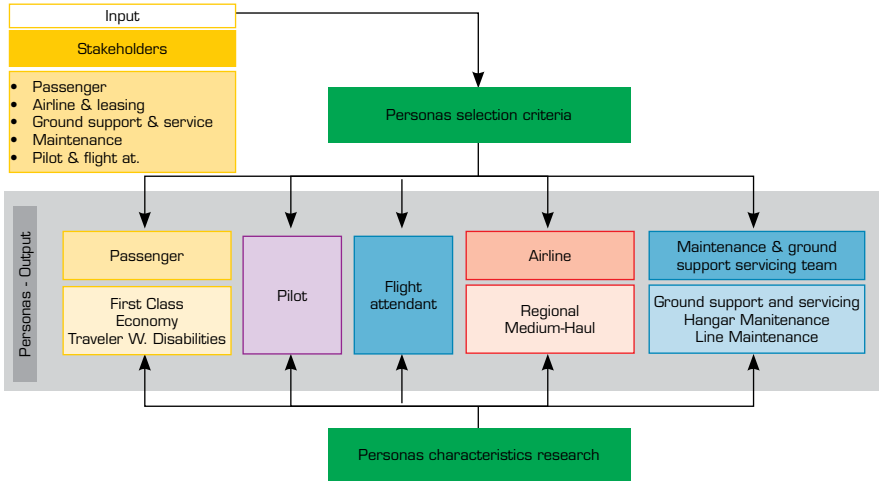
The passengers, the flight attendant and the pilot are the stakeholders with a higher level of interaction with the cabin because they utilize all the primary functions of the system; therefore, they are the stakeholders with more importance. The ground support and servicing team, together with the maintenance team, do all the interactions to maintain the smart cabin functions working, and they also utilize some of the technologies implanted to help on the respective tasks and activities. The airline and leasing companies are below the other five stakeholders because, when all the desires of the top five stakeholders are solved, consequently, the cabin can turn the airplane operation more profitable by attracting more clients, reducing the turnaround time, providing more availability, inducing companies (Leasing, Airlines) to implement the Smart Cabin Concept on their final products. Finally, the OEM engineering must act according to Authorities and focus on stakeholders' desires. The following sections focus on the understanding of the characteristics, necessities, desires, and problems that each stakeholder has during its interaction with the current cabins. To do so, two design thinking tools are used: the "Personas Method" and the "User Journey Method".

PERSONAS

The Personas method developed in this article is based on Nielsen (2019), Matthews *et al.* (2012) and Ferreira *et al.* (2015). The method definition can be resumed as "Personas are the creation of fictional archetypes based on a research on user experience, which represents demographics, attitude, behavior, motivation, objective and obstacles to the user experience". To summarize, one stakeholder is composed of a varied type of individuals, and the Persona is a representation of a niche of individuals which forms a stakeholder. For example, one stakeholder is the "Passenger". This stakeholder is composed of a varied type of passengers. Therefore, the "Economy Passenger" is a persona which represents a niche of the primary stakeholder "Passenger".

Thus, the next step is the development of Personas based on the stakeholders chosen on List 1. Some archetypes that are created represent the stakeholders' niches that will be presented in the following topics. The characteristics correlated to a certain archetype are identified and summarized into keywords to provide a better view of each specific persona. These characteristics are defined according to the previous research on interviews with users, IATA reports, passengers' opinions about air travel, etc. The flowchart in Fig. 5 describes how it is made the decision of the persona's definition for each niche of stakeholders.

As presented before, the stakeholders are defined. Then, according to each stakeholder characteristic the number of personas that represent a specific stakeholder is defined. The stakeholders' personas development and its selection criteria are better described in the sections ahead.



Source: Elaborated by the authors.

Figure 5. Persona's definition flowchart.

Passenger

Related to the stakeholder passenger, there are many possibilities of persona's creation. According to many studies done earlier on IATA (2018; 2019; 2020) and Nextt (2020a; 2020b), it is possible to name many possibilities of personas as low-cost passengers, students, business class, 1st class, travelers with disabilities, elderly travelers, family on vacation, executives, travelling at work, and many others stereotypes and personas.

The ideal situation is to study and consider all the possible personas, but this is not possible for this project because of the time and the limited manpower; therefore, aiming for the simplification, one chooses three archetypes that represent some of the main niches that utilize regional airlines. Those three archetypes are The Business Class Passenger, the Economy Class Passenger, and the Travelers with Disabilities. The general explanation for these archetypes is that the regional airplanes have naturally fewer passengers and so, less space for a vast variety of classes. Therefore, the Business and Economy classes represent the two main niches on a regional airline. The choice for travelers with disabilities allows understanding different barriers and difficulties that are faced by this niche of passengers as compared with other options. Some examples that are utilized to create each persona that represents its respective niche follow.

The Business Class Passenger: executives, traveling at work, that have necessity of travel from larger cities to small (or the contrary), work during the travel, normally carry only one baggage with personal items, travel on the beginning of the day and return to the initial destination at the end of the day, regular passengers (passengers that flies a lot during the year – special pass). The Economy Class Passenger: Low-cost passengers, families on vacation, students, occasional passengers on travel, autonomous workers. Traveler with disabilities: limited locomotion, elderly travelers, wheelchair utilization. Those personas and their characteristics are presented on Table 2.

Table 2. Passengers Personas.

Information		Characteristics
Susan Gomez 41 years old	Businesswoman: CEO in a Bank	First class passenger, demanding high quality of service;
		Flexibility of routes and speed of travel;
		Be connected during the flight;
		Fast boarding with the reserved space for its carry-on baggage;
		A quiet ambient to enable online meetings and onboard conversations;
		Wants a different treatment, exclusive queues for check-in, baggage tagging, documentation-checking boarding etc.;
		Wants to know flight status and wait time at border control.
Juan Parker 27 years old	Student Low Cost: Law Student	Price centered;
		Comfort is not a decisive factor when choosing the airline;
		Wants to be entertained during the flight;
		Onboard space for its carry-on baggage;
		Will not spend money on extra services;
		Wants a fast travel experience, not needing airport staff to do procedures like check-in, baggage tagging, documentation checking, boarding etc.
Carter Williams 34 years old	Traveler with Disabilities: Wheelchair racer	Wants to be connected when on board;
		Wants to be entertained during the flight;
		Preferential boarding, with accessibility and comfort;
		Accessibility and customized care in all steps of the journey: Boarding, Toilet, cabin locomotion, deboarding;
		Customized experience, accepting to provide more personal data to have it;
		Easy way to check baggage is valuable;
		Wants to receive its wheelchair without damage at the end of flight.

Source: Elaborated by the authors.

The characteristics and routine observations established for each type of persona are presented on Table 3. Some of these characteristics are filled by more than one persona, which indicates that these specific characteristics can reach more niches, and, consequently, be more beneficial for all of them.

Table 3. Passengers Characteristics & Routine Observations.

Nº	Characteristics & Routine Observations	First Class	Economy	T. Disabilities
1	Wants to be entertained during the flight	X	X	X
2	Wants a fast travel experience, not needing airport staff to do procedures	X	X	
3	First class passenger, demanding exclusive treatment	X		
4	Total connectivity with her/his own device	X		
5	Carry-on baggage only	X		
6	Easy way to check baggage is valuable	X		X
7	Price centered, comfort is not a decisive factor and do not spend money on extra services		X	
8	Wants to know baggage status if it is necessary to dispatch		X	X
9	Autonomy to do all cabin tasks			X
10	Accessibility in all steps of the journey			X

Source: Elaborated by the authors.

Flight Attendant & Pilot

There are a few different archetypes related to regional pilots that were captured during the studies based on McFly (2016), Zago (2019), Pardes and Santilli (2020) and Borthole (2020), whose main aspects correlated are the adaptation to different avionics technologies and cockpit preferences related to the airplane controlling such as side-stick vs manche. However, because of the differences and the limited information that were captured in the research, it is decided that only one persona correlates to the stakeholder in question. This persona personifies the main and mutual characteristics that englobe these pilots' archetypes: characteristics that are related to the cabin and cockpit environment. On the other hand, the characteristics that have a relation with avionics, airplane controllability, and so on, are not going to be considered because this is not the focus of this project.

The flight attendant persona's selection criterion follows the same principle and criteria adopted for the pilot. The differences between the flight attendant archetypes are more restricted with the age of the flight attendant and, consequently, to the difficulty to do some activities that require more physical attributes, that can be facilitated with an ergonomics study. Therefore, one decides to create only one persona for the flight attendant who works on a regional jet flight. They have the same activity inside the cabin, the physical activities being the unique difference, what leads to a more restrictive persona. Finally, if the flight attendant with these restrictions can work properly in a cabin,, one more physically prepared can also be able to easily exercise her tasks inside the cabin. The pilot and flight attendant personas are presented in Table 4 and their characteristics and routine observations are presented in Table 5.

Table 4. Regional Pilot & Flight Attendant Personas.

Information		Characteristics
Serena Alvarez 37 years old	Regional Airplane Pilot	Reduce cabin workload on critical phases of the flight;
		Ease the documents fill-up before and after the flight;
		Cockpit ergonomics is highly relevant;
		Training for each new procedure/airplane;
		On days with numerous flight hours, fatigue is an important factor.
Jonas Silva 46 years old	Regional Airplane Flight Attendant	Ease the locomotion of trolleys inside cabin;
		Ease the galley procedures when there is a small space to work;
		Have more experience with passenger interaction;
		Types of overhead bin could intensify some problems such as pain in the back;
		Types of shoes/floor can be a problem;
		Wants a way to communicate with passengers and cockpit without the necessity of going through all the corridor;
		Reduce the times of pre and post-cabin checks for bigger regional airplane;
		Easy and fast baggage allocation on overhead;
		Necessity of a different training for different airplanes.

Source: Elaborated by the authors.

Table 5. Flight Crew and Pilot Characteristics & Routine Observations.

Nº	Characteristics & Routine Observations	Flight Attendant	Pilot
1	High workload and pressure in most part of flight	X	X
2	Reduce the time spend on documents filling		X
3	Need of training for different planes	X	X
4	Small space and poor ergonomics to realize flight tasks	X	
5	Communication with passengers and the pilot needs to be eased	X	
6	Ease cabin security checks procedures	X	
7	Valorize cockpit environment control and ergonomics		X

Source: Elaborated by the authors.

Maintenance & Ground Support Servicing Team

Another stakeholder on the list is the Maintenance & Ground Support Servicing. For this niche of stakeholders, the studies done by Yeager (2019), Page (2019), Aircraft Engineer (2016), Borthole (2020) and The Airport School (2020), have returned different types of archetypes such as: Ground Support Outstation crew and HUB crew, Hangar mechanic and Line Mechanic. Due to big differences between the journeys of the Line and Hangar Mechanics, each of them is going to be represented as one persona. On the other hand, the Ground Support and Service teams categories, outstation, and HUB crews have an elevated similarity, making it possible to represent both stakeholders in only one persona that represents the niche of the Ground Support and Servicing teams. Three types of personas are developed for the stakeholder Maintenance & Ground Support Servicing Team: "Ground Support and Servicing Team", "Hangar Maintenance Team" and "Line Maintenance Team". These personas are represented in Table 6 and their characteristics and routine observations are presented in Table 7.

Table 6. Maintenance & Ground Support Servicing Team Personas.

Information		Characteristics
Robert Boomer 51 years old	Ground Handling	Works for the main airline;
		He is highly experienced and recognized;
		Works under high pressure (schedule constraints);
		High occupation rate;
		He is constantly aware of is impact on safety;
		Works on outside weather.
Elliot Grand 47 years old	Hangar Mechanic	Ex-military. 15-year experience with multiple planes models;
		There is too much pressure everyday (stress management);
		Responsible and concerned about activities reporting;
		Real chances of getting hurt on the job;
		Continuous improvement on everyday-job;
		Usually concerned about maintenance issues.
Anthony Loth 33 years old	Line Mechanic	Recently got his work license;
		Must solve problems quickly under pressure from schedule constraints;
		Usually does not know in advance the next day workload;
		Sometimes needs to work long hours (fatigue);
		Deals well with pressure and has good communications skills.
		Accessible and up-to-date technical publication is primordial.

Source: Elaborated by the authors.

Table 7. Maintenance & Ground Support Characteristics & Routine Observations.

Nº	Characteristics & Routine Observations	GS & ST	Hangar MT	Line MT
1	There is too much pressure everyday (stress management)	X	X	X
2	Information to adequate the tasks to the required airplane	X	X	X
3	Reduce the time to training low the costs and accelerate the expertise	X	X	X
4	Ergonomics to execute required tasks	X	X	X
5	High necessity to report activities		X	X
6	Demands a plane with advanced maintainability		X	X
7	Sometimes he needs to work long hours		X	X
8	Need to deal with pressure and good communications skills is necessary	X		X
9	Ease to made necessary activities [Catering, Cleaning, W&W, Fuel, GSE]	X		
10	Ease to exchange information between Airline-Plane-Ground Services	X		
11	There are real chances of getting hurt on the job		X	
12	Accessible and up-to-date technical publication is primordial to him			X
13	He usually does not know in advance the next day workload			X
14	Works on outside weather	X		

Source: Elaborated by the authors.

Airline

About the airlines, there are a vast number of airline types and business models. From the studies based on Creedy (2019), Lake (2019), Mototok (2018), Salas (2020) and Nextt (2020c), it is possible to list some of these types: Legacy, Low Cost, Low Fare, US Regional, European medium-haul, State-owned, Eco Carriers, Short-haul, regional flights, etc. However, when the focus goes to the main operators of regional jets, they are the US airlines, which have a huge market for regional airplanes. There are also the legacy carriers that contract smaller airlines to fly these regional routes that can be also some medium-haul routes. Another important category of airline that operates regional airplanes is the worldwide smaller markets. These markets have a small demand of passengers or have airports that do not support bigger airplanes. Therefore, because the described characteristics, the decision is to develop two personas to represent the airline stakeholder: the Regional Airline, which includes some characteristics of the US regional market, and the Medium-Haul Airlines, which gets the other part of the market that summarizes the European market, South America, and the other routes that only a smaller plane can operate – directly linked to "small" airport infrastructure or lower demand of passengers. Some airlines can represent these personas, for the Regional Airline in the US, it is possible to mention American Eagle, Express Jet and Jet Blue. Thus, for Medium-haul airlines, some examples are Air Kiribati, Helvetic and Azul.

So, these two types of personas developed for the stakeholder Airline, the "Regional Airline in the US" and the "Medium-Haul Airline", are presented in Table 8 and their characteristics and routine observations that represents the most each persona is presented in Table 9.

Table 8. Airlines Personas.

Information		Characteristics
Reg Jet airways	Regional Airline in US	Takeoff and landing in small airports/short runaways;
		Point to HUB: Feed widebody planes for long haul flights;
		Efficiency airplanes to transport up to 76 passengers;
		Point to point (small city to small city, places not accessible by any other transportation);
		Two classes possibility;
		Scope Clause is a driver.
Windeco	Medium Haul Airline	Connectivity necessity;
		Capacity to fit baggages on overhead equivalent to those utilized on 737/A320;
		Low external noise;
		Fast Turnaround Time (TAT) to allow a more elevated frequency of daily flights;
		More ecological technologies: hybrid and electric power;
		Possibility to operate on smaller airports with less infrastructure.

Source: Elaborated by the authors.

One observation is that a scope clause is a contract that aims to protect pilots' jobs by limiting the number and size of aircraft that are utilized by an airline's regional airline affiliate. This clause exists mainly in the US, Canada, and Mexico.

The next step of the project is the identification of each persona's routine and its problems and necessities associated to the interaction with the airplane journey.

Table 9. Airline Characteristics & Observations.

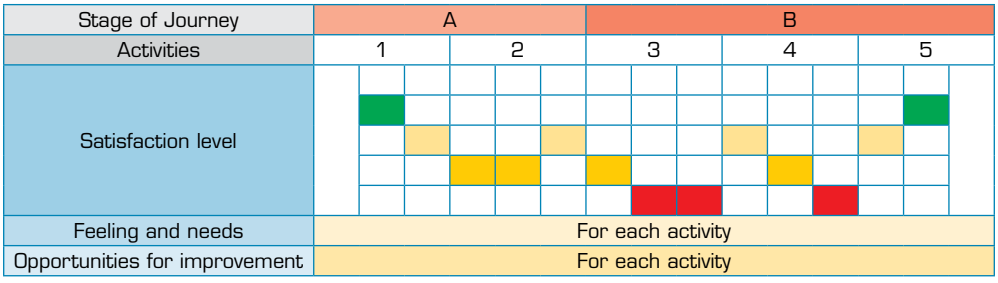
Nº	Characteristics & Routine Observations	Regional	Medium-Haul
1	Limited Operation Station [Small Airports, poor infrastructure, no finger, limited GSE's]	X	X
2	HUB Operation [Big Airports, capacity to use finger and bigger planes equipment services]	X	X
3	Connectivity during all the flight	X	X
4	Attractive IFE to short distances	X	
5	Capacity of Medium-haul airplanes bin [737 – A320] and cabin baggage	X	X
6	Comfortable Seat and Cabin Space Sensation [comparable with bigger planes]	X	
7	Fast boarding and deboarding	X	
8	Cabin health environment, low emissions, and less trash		X
9	Possibility to 2 passengers' classes	X	
10	Cabin easy maintenance [High frequency of Flights]	X	
11	Attractive IFE to medium distances		X
12	High Connectivity and Personalization for the passengers		X

Source: Elaborated by the authors.

USER JOURNEY

The user journey is utilized to understand more about users' characteristics, necessities, activities, and problems experienced by them. These observations are done using web research on flight experiences, airline companies' research, interviews, IATA reports, etc. This method is based on Path (2013) and Jurcic (2015).

The Fig. 6 shows how the method is done graphically, and its steps explained ahead. This tool consists of splitting all the persona's journeys into delimited stages, Stage of Journey. For example, to the pilot, it is possible to consider his journey from the moment when he enters the briefing room until he leaves the airplane after parking. After this, it is necessary to list the Activities performed by the user in each stage of his/her journey, writing down the Satisfaction Level to perform a specific action. Then, the Feeling and Needs to perform that action are marked in the table. Finally, with all these steps done, it is possible, in the end, to identify potential opportunities for the product, Opportunities for Improvement.



Source: Adapted from Path (2013) and Jurcic (2015).

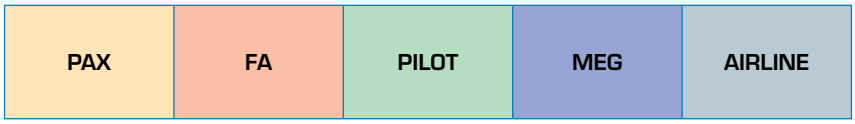
Figure 6. User Journey Method.

NEEDS MAPPING

After the development of the Personas & User Journey, it is necessary to summarize all the gathered information on a Necessity Map that is based on Silva Junior (2018). This map presents all the previous information of each respective persona described as necessities that are separated into classes that have the same bias of technology or interest. The writing of these needs is adapted and organized to help on the requirements development further ahead in this paper.

It is important to remember that the focus of this project is the passenger cabin. Thus, the cockpit, cargo compartment and other systems and ecosystems that surround the passenger cabin can also be benefited from a passenger-centered approach. However, many of the necessities found before are related to other aspects of each persona's journey that do not correlate with the airplane cabin such as check-in, airport security, and others. Therefore, some of the necessities cannot be solved by the smart cabin concept, so they were excluded from the final necessity map.

The necessities classes are Passenger Experience, Comfort, Cabin Operations, Ground Passengers Services and Ground Airplane Services (Fig. 7) and each different color represents a determined stakeholder.



Source: Elaborated by the authors.

Figure 7. Stakeholders label.

where PAX refers to Passengers, FA to Flight Attendant and MEG to Maintenance & Ground.

The organized necessities and its more relevant stakeholders are in Table 10-14. It is important to call the attention to the fact that: the definition of each stakeholder is affected by the respective need; the definition of need, by its turn, is based on the results from personas and user journey tools.

Table 10. Passenger Experience Needs.

Passenger Experience	PX	FA	PT	MG	AIR
Cabin cleaning perception					
Communicate with flight attendant with more velocity					
Possibility of use any type of personal device inside the airplane					
Safe and healthy environment perception					
Baggage storage accessibility and placement					
IFEC(*) should suit to each personal configurations					
Connectivity during all flight journey					
Receive real time information: estimated time of arrival, climate conditions and baggage location					
Control of seat environment					
Interior reliability perception					
Receive information from the passenger in any part of cabin					

(*) In-Flight Entertainment and Connectivity. Source: Elaborated by the authors.

Table 11. Comfort Needs.

Comfort	PX	FA	PT	MG	AIR
Seat comfort: cushion, armrest, leg room, width, reclination					
Cabin accessibility: seat, lavatory, galley, IFEC, baggage					
Ample cabin perception					
Do the maintenance tasks on restricted spaces					
Thermal and acoustic comfort					
Control comfort aspects of the cockpit					

Source: Elaborated by the authors.

Table 12. Cabin Operations Needs.

Cabin Operations	PX	FA	PT	MG	AIR
Communicate with other crew members during the cabin tasks					
Do the cabin tasks with a limited workspace					
Fast and easy filling of pre and post-flight check-list checks					
Speed up and simplify safety and security checks					
Do cabin cleaning tasks during the flight: galley, floor, lavatory, full cabin					
Board servicing on a limited space and time					

Source: Elaborated by the authors.

Table 13. Ground Passengers Services Needs.

Ground Passengers Services	PX	FA	PT	MG	AIR
Flight on time					
Baggage tracking					
Easy and fast boarding and deboarding					
Easy and fast baggage take over					

Source: Elaborated by the authors.

Table 14. Ground Airplane Services Needs.

Ground Airplane Services	PX	FA	PT	MG	AIR
Reduce work daily stress					
Ease pre and post-flight bureaucratic documentation filling					
Communication between the airplane and the ground servicing					
Reduce the time spent on maintenance and cabin services					
Operate with limited airport services and GSE(*)					
Simple and fast cabin reconfiguration					

(*) Ground Support Equipment. Source: Elaborated by the authors.

With the classes created, and the needs spread all along the tables, the next step is to create a first version of High-Level Requirements (HLRs) based on the previous needs and validate these requirements with specialists. This stage is essential in the creation of HLRs.

FIRST HLR VERSION AND VALIDATION

Based on each need captured during the stakeholders research, personas method, user journey method and the necessity mapping it is possible to create the first version of the High-Level Requirements presented in Table 15, which also shows the respective needs that are the basis for the requirements creation.

Table 15. High-Level Requirements First Version.

Needs			ID	Requirements
Passenger Experience	1	Cabin Cleaning Perception	1	The cabin must have materials that are easy to clean
			2	The cabin must have tools to assist in the cleaning and waste removal process.
	2	Communicate with flight attendant with more velocity.	3	The cabin must have an information exchange system to allow communication between attendant and passenger.
		Receive information from the passenger in any part of the cabin.	4	The communication system between attendant and passenger must be accessible for the attendant to utilize in any part of the cabin.
	3	Possibility of using any type of personal device inside the airplane.	5	The cabin must allow the connection of tablets, smartphones, notebooks, and other PEDs(*) to the internet.
	4	Safe and healthy environment perception	6	The cabin must provide a healthy environment for occupants considering air quality, humidity, pressure, temperature, contamination, lighting, and noise.
	5	Baggage storage accessibility and placement	7	The aircraft must have an easily accessible baggage compartment that assists in the storage of the user's baggage.
Passenger Experience	6	IFEC should suit to each personal configurations	8	The IFEC system must be customizable in terms of content [Applications, Language, Accessibility for people with any type of disability]
	7	Connectivity during all flight journey	9	The aircraft must provide uninterrupted connectivity.
			10	The aircraft must provide a speed connection that provides media streaming.
	8	Receive real time information: Estimated time of arrival, climate conditions and baggage location.	11	The aircraft must provide passengers real-time information on: Estimated time of arrival, climate conditions and baggage location.
	9	Control of seat environment	12	The cabin must provide means for controlling the temperature and lighting in the seat region.
	10	Interior reliability perception	13	The cabin components must support abuse loads.
Comfort	11	Seat comfort: Cushion, Armrest, Leg room, Width, Reclination	14	The seat must comply with the minimum comfort dimensions
			15	The seat must provide control for reclination, headrest and armrest.
	12	Cabin accessibility: Seat, Lavatory, Galley, IFEC, Baggage	16	The cabin must be accessible for people who have a disability or reduced mobility. [Physical, Sensory, Cognitive]
			17	The cabin functions must be accessible for Female [5%] and Male [95%] percentiles
			18	The IFEC system must have a navigational interface to an objective that must be complete and without misinterpretation. [The IFEC system must be immersive and have a navigational interface to an objective that must be complete and free from misinterpretation.]
	13	Ample cabin perception	19	The cabin height must be at least 2 meters [The cabin must provide tools that help to optimize space]

Continue…

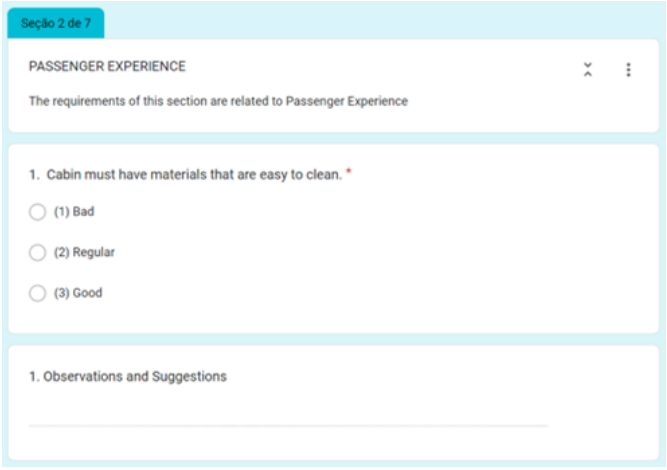
Table 15. Continuation.

Needs			ID	Requirements
Comfort	14	Do the maintenance tasks on restricted spaces	20	The cabin components should be easy to remove and rated for Female [5%] and Male [95%] percentiles.
			21	The cabin components should require only standard tooling for maintenance.
	15	Thermal and Acoustic Comfort	22	The maximum cabin internal noise must be X dbs
	16	Control comfort aspects of the cockpit	23	The aircraft must allow temperature control of the cockpit and passenger cabin separately.
Cabin Operations	17	Communicate with other crew members during the cabin tasks	24	It shall be possible to use a crew communication system within the cabin that is accessible throughout the cabin.
	18	Do the cabin tasks with a limited workspace	25	The cabin tasks performed by the crew must be possible for the Female [5%] to Male [95%] percentile range.
	19	Fast and easy filling of pre and post flight checklist documents	26	The aircraft must enable the use of a tool for the exchange of data with the ground service team in order to fill out pre and post-flight documents.
	20	Speed up and simplify safety and security checks	27	The cabin must have systems to assist with cabin security checks.
	21	Do cabin cleaning tasks during the flight: Galley, Floor, Lavatory, Full Cabin		HLR 1, 2
	22	Board servicing on a limited space and time	28	The cabin must provide tools that assist in the preparation and task of on-board service.
Ground Passengers Services	23	Flight on time	29	The aircraft must allow the use of tools that assist in the organization and performance of on-board tasks that are in the critical line of the TAT.
	24	Baggage tracking	30	The cabin must allow for the receipt of baggage location information during the flight.
			31	The cabin must allow the transmission of baggage information to passengers.
	25	Easy and fast boarding and deboarding	32	The cabin allows the use of tools to assist in the embarkation and disembarkation of passengers.
	26	Easy and fast baggage take over	33	The aircraft must have an organization system that assists in the loading and unloading of baggage
Ground Airplane Services	27	Reduce work daily stress	34	The cabin must implement Poka Yoke solutions to reduce maintenance errors.
			35	Routine maintenance tasks must be capable of being performed utilizing standard tools during TAT.
	28	Ease pre and post flight bureaucratic documentation filling	36	The aircraft must allow the use of a data exchange system with the ground service team to fill in maintenance documents
	29	Communication between the airplane and the ground servicing	37	The aircraft shall provide means of transmitting information about the status of its components to teams on the ground.
	30	Reduce the time spent on maintenance and cabin services		HLR 28, 35, 36
	31	Operate with limited airport services and GSE	38	The cabin must provide, when on the ground, all its main functions to the occupants even without the support of GSE's.
	32	Simple and fast cabin reconfiguration	39	The cabin must have ways to be reconfigured within 70 minutes for use as a freighter [Considering 120 passengers].

(*) Personal Electronic Device. Source: Elaborated by the authors.

The following stage is based on the creation of a questionnaire that evaluates the writing, the importance and existence of each requirement previously listed. This questionnaire was fulfilled by seven specialists of different areas such: Cabin Crew, Maintenance, Passenger, and Interior Engineers, who, based on their experience and knowledge, provided their opinions and suggestions on requirements.

On Fig. 8, it is presented an example of the questionnaire fulfilled by the specialists. The first topic presents the requirement, "Cabin must have materials that are easy to clean."; in the second topic, the specialist answered if that requirement writing and content is (1) Bad, (2) Regular, or (3) Good; finally, in the last topic, the specialist can write its opinion and suggestions related to the specific requirement.



Source: Elaborated by the authors.

Figure 8. Questionnaire Example.

With the initial version of the requirements table created, with the questionnaire suggestions and corrections made, it is possible to start the opportunity identification stage.

OPPORTUNITY IDENTIFICATION

The stage of opportunity identification consists in evaluating which requirements have a higher level of opportunity according to all the research previously performed. In order to achieve the answer of opportunities, it is necessary to consider stakeholders actual satisfaction and importance for each specific requirement and its respective necessity. First, it is important to understand how the value of opportunity is obtained. Its formula utilizes two variables:

- Importance: this variable represents the importance of the requirement for the stakeholder. Its range of value varies from 0 to 10.
- Actual Satisfaction: this variable represents the satisfaction of the stakeholder in relation to the requirement. Its range of value varies from 0 to 10.

Therefore, the utilized formula is (Eq. 1):

$$Opportunity\ [\%] = \frac{[Importance + (Importance - Satisfaction)]\ x\ Stk.P.}{20} \quad (1)$$

where: Stk.P. is the Stakeholder Prioritization Value. The value for each specific stakeholder is presented on Stakeholder Prioritization Label, Table 16, and varies from 0.8 to 1; The difference of (*Importance-Satisfaction*) cannot be less than zero. Thus, if Satisfaction is bigger than Importance, the result of this difference shall be zero.

The formula is adapted from Silva Junior (2018) to consider a prioritization of stakeholders and to return a percentage of opportunity. The value of Opportunity adds up to 100%;

As previously mentioned, it is necessary to create a list of stakeholders that will prioritize the HLRs according to the stakeholder importance for the concept. Thus, this list utilizes previous studies that made it possible to identify the stakeholders' prioritization for the smart cabin concept. Therefore, the final list is presented in Table 16.

Table 16. Stakeholder Prioritization Label.

Stakeholders adjustment	Value	Stakeholder Prioritization
Pax	1.00	1. Passengers 2. Flight Attendant 3. Pilot 4. Ground Support & Servicing Team 5. Maintenance Teams 6. Airline & Leasing 7. Engineering 8. Requirements & Certification
All occupants		
Attendant	0.95	
Crew		
Pilot	0.90	[Importance + (Importance – Actual Satisfaction)] = Opportunity Obs.: Importance – Satisfaction cannot be less than 0
Ground support	0.85	
Maintenance	0.80	(OPPORTUNITY X STAKEHOLDER VALUE)/20 = OPPORTUNITY ADJUSTED [%]

Source: Elaborated by the authors.

The prioritization table reflects the stakeholders' importance for the project, so, it is possible to visualize that the passengers' value is equal to 1, which represents the biggest value. On the other hand, the stakeholder that has the lowest prioritization, for example, the maintenance team, has the value of 0.8. The variation of value between stakeholders is only 0.05, because the idea is to prioritize the main stakeholders, but not to exclude the stakeholders with less power such as maintenance and ground support, which makes the Smart Cabin Concept more integrated with the several areas of an airplane life cycle.

One last observation is related to the stakeholders "All occupants" and "Crew". The stakeholder "All occupants" is assigned to HLRs that influence each person on-board in the same way, passengers, pilot, and attendant. In relation to "Crew", the stakeholder "Crew" is assigned to HLRs that influence both, the pilot, and the attendant, in the same way. For both stakeholders, the defined value is, respectively, 1 and 0.95, in order to respect always the stakeholder most valuable to "All occupants", which is the passenger, and relate it to the "Crew", which is the attendant.

It is necessary to define which stakeholder will be mainly affected by each requirement fulfilment. For that stakeholder definition, one utilizes the studies of prioritization in combination with the user journey studies. Then, the importance and actual satisfaction grades are fulfilled based on the research previously done, being possible to establish the final adjusted opportunity for each high-level requirement, Table 17.

From Table 17, it is possible to obtain some vital attributes. The first important aspect is each HLR associated percentage of opportunity. For all HLRs with a percentage of opportunity superior to 50%, the HLR is considered as a Smart Cabin Concept High-Level Requirement. Thus, for the remaining HLRs with less than 50% of opportunity, requirements 5, 9, 11, 12, 13, 15, 16, 18, 22, 25 & 26, it will be necessary to determine if each specific requirement can be excluded from the concept or must be part of the final HLRs list because of some important factor. Therefore, the only requirement that are going to be part of the Concept High-Level Requirement List is Requirement 13: "The cabin shall provide accessibility to users with any kind of disability: Physical, Sensory or Cognitive", because of its importance for the inclusion of users with any kind of disability. Finally, it is possible to obtain the last version of the High-Level Requirements list.

Table 17. Adjusted Opportunity

ID	Final High-Level Requirements	Mainly affected stakeholder	Importance	Actual satisfaction	Opportunity	Stakeholder value	Opportunity adjusted
1	The cabin shall have tools that assist in the cleaning process.	Attendant	10	2	18	0.95	86%
2	The cabin shall have a system that enables the exchange of information between attendant and passenger.	Attendant	9	3	15	0.95	71%
3	The cabin shall have a communication system, attendant-pax and attendant-cockpit, accessible to the attendant on any part of the cabin.	Attendant	8	3	13	0.95	62%
4	The cabin shall enable the battery charging and internet connection of any type of Personal Electronic Device (PED).	Pax	9	5	13	1	65%
5	The In-flight Entertainment & Connectivity (IFEC) system shall have a navigation interface that is complete, without misunderstanding errors, and similar to PEDs.	Pax	5	7	5	1	25%
6	The In-flight Entertainment & Connectivity (IFEC) system shall allow the customization of its content such apps, language, theme.	Pax	10	3	17	1	85%
7	The cabin shall provide an immersion between the passenger and the cabin entertainment system.	Pax	8	3	13	1	65%
8	The aircraft shall have a compartment for user's hand luggage that is easily accessible and helps with the luggage storage.	Pax	7	4	10	1	50%
9	The aircraft shall have an organization system that helps on the loading and unloading of cargo.	Ground support	7	5	9	0.85	38%
10	The aircraft shall provide uninterrupted connectivity during all the flight phases.	Pax	9	4	14	1	70%

Continue…

Table 17. Continuation

ID	Final High-Level Requirements	Mainly affected stakeholder	Importance	Actual satisfaction	Opportunity	Stakeholder value	Opportunity adjusted
11	The aircraft shall have a minimum connectivity velocity to allow media streaming.	Pax	6	3	9	1	45%
12	The aircraft shall provide real time information of estimated time of arrival, climate conditions and baggage location to passengers.	Pax	6	7	6	1	30%
13	The cabin shall provide accessibility to users with any kind of disability: Physical, Sensory or Cognitive.	Pax	7	6	8	1	40%
14	The cabin shall have a health environment for its occupants respecting air quality, humidity, pressure, temperature, contamination, illumination, and noise.	All occupants	10	3	17	1	85%
15	The cabin shall have instruments to control temperature and illumination on the seat zone.	Pax	5	6	5	1	25%
16	The cabin shall have an internal noise lower than [X] dbs.	All occupants	4	8	4	1	20%
17	The cabin shall have instruments to control the passenger cabin and the cockpit temperature separately.	Crew	7	3	11	0.95	52%
18	The cabin shall allow that users from [X%] to [Y%] percentile - according to each specific program - performs all the functions and tasks related to the cabin operation.	Attendant	6	7	6	0.95	29%
19	The cabin inboard systems such as galley, lavatory, illumination, entertainment, and cabin environment shall communicate with each other using a common language.	Ground support	8	1	15	0.85	64%
20	The cabin shall assist on safety and security checks.	Attendant	7	1	13	0.95	62%

Continue...

Table 17. Continuation

ID	Final High-Level Requirements	Mainly affected stakeholder	Importance	Actual satisfaction	Opportunity	Stakeholder value	Opportunity adjusted
21	The cabin shall assist the preparation and fulfillment of the on-board service tasks.	Attendant	8	3	13	0.95	62%
22	The cabin shall have instruments to assist the passengers' boarding and deboarding. [Not necessary]	Pax	3	5	3	1	15%
23	The airplane shall have an exchange information system with ground support team to allow the filling of maintenance documents, and pre & post flight documents.	Ground support	9	4	14	0.85	60%
24	The airplane shall transmit the components status data to the ground support team.	Maintenance	10	5	15	0.8	60%
25	The airplane shall provide all the main cabin functions for the passengers, even during its time on the ground.	Pax	7	6	8	1	40%
26	The seat shall have instruments to control all of its adjustments.	Pax	5	4	6	1	30%
27	The cabin shall provide means to elevate the space perception for its occupants.	All occupants	8	3	13	1	65%

Source: Elaborated by the authors.

HIGH-LEVEL REQUIREMENTS

The final High-Level Requirements list for the smart cabin is presented in Table 18, and is composed of seventeen requirements. The considered requirements are those which provide the values and differentials to the concept of Smart Cabin.

It is important to remember that all stakeholders' necessities are relevant to the final concept; however, the final list of High-Level Requirements summarizes those requirements and respective stakeholders' necessities that aggregate more value and importance for the concept of Smart Cabin.

In the second part of this series of this paper, Silva *et al.* (2023), will be presented an analysis of the baseline requirements of the Smart-cabin concept defined in this article with the objective of showing a system architecture suggestion that shall fulfil each important issue, necessity and respective requirement established.

The definition of system architecture will also be employed in the methodology presented in the NASA Systems Engineering Handbook, because it is a methodology already validated in several programs, used worldwide and widely disseminated and known in the community. However, it is worth mentioning that for future work it is important to keep up to date, and that new methodologies are always being studied, such as Model Based Systems Engineering (MBSE), with expectations that it will help manage the increasing

complexity and reduce the development time of complex system as presented by Helle (2020) and Bi *et al.* (2021). Another point of importance is a future application of AI in methodologies to define requirements. In this paper, the methodology of the NASA Systems Engineering Handbook is used, however, in future studies where AI can be employed, it is important to capture how aspects of social acceptability, trustworthiness, ethical aspects, security, and AI-based system certification would be treated. In addition, the analysis of technologies to be employed in the concept of smart cabin, involves establishing the expected TRL of the components when judging risk, entry into service, and cost for the use of possible solutions to the final architecture Fahimian and Behdinan (2017).

Table 18. Final High-Level Requirements.

HLR ID	Final high-level requirements	Class
1	The cabin shall have tools that assist in the cleaning process.	Cleaning
2	The cabin shall have a system that enables the exchange of information between attendant and passenger.	Cabin communication
3	The cabin shall have a communication system, attendant-pax and attendant-cockpit, accessible to the attendant on any part of the cabin.	
4	The cabin shall enable the battery charging and internet connection of any type of Personal Electronic Device (PED).	Entertainment
5	The In-flight Entertainment & Connectivity (IFEC) system shall allow the customization of its content such apps, language, theme.	
6	The cabin shall provide an immersion between the passenger and the cabin entertainment system.	
7	The aircraft shall have a compartment for the user's hand luggage that is easily accessible and helps on the luggage storage.	Baggage handling
8	The aircraft shall provide uninterrupted connectivity during all the flight phases. [Excluding certification requirements that must be attended].	Connectivity
9	The cabin shall provide accessibility to users with any kind of disability: Physical, Sensory or Cognitive.	Flexibility
10	The cabin shall have a health environment for its occupants respecting air quality, humidity, pressure, temperature, contamination, illumination, and noise.	Cabin environment
11	The cabin shall have instruments to control the passenger cabin and the cockpit temperature separately.	
12	The cabin inboard systems such galley, lavatory, illumination, entertainment, and cabin environment shall communicate with each other using a common language.	Cabin tasks
13	The cabin shall assist on safety and security checks.	Safety checks
14	The cabin shall assist the preparation and fulfillment of the on-board service tasks.	Boarding service
15	The airplane shall have an exchange information system with ground support team to allow the filling of maintenance documents, and pre & post flight documents.	Support
16	The airplane shall transmit the components status data to the ground support team.	
17	The cabin shall provide means to elevate the space perception for its occupants.	Cabin comfort

Source: Elaborated by the authors.

CONCLUSION

As new technologies are created, new requirements and needs are imposed by stakeholders who use regional aircraft, and, consequently, it is necessary for airlines to update their airplanes to stay competitive. However, to understand which technologies can be used to meet market expectations, it is first necessary to understand the needs and requirements of those stakeholders, and for that, design thinking techniques were used.

First, it is performed an assessment to stakeholders' interaction with airplane cabin and which of these stakeholders have more power and influence on cabin design. Each stakeholder has been separately studied aiming to discover what are stakeholders' necessities, desires and problems, aiming the identification of opportunities that could be explored by the smart cabin concept. With the information gathered, the first version of High-Level Requirements was established and validated.

After the validation and modification of some aspects of the requirements initial version, the High-Level Requirements of Smart Cabin Concept for Regional Airplanes final version is defined. These requirements highlighted several cabin aspects that can be organized into ten classes:

- Cleaning: embraces requirement 1 that aims to facilitate the cabin cleaning process, bringing a more pleasant trip for the passenger and faster service during the ground tasks;
- Communication: includes the requirements 2, 3 and 12, requirements that envision an improvement in communication between passengers and attendants, but also aims to improve the exchange of information between cabin systems. The result of these actions brings an improvement in passenger comfort, but also assists on-board services, maintenance services and integration of cabin systems;
- Entertainment: has the requirements 4, 5 and 6 as its backbone. The main objectives of these requirements are to improve the integration of passengers' Personal Electronic Device (PED) into the aircraft cabin entertainment system and elevates the customization and immersion of the entertainment content to its respective user;
- Accessibility: has requirements that are part of this class is the 7 and 9. These requirements have as their main objective the improvement in the accessibility of the aircraft in terms of physical, sensory, and cognitive issues;
- Connectivity: has the requirement 8, which aims to increase cabin connectivity for all stakeholders during all phases of flight, resulting in an even more seamless journey;
- Environment: embraces the requirements 10 and 11. Both requirements aim to improve the cabin environment, considering aspects such as lighting, temperature, noise, and more. Which, in addition to improving the trip, will help to fewer occupants' post-flight symptoms;
- Safety: contains the requirement 13. This requirement considers safety tasks that can be optimized with a more integrated and smarter cabin design, which further enhances flight safety;
- Boarding Service: has the requirement 14. This requirement aims to improve and assist in the preparation and fulfilment of the tasks performed by flight attendants. Improving the working conditions of attendants, and streamlining the tasks performed;
- Support: has the requirements 15 and 16. Both requirements have as main objective the exchange of information from the aircraft's on-board systems with the ground support. In this way, it is possible to have a faster identification of problems and improve the speed at which maintenance tasks are performed;
- Cabin Comfort: includes the requirement 17. This requirement aims to help improve the cabin space perception by its occupants;

These classes are going to be the concept focus and the establishing of these requirements is essential for the design of a modern cabin that brings benefits to passengers and crew. Based on these requirements, it is possible to look for the existing technologies, functionalities and concepts that could be utilized in a project to satisfy these High-Level Requirements. Finally, it is worth noting that the methodology utilized in this study not only provides solutions for establishing high-level requirements for a "Smart Cabin" concept in regional airplanes ranging from 60 to 120 seats but also methodically develops and validates market requirements for application in various systems and functionalities. The methodology employed in this research not only addresses the specific requirements of the "Smart Cabin" concept but also ensures its applicability and relevance across different systems and functionalities. By adopting this comprehensive approach, the study not only offers solutions for immediate implementation but also lays the groundwork for future developments in the field.

The second part series will utilize the outputs gathered on this first paper to develop a preliminary system architecture with functionalities that shall enhance passenger experience, reduce airplane time on ground with operation optimization, create revenues opportunities for airlines, make airplane operation more sustainable, create new business opportunities for all stakeholders involved on regional aviation ecosystem and elevate product value for its stakeholders allowing OEM to increase client's confidence and satisfaction.

CONFLICT OF INTEREST

Nothing to declare.

AUTHOR CONTRIBUTIONS

Conceptualization: Silva ELS, Moraes AO and Ciaccia FRDAS; **Research:** Silva ELS; **Methodology:** Silva ELS, Moraes AO and Ciaccia FRDAS; **Project administration:** Silva ELS and Moraes AO; **Validation:** Silva ELS; **Writing - Preparation of original draft:** Silva ELS; **Writing - Proofreading and editing:** Moraes AO and Ciaccia FRDAS.

DATA AVAILABILITY STATEMENT

All datasets are analyzed in the present study.

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