Review

Implementation of ADS-B in Latin America and Its Projection

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Implementation of ADS-B in Latin America and Its Projection

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Abstract: The adoption of ADS-B in Latin America has been gradual but steady. Some countries, such as Brazil, Chile and Mexico, have made significant progress in the implementation of this system, while others are still in the early stages. It should be noted that the implementation of ADS-B is used in both military and civilian environments. For this reason, this research aims to provide information on the different characteristics that make up the surveillance systems. However, there are fundamental factors to promote the adaptation of ADS-B in Latin America, since they reduce the risk of collisions and air accidents by providing accurate and real-time information on the position and altitude of aircraft. On the other hand, it allows optimizing flight routes and reducing waiting time on the ground, which translates into fuel and cost savings for airlines. ADS-B increases the number of aircraft that can safely operate in the same airspace, which is especially important in regions with growing air traffic. ADS-B adoption in Latin America is expected to continue to grow in the coming years. The drivers for ADS-B adoption remain in place, and governments in the region are taking steps to accelerate its implementation.

Keywords: ADS-B; ADS-B projection; Latin American airspace; safety

Objectives

General objective:

-    Identify challenges and opportunities for ADS-B implementation in Latin America.

Specific objectives:

-    Evaluate the potential benefits of ADS-B for the safety, efficiency and capacity of Latin American airspace.
-    Propose recommendations for a successful implementation of ADS-B in Latin America.
-    To analyze the current status of ADS-B implementation in Latin America.

Introduction

The Automatic Dependent Surveillance-Broadcast-Broadcast (ADS-B) system is a fundamental technology in the modernization of air traffic control. This system, which has revolutionized the way aircraft are tracked and managed in airspace, has become a crucial pillar of the safety, efficiency and capacity of the global aviation system. (Cook, 2022)

ADS-B works by broadcasting radio signals from aircraft equipped with ADS-B transponders. These signals contain precise information about the aircraft's position, speed, altitude and other characteristics. This information is transmitted both to other nearby aircraft and to air traffic control ground stations. (Abbud, 2015)

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One of the most outstanding features of ADS-B is its ability to provide much wider and more accurate surveillance coverage than conventional radar systems.(Ricaud, 2016) Traditional radar systems have limitations in terms of range and accuracy, especially in remote or difficult-to-access areas. However, with ADS-B, aircraft can be tracked in real time almost anywhere in the world, as long as they are within range of a receiving ground station. (Cook, 2022)

This real-time tracking capability enables better air traffic management, as controllers can more accurately see the location and trajectory of all aircraft in their assigned airspace.(Ricaud, 2016)

This facilitates collision avoidance, congestion management and flight path optimization to improve efficiency and reduce flight times. (Ramirez, 2018).In addition to its usefulness for air traffic management, ADS-B also offers significant benefits in terms of safety. By providing controllers and aircraft with accurate and up-to-date information on the location of other aircraft, the system helps prevent mid-air collisions and reduces the risk of incidents. (Ricaud, 2016)

Another important aspect of ADS-B is its contribution to operational efficiency. By enabling more accurate surveillance and better air traffic management, the system helps reduce delays, improve flight punctuality and optimize the use of airspace and airports. This translates into time and cost savings for airlines and passengers alike. (Ramirez, 2018)

ADS-B also plays a crucial role in the implementation of new air traffic management concepts, such as performance-based navigation and trajectory-based approach and landing procedures. These approaches, which rely heavily on the availability of accurate aircraft position and velocity information, can further improve the efficiency and safety of the aviation system. (Dirección general de aeronáutica civil, 2017)

To take full advantage of the benefits of ADS-B, widespread implementation is required in both aircraft and air traffic control ground stations. Fortunately, many countries and regions have been actively working on the adoption of this technology, and its use is expected to continue to expand in the coming years. (Arévalo, 2020)

The implementation of the ADS-B (Automatic Dependent Surveillance - Broadcast) system in Latin America is progressing with several projects and developments underway. This system, which allows aircraft to report their precise position and other data via satellites, is critical for air traffic management and surveillance. (Arévalo, 2020)

In Mexico, for example, a set of 10 ADS-B stations that meet international standards have been installed and integrated into the country's four Area Control Centers (ACC). These stations aim to increase the safety and efficiency of air and ground operations, provide coverage redundancy and offer surveillance in areas where there is no radar coverage. (Ramirez, 2018)

The projection for ADS-B implementation in the region is positive, with expectations that it will contribute to more efficient airspace, more effective flight paths and a reduction in fuel consumption, which in turn will reduce CO2 emissions. In addition, it is expected to improve warning systems both in flight and on the ground, reducing runway incursions and increasing operational safety. (Arévalo, 2020)

Methodology

1.   Approach

The present research has a mixed approach, since according to authors it is described as: "A process that collects, analyzes and links quantitative and qualitative data in a single study or a series of investigations to respond to an approach". (Ruiz, 2013)

The mixed approach to research is presented as an innovative methodology that combines the best of two worlds: quantitative and qualitative research, allowing researchers to obtain a deeper and more complete understanding to answer any question.(Ruiz, 2013)

In this approach, quantitative methods, such as surveys and experiments, bring rigor and generalization to the research, allowing to quantify aspects of the phenomenon and establish relationships between variables. On the other hand, qualitative methods, such as interviews and focus groups, provide depth and understanding of the context, allowing us to explore the experiences, perceptions and motivations of individuals. (Pereira, 2011)

The integration of these two types of data is not limited to a simple sum, but seeks to establish synergies between them. Through triangulation, researchers can validate and enrich the findings of each method, obtaining a more complete and robust view of the reality studied. (Ruiz, 2013).

The mixed approach is particularly useful when research questions are complex and require a multifaceted understanding of the phenomenon. It is ideal for addressing sensitive or emerging issues, where quantitative information alone may be limited or superficial. (Pereira, 2011)

2. Design

Descriptive design is defined as a fundamental pillar in scientific research, allowing researchers to characterize and understand the nature of a phenomenon without manipulating or modifying it. Through this approach, it seeks to capture an accurate and detailed picture of reality at a given time, providing valuable information for decision making and understanding of various contexts. (Taiman, 2022)

In descriptive design, the researcher becomes a meticulous observer, gathering information in a systematic and organized manner. Quantitative methods, such as surveys and statistical analysis, play a crucial role in this process, making it possible to quantify aspects of the phenomenon and describe its distribution in the population studied. (Taiman, 2022)

In addition, qualitative methods, such as interviews and participant observation, add richness and depth to the description, revealing the experiences, perceptions and motivations of individuals. The combination of these methods allows a more complete and holistic view of the phenomenon in question to be obtained. (Taiman, 2022)

Descriptive design finds great utility in a variety of fields, from the social sciences to the natural sciences. It is particularly useful for exploring new topics, describing specific populations or groups, and evaluating programs or interventions. (Taiman, 2022)

3. Collection of information

3.1. Scientific Articles

Scientific articles go through a rigorous peer review process, which guarantees the quality and reliability of the information presented. This makes them a primary source of data to support the claims and analysis of the working paper.(Enago Academy Spanish, 2022)

By reviewing a large number of scientific articles on a specific topic, researchers can gain a deep and comprehensive understanding of the current state of knowledge in the area. This allows them to identify trends, research gaps, and areas of debate, which is crucial for critical and reflective review.(Atkinson, 2010)

By comparing and contrasting the findings of different studies, researchers can identify patterns, similarities and differences, which strengthens the argumentation and the contribution of the working paper.(Atkinson, 2010).

3.2. Surveys

Surveys can be designed to collect both quantitative data (such as numbers, frequencies and percentages) and qualitative data (such as opinions, comments and experiences). This combination of data can provide a more complete and nuanced picture of the issue at hand.

These can be administered to a large number of people, allowing a representative sample of the target population to be obtained. This increases the generalizability of findings and reliability of the study.(Atkinson, 2010).

Compared to other data collection methods, such as in-depth interviews or focus groups, surveys can be a more economical and efficient way to collect information from a large number of people.(Creswell, 2019)

Survey data are collected in a standardized format, which facilitates comparison and statistical analysis. This allows researchers to identify patterns, trends, and relationships between variables.(Creswell, 2019)

3.3. News

News can provide recent and relevant information about ongoing events, trends, and debates related to the research topic. This can be particularly useful for current or rapidly evolving topics.

They also present information from a variety of sources, including experts, key stakeholders, and the general public, which can provide a wide range of perspectives on the topic. News stories can complement other data sources, such as scientific articles and books, by providing contextual information and concrete examples (Atkinson, 2010).

Results

As mentioned above, the research method of this work is based on the collection of information through the review of different documents, therefore, each of them will be explained below in order to provide a discussion and analysis of the implementation of ADS-B in Latin America and its projection.

Research 1

Research Title	ADS-B Technologies Use and Appropriation at CETAD
Author	Jimmy Flórez-Zuluaga
Date of publication	November 18 2014
Abstract	Air transport is constantly growing, presenting considerable challenges to maintain safety and optimize navigation in an increasingly congested airspace. In this context, the integration of satellite navigation systems with autonomous broadcasting systems on aircraft, commonly known as ADS-B (Automatic Dependent Surveillance-Broadcast), has become a globally accepted alternative due to its advantages in terms of cost and performance.(Zuluaga, 2014). ADS-B functions as an automatic aircraft-dependent surveillance system, allowing each aircraft to periodically transmit crucial information about its position, altitude, speed and identification through a data link. This information is disseminated to both other nearby aircraft and ground stations, regardless of the coverage of traditional air traffic control systems (CNS/ATM).(Zuluaga, 2014).(Zuluaga, 2014)

Research 2

Research Title	Automatic Dependent Surveillance (ADS-b) in Colombia
Author	Leonardo Gómez
Date of publication	October 30 2015
Abstract	In the dynamic world of aviation, Colombia is at the forefront in the adoption of innovative technologies to ensure the safety and efficiency of air navigation. This article explores the current technologies employed in the country to provide aeronautical navigation and surveillance services, with a particular focus on the ADS-B (Automatic Dependent Surveillance-Broadcast) system and its impact in the Colombian context. (Gómez, 2015) ADS-B is emerging as a fundamental piece in the future of air navigation in Colombia. This system allows aircraft to automatically transmit identification, position, altitude and speed data to other aircraft and ground stations, significantly improving situational awareness and safety in the airspace.(Gómez, 2015)

Research 3

Research Title	Benefited towards new navigation technologies: Automatic Dependent Surveillance System (ADS-B) for Colombia
Author	Sergio Alfredo García Castro
Date of publication	2019
Abstract	This essay explores the navigation and surveillance technologies currently employed by Colombian aircraft, providing a concise description of each and analyzing their advantages and disadvantages in the Colombian context. The ADS-B (Automatic Dependent Surveillance-Broadcast)

	system is positioned as a transforming element in the future of Colombian air navigation. (García, 2019)
	This system allows aircraft to automatically transmit identification, position, altitude and speed data to other aircraft and ground stations, significantly improving situational awareness and safety in the airspace. (García, 2019)

Research 4

Research Title	Prediction of flight arrival times by machine learning
Author	Arévalo Llorente Beatríz
Date of publication	2020
Abstract	Development of an application that makes use of artificial intelligence techniques in order to make predictions about flight landing times. The data used have been collected both from flight plans and from the Automatic Dependent Surveillance-Broadcast (ADS-B) system. Apache Spark and the MLlib library are used to extract the learning models in order to speed up the information treatment and the processing of large amounts of data. (Arévalo, 2020)

Research 5

Research Title	Drone Implementation in Logistics Activities
Author	William Yesid Guzmán Alarcón
Date of publication	2020
Abstract	Colombian companies seek to improve their logistics processes to reduce costs, mainly in warehousing and distribution. However, they lack the knowledge and

| | implementation of innovative technological solutions. (Guzmán, 2020)

Therefore, we seek to explore the benefits of emerging technologies, specifically the use of drones, to optimize logistics management through a literature review of secondary sources, including refereed databases and libraries, to analyze existing cases and studies on the use of drones in logistics.   (Guzmán, 2020)

Finally, identify the contributions and benefits of drones in logistics, describe successful cases in the implementation of drones to optimize logistics processes and propose recommendations for the adoption of drones in Colombian logistics. (Guzmán, 2020) |
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Research 6

Research Title	The Violation of the right to intimacy and privacy in Colombia for the Use of unmanned Aircraft (UAS)
Author	Lopez Puerta Mateo
Date of publication	May 12 2021
Abstract	Colombia's booming drone industry requires regulations to balance its benefits with privacy concerns. This analysis examines current legislation and its effectiveness in protecting the right to privacy from drone surveillance. (Lopez, 2021)

By comparing Colombian regulations to the EU's focus on privacy, the study identifies potential gaps and the need for laws that safeguard fundamental rights in a digital age. (Lopez, 2021) |

Research 7

Research Title	DATA LINKS IN VHF (VDL) INSIDE THE CONTEXT CNS/ATM FOR THE INSTALLMENT OF THE SERVICES OF AIR TRAFFIC IN COLOMBIA

Author	Leonardo Gómez y Jorge Ortíz
Date of publication	2012
Abstract	The article presented offers an in-depth perspective on the VHF data link communications protocol (VDL) and its crucial role in the ICAO CNS/ATM concept with the help of ADS-B. The analysis highlights the importance of VDL as a fundamental element for the modernization of air traffic services in Colombia, considering the geographical characteristics and air traffic flow of the country. (Gómez y Ortíz, 2012)

Research 8

Research Title	Feasibility of TCAS systems on UAV platforms
Author	Pareja García Jonathan
Date of publication	2009
Abstract	The presented research work explores the feasibility of integrating Sense and Avoid (SAA) systems in UAVs, analyzing both TCAS and other alternatives. The final objective is to propose a suitable SAA solution for UAVs, considering the specific limitations and requirements of these aircraft. (Pareja, 2009) TCAS integration in UAVs presents several challenges, mainly related to latency, Alert Resolutions (AR) generation and compatibility with autopilots. These obstacles hinder the effective implementation of TCAS in this type of aircraft. (Pareja, 2009)

Research 9

Research Title	Considerations for the implementation of the automatic dependent surveillance system - Broadcasting (Ads-B) in Colombia
Author	Benavides Moncayo Olga Luisa
Date of publication	2016
Abstract	*"This article describes the basic principles of operation of the Automatic Dependent Surveillance System - Broadcast (ADS-B) and the corresponding main considerations that the Special Administrative Unit of Civil Aviation (UAEAC), have established for its implementation and operation in Colombia; The purpose of this is to increase the operational efficiency of the airspace, as well as to improve flight safety conditions, providing surveillance outside the radar range, increasing the accuracy of aircraft position in emergency situations and in normal operation, facilitating the early detection of errors in the insertion of notification points"* (Benavides, 2016)

Research 10

Research Title	Feasibility and implementation of ADS-B technology in Philippine airspace.
Author	Morata Pérez Alejandro
Date of publication	2023
Abstract	ADS-B has revolutionized air traffic control, offering a more efficient, reliable and secure system for aircraft monitoring and management. Worldwide, its implementation has grown exponentially, presenting itself as an alternative or complement to traditional radars. ADS-B implementation in the Philippines has faced challenges that have delayed its widespread adoption. Actions are required to address safety gaps and assess the real need for ADS-B in the country

	context. (Morata, 2023)

Research 11

Research Title	Development of AM, FM and ADS-B receiver systems using software defined radio, hardware and open source software.
Author	Santiago Romero
Date of publication	2015
Abstract	This article demonstrates how RDS technology, in conjunction with open source hardware and software, opens up a range of possibilities for creating low-cost communications systems. From receiving AM and FM broadcasts to decoding ADS-B data, RDS becomes a versatile tool for enthusiasts, students and professionals. (Romero 2015)

Research 12

Research Title	Analysis, design and development of a 4-channel ADS-B receiver for Mode S and Mode 5.
Author	Gallego Menéndez Laura
Date of publication	2020
Abstract	Secondary radar systems are constantly evolving, incorporating automatic communications and digital signal processing to take full advantage of new telecommunications technologies. In response to this development, civil air surveillance authorities globally have mandated the mandatory upgrade of communication equipment starting in 2021. Although the military field does not yet have a defined date, it is expected to follow the same trend. (Gallego, 2020) In this context, this TFM proposes the design of a secondary radar reception subsystem for a 4-channel sector ground

	station. This solution not only allows us to comply with current regulations and anticipate future changes, but also contributes to significantly improving airspace safety. Benefits include optimized aircraft positioning, more efficient data communication and an overall increase in system capabilities. (Gallego, 2020) The implementation of this secondary radar reception subsystem represents a crucial step towards a more modern, safer and more efficient air surveillance, adapting to the demands of the current and future technological environment. (Gallego, 2020)

Research 13

Research Title	Optimization of air transport with self-separation monitoring during cruise flight phase
Author	Ricaud, E
Date of publication	2016
Abstract	The increase of air traffic in the last decades demands greater control and safety in the airspace. In this context, the Airborne Separation Assist System (ACAS) emerges as an innovative solution for autonomous aircraft surveillance and control. (Ricaud, 2016) The ACAS uses an automated system (CDTI) that provides real-time information on the surrounding traffic and executes automatic maneuvers to maintain vertical and horizontal separation, preventing collisions. (Ricaud, 2016) This study evaluates the adaptability of crews to this automated system, demonstrating a high degree of acceptance and ease of use. Tests confirm that ACAS optimizes the volume of air transport operations without compromising safety.In short, ACAS represents a significant advance in air surveillance, improving the efficiency and safety of air transport in an increasingly complex environment. (Ricaud,

	2016)

Research 14

Research Title	Aircraft localization and tracking using wide-area multilateration systems
Author	Abbud Momma Jorge José
Date of publication	2020
Abstract	Increasing demand in air transport and new military scenarios make it necessary to optimize the use of airspace. The EU and the US with SESAR and NextGen are looking for a new air traffic management (ATM) to increase the capacity of airports and air routes with greater flexibility and safety. The key to this change is to know the position of each aircraft in real time, and the trend in ATM is to use ADS-B as the main source of positioning. However, an independent tracking system is needed. (Abbud, 2020)

The proposal of this thesis is to migrate from secondary surveillance radar (SSR) to wide area multilateration (WAM) to improve position accuracy. ADS-B base stations would be reused for WAM, and each station would send the time-of-arrival (TOA) measurement of the ADS-B message to the air traffic center. The aircraft position would be obtained by multilateration. (Abbud, 2020)

The objective is to estimate the position of each aircraft as accurately as possible. For this purpose, errors affecting the TOA measurement (tropospheric refraction and synchronism error) are studied and tracking systems based on sophisticated versions of the Kalman filter (IMM, UKF) are proposed. (Abbud, 2020)

The thesis presents a system that allows the tracking of aircraft, correcting the effects of the main distortions affecting the TOA measurement. The improvement in localization accuracy has been evaluated by simulation of hypothetical |

	scenarios. (Abbud, 2020)

Discussion

ADS-B in Latin America

ADS-B (Automatic Dependent Surveillance-Broadcast) is not a new technology, but its implementation in Latin America is gaining relevance due to the significant benefits it offers to aviation. Among these benefits are the ability to provide coverage in areas where previously there was none, help airlines reduce the separation between aircraft in flight, and facilitate the creation of new, more direct and efficient routes, optimizing flight operations.

The ADS-B satellite system works as follows: the aircraft sends a direct message to a satellite, which is connected to a network of other satellites. This information is transmitted to a ground station, which passes it to a processor. The processor then delivers the information to an air traffic service provider. This system complements traditional radar by providing data such as aircraft speed, altitude and heading, regardless of location. In order to provide aircraft information services to air traffic control, EASA (European Aviation Safety Agency) certification is required. The ADS-B system ensures that there are no gaps in coverage, guaranteeing continuous and accurate monitoring of aircraft.

The company providing this service charges according to the number of flights performed, offering a payment model based on the actual use of the service. This allows for greater transparency and efficiency in operating costs.

Compared to the major free platforms, ADS-B is distinguished by its real-time accuracy. Free platforms often lack this accuracy, affecting monitoring efficiency. ADS-B makes it possible to optimize aircraft operations thanks to its high accuracy, something that platforms such as Fly Radar cannot achieve due to their delays.

Regarding expansion in Latin America, the necessary legal approvals are being sought to offer this service in different countries in the region. The objective is to comply with the regulatory standards of each country in order to provide a safe and efficient service. In summary, satellite ADS-B in Latin America promises to significantly improve the safety and efficiency of air operations, offering complete and accurate coverage that optimizes routes and reduces operating costs for airlines.

The five articles and report reviewed provide an overview of ADS-B implementation in Latin America. The articles initially disclosed the benefits of the technology, such as improved safety, efficiency and cost reduction. They also discuss the challenges of implementation, such as the cost of infrastructure and the need for regional cooperation.

On the part of the Colombian Air Force, it provides a context that describes the current panorama of the technologies used for air navigation and surveillance in Colombia; incorporating concepts such as communication, navigation, Surveillance/Air Traffic Management (CNS/ATM), with a particular focus on Automatic Dependent Surveillance (ADS-B) technology. The main objective of the article is to analyze the advantages and disadvantages of ADS-B implementation in the context of air traffic and geography of Colombia, besides presenting the current status of ADS-B service in the country and the technologies being used for its implementation (Ciencia Y Poder Aéreo, 2024).

From the above mentioned, it can be inferred that for the use of ADS-B systems, services such as the following are used

- Radars: Ground-based radars are used to detect and track aircraft, providing air traffic controllers with information on their location, altitude and speed.

- Secondary surveillance systems: These systems, such as the Secondary System of Identification (SSR), allow aircraft to transmit their identity and other information to air traffic controllers.

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- Satellite navigation systems: Systems such as the Global Positioning System (GPS) allow aircraft to accurately determine their position.

On the other hand, CNS/ATM is a conceptual framework that integrates communication, navigation, surveillance and air traffic management to improve airspace safety, efficiency and capacity, the key services of CNS/ATM are:

- Communication: Effective communication between air traffic controllers, aircraft and other stakeholders is essential for safe and efficient air operations.
- Navigation: Aircraft need accurate navigation systems to determine their position and follow safe routes.
- Surveillance: Air traffic controllers need accurate information about the location and movement of aircraft to manage air traffic safely and efficiently.

Air traffic management: Air traffic controllers use a variety of tools and procedures to manage air traffic flow and ensure safe operations.

However, for the implementation of ADS-B in Colombia, according to the Colombian Air Force, there are several challenges to be faced, initially with the significant investment in ground infrastructure to implement ADS-B. Most of the aircraft must be equipped with ADS-B transponders to participate in the system and finally air traffic controllers and airline personnel need training to use the new technology. (Gomez, 2015).

Report 1 provides a specific example of ADS-B implementation in Brazil, which can serve as a model for other countries in the region. The report describes the Brazilian airspace surveillance system, which is mainly based on primary and secondary radars. These radars cover 95% of the Brazilian continental territory at an altitude above 245 meters. However, due to the difficulty of installing radars on oil platforms, ADS-Bs were implemented in 2018. (ICAO, 2024)

These were initially implemented in the Campos Basin to monitor helicopters traveling between the mainland, the Macaé terminal and oil platforms. This implementation was successful and has improved the safety and efficiency of air operations in the region. (ICAO, 2024)

Due to the excellent result in the positive experience in the Campos Basin, the Brazilian Airspace Control Department plans to implement ADS-B throughout the country's continental airspace. For this purpose, 66 ADS-B stations are needed to cover the four Flight Information Regions (ICAO, 2024).

The implementation of ADS-B throughout the Brazilian mainland has the potential to offer several benefits, firstly that it provides more accurate position and altitude data than traditional radar-based systems, which can help reduce the risk of collisions and other accidents. On the other hand, air traffic controllers manage air traffic more efficiently, which can reduce waiting times and fuel consumption.

The implementation of ADS-B systems in Latin America has the potential to transform the aviation industry. The technology can help improve safety, efficiency and cost reduction, benefiting both airlines and passengers.

ADS-B implementation is expected to continue to grow in Latin America in the coming years. As more countries adopt the technology, the benefits will become more evident. The region is well positioned to become a leader in ADS-B implementation, which can have a significant positive impact on the global aviation industry.

Conclusions

To conclude, ADS-B systems initially improve the efficiency of the aeronautical industry, due to the advantages they present, such as air safety supervision, increased air traffic efficiency, coverage in uncontrolled areas, which helps to create new air routes.

On the other hand, the implementation of ADS-B systems in Latin America has had a growth rate with some countries that have acquired such operations such as Brazil and Colombia.

In addition, in order to see an advanced growth in the implementation of the aforementioned systems, it would be necessary the intercommunication between countries and aeronautical

authorities, to be able to effectively guarantee such growth. It should also be noted that in order for these systems to work effectively, it is necessary that where the majority of the airlines' fleets are incorporated, they must have carrier upgrades to ensure the operation of the ADS-B systems.

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