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New trends in urban and advanced air mobility

Nuevas tendencias en la movilidad aérea urbana y avanzada

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Abstract

This article addresses issues related to technological innovation as part of a systemic approach to reduce or neutralise aviation emissions and their contribution to climate change, aircraft noise and emissions associated with local air quality.

Resumen

En este artículo se plantea un abordaje de los aspectos relacionados con la innovación tecnológica como parte de un enfoque sistémico tendiente a disminuir o neutralizar las emisiones de la aviación y su aporte al cambio climático, el ruido generado por las aeronaves y las emisiones asociadas a la calidad del aire local.

Introduction

Air transport can be analyzed and assessed from various perspectives, whether international, regional, national, provincial, local, or specific, depending on the facility or infrastructure under consideration. Additionally, the inherent dynamics, evolution, and transformation of this activity must be considered, which implies defining different spatial and temporal scales of action and execution, all in line with the appropriate operational contexts that correspond to it.

Also, the air transport system should be integrated with an intermodal transport plan in support of strategic development plans, all in accordance with state policies and associated objectives, among which safety, environmental protection (and within, the concept of sustainability), the regulatory legal framework and the optimization of management models should be present in a harmonious manner.

In this context of permanent change, the International Civil Aviation Organization (ICAO) establishes a series of lines of action, generates reference documentation and sets strategic objectives (SOs) in accordance with the Sustainable Development Goals (SDGs) of the United Nations.

> ***The air transport system should be integrated with an intermodal transport plan in support of strategic development plans, all in accordance with state policies and associated objectives".***

Thus, taking the above into consideration, the present work aims to address in a general manner certain trends in specific aspects of research and development, also delving into the new concepts of Urban Air Mobility (UAM) and Advanced Air Mobility (AAM), keeping in mind the overall context of operation within the international civil aviation framework and highlighting certain actions related to the thematic axes of this publication.

United Nations and Sustainable Development Goals

The Charter of the United Nations established, in 1945, the creation of the Economic and Social Council (ECOSOC) being today one of the six main organs of that body. In its website[1], its mission is evident, which is transcribed below:

> "The Economic and Social Council is part of the core of the United Nations system and aims to promote the realization of the three dimensions of sustainable development (economic, social, and environmental). This body serves as a fundamental platform for fostering debate and innovative thinking, achieving consensus on how to move forward, and coordinating efforts aimed at achieving internationally agreed-upon goals. It is also responsible for monitoring the outcomes of major United Nations conferences and summits."

To carry out this mission, it is necessary to coordinate efforts and actions among the different entities of the United Nations that work on issues related to sustainable development. These areas of operation and action include regional economic and social commissions, organic commissions —responsible for facilitating intergovernmental debates— specialized agencies, programs and funds, research institutes, and other entities and bodies that coordinate specific actions with the goal of ensuring that commitments related to development translate into real changes in people's lives.

In this framework of containment, it is now the moment to make a general reference to the UN Sustainable Development Goals (SDGs), which can be clearly seen in their website[2].

By exploring the general contents of each SDG, we can appreciate that there are currently about 169 targets related to poverty, hunger, nutrition, food security, promoting sustainable agriculture, the health and well-being of the population, inclusive, equitable, and quality education, gender equality, the empowerment of women and girls, access to water and sustainable water management, affordable, safe, and sustainable energy, sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all, resilient infrastructure, inclusive and sustainable industrialization, innovation, inequality, inclusive, safe, resilient, and sustainable cities, sustainable consumption and production, climate change, the sustainable use of water resources, terrestrial ecosystems, and biodiversity, societies, institutions, and the global alliance for sustainable development.

The question that arises then is: which of these SDGs have their direct correlation with ICAO SOs? This question has an answer on the ICAO[3] website, indicating that its 5 SOs relate to 15 of the 17 UN SDGs.

1. Available in <https://www.un.org/ecosoc/es/content/about-us>

2. Available in https://www.un.org/sustainabledevelopment/es/sustainable-development-goals

3. Available in <https://www.icao.int/about-icao/aviation-development/Pages/ES/SDG_ES.aspx>

By exploring them, we can observe the actions that the International Civil Aviation Organization is carrying out to contribute to each of the referenced SDGs.

> ***"ICAO has defined three major environmental objectives by limiting or reducing aircraft-generated noise and emissions associated with local air quality.***

Clearly, we could analyze and specify which programs, plans and actions are specific to each SDG in relation to each SO, but attentive to the extension that this would entail, we'd better leave this for another publication.

ICAO, its Strategic Objectives and Lines of Environmental Action

ICAO regularly establishes general strategic objectives[4] (SOs), the following five being in force:

- Safety
- Capacity and efficiency
- Security and facilitation
- Economic development
- Environmental protection

From the review of the thematic areas addressed by each SO we can infer their contents without the need to delve too deep into them. However, on this occasion, and considering the subject chosen for this article, we will make specific reference only to one of them, with the intention of reviewing, in a reflective manner, certain aspects and then link them in a very general way with the UN's SDGs.

Environmental Protection, a Strategic Objective of ICAO

> "Minimize the adverse environmental effects of civil aviation activities. This strategic objective promotes ICAO's leadership in all environmental and aviation-related activities and is consistent with ICAO's and the United Nations system's environmental protection practices and policies[5]".

From the above, the indicated guidelines are clearly linked to social, economic and environmental development as a whole, in accordance with the precepts of sustainable development.

In this context, ICAO[6] has defined three major environmental goals in which it seeks to limit or reduce:

- aviation emissions and their contribution to climate change,
- noise generated by aircrafts,
- emissions associated with local air quality.

When analyzing them, we can appreciate different scales of action and impact. The first one is mainly related to the interurban section and the plane, while the next two are linked to the airport and its immediate surroundings, all according to an urban or suburban context of multimodality.

In turn, in accordance with this, the following areas of action have been established seeking to contribute to the achievement of the established goals, to obtain a 2% annual improvement in fuel efficiency and carbon neutral growth for 2020:

- implementation of aircraft technologies and standards,
- improved air traffic management and operational improvements
- development and use of sustainable aeronautical fuels,
- implementation of the carbon offsetting and reduction scheme for CORSIA international aviation.

These new technologies are evidenced and projected in all the links that make up the air transport system, as they seek to optimize the processes and operations that occur in their own airports, in airspace, in support elements at aerodromes and, of course, in the aircrafts themselves and their assistance vehicles.

The intention is to optimize the processes and operations, contributing significantly to environmental care and protection, minimizing the emission of polluting gases and reducing the acoustic impact, in accordance with the concepts of sustainability and the ICAO SOs.

4. Available in <https://www.icao.int/about-icao/Council/PAges/ES/Strategic-Objetives.aspx>
5. Available in <https://www.icao.int/Documents/strategic-objectives/strategic_objectives_2005_2010_es.pdf>
6. Available in <https://www.icao.int/environmental-protection/Pages/default.aspx>

Air Transport Industry and Innovation

In line with the above, the Member States are working towards a more environmentally friendly transport system, and it is in this context that they have published their action plans, which show the different strategies used to achieve the objectives set. Technological innovation is one of the fundamental axes of investigation, development and action of the aviation sector.

In this context of permanent transformation, the concept of biomimicry appears, where it seeks to imitate the designs and processes of nature to solve technical problems, generating certain development patterns that allow, in the case of aircraft, to reduce aerodynamic resistance and the weight as negative forces, while optimizing those positive forces that are related to the lift and thrust of the engines.

Weight-Focus Innovation Overviews

This line of action basically seeks to have lighter aircraft by using composite and alternative materials, applied to primary and / or secondary structures, allowing in turn optimized maintenance processes. Accordingly, Airbus is studying:

- **Biomass fibers:** obtained by carbonizing precursors obtained from biomass derived from raw materials. Its use in biocomponents could result in composite materials that provide an alternative to carbon fibers obtained from petroleum. Research areas include algae.
- **Resins of biological origin:** derived from biological sources, such as sugar cane and lignin, among others. Its use could provide an alternative to phenolics in aircraft. Research areas include furan, epoxy and polyamide.
- **Natural fibers:** these are derived from animals, plants or minerals and, due to their low weight and high strength properties, can be used as biocomponents in non-critical secondary aircraft structures. Areas of study include basalt fibers, spider silks, bamboo reeds and linen.

General Aspects of Innovation Focused on Strength and Lift

This line of action aims to ensure that aircraft and their components are adapted to the functional requirements of established missions. Reconciliation involves changes in the system's characteristics, including the aircraft's states during various flight profiles, giving rise to the concept of morphing wings.

The idea, although a bit futuristic, focuses on the fact that the plane or its wings can be transformed in flight adapting to the condition of minimum resistance according to the flight profile (altitude and speed), as if it were a bird.

Furthermore, there is a desire for improved aerodynamic cleanliness of the airflow over the wings, aiming for laminar flow over them, which would reduce wing friction by increasing collaborative widths, thus delaying boundary layer separation during takeoff.

Another example is the ability for aircraft to modify the aspect ratio of their wings using semi-aeroelastic hinges at the wingtips. This directly impacts induced drag, which in some cases accounts for more than 30% of the aircraft's aerodynamic resistance.

Other trends focus on designing lightweight, ultra-thin, and more aerodynamic wings to increase fuel efficiency.

In line with these developments, there are new coatings or textures that mimic sharkskin or shape-memory alloys, where a metal exhibits unique properties that enable the device to adapt to each flight condition on its own.

> ***"Member States work to get a more environmentally friendly transport system. The technological innovation is one of the fundamental lines of investigation, development and performance of the aviation sector.***

Propulsion-Focused Innovation Overviews

Developments related to engines are focused, among other things, on improving the processes associated with combustion, propulsion efficiency and thermodynamic fluid, weight reduction and neutralization of pollutant inputs.

In this context, and in relation to polluting products, work is being done on biofuels, alternative fuels and other means of propulsion that are under study and development:

- **Biofuels:** Among them, we have first, second, third, and fourth-generation biofuels, with third-generation biofuels being those derived from aquatic plants. These do not require direct land use and can be cultivated in bioreactors or directly in the sea. The fuel obtained has the least resource competition in terms of the amount of fuel produced. This classification of biofuels has been introduced by the aviation industry in recent years, and studies have already been conducted regarding the feasibility of large-scale production to meet the requirements of civil aviation. On the other hand, there are those known as fourth-generation biofuels, which can be produced without using land and do not require the destruction of biomass to be converted into fuel.

- **Photobiological fuels and electrofuels**: These terms refer to production processes. Among them is "green hydrogen," which is obtained through the electrolysis of water using electricity from renewable energy sources.

- **Other hydrogen sources:** Currently, approximately 95% of the world's hydrogen production is derived from fossil fuels and is known by various names, such as gray hydrogen (obtained from steam methane reforming) or blue hydrogen, which involves carbon dioxide capture during production.

- **Other propulsion methods:** Among them is the development of lithium-ion batteries and other types of batteries, with the aim of using them as energy sources for propulsion. This way, aircraft would have a wide range of torque and power options for different flight levels.

One aspect to highlight regarding fuels is their energy density, as it indicates the amount of energy they possess per unit of volume or weight. Lower energy density necessitates the consumption of more fuel (both in terms of volume and mass) to produce the same amount of work. The current approximate average values for this relationship can be seen in the following reference data:

FUEL	ENERGY DENSITY
Gaseous fossil fuel	13,000 Wh/Kg
Liquid fossil fuel	12,000 Wh/Kg
Hydrogen	34,500 Wh/Kg
Lithium battery	300 Wh/Kg
Lead-acid battery	30 Wh/Kg

Clearly, it can be observed that the fuel of the future will be centered around hydrogen, or more precisely, green hydrogen, even though this technology is still in its infancy for application in the aviation transportation system.

Aspects Related to New Trends in Air Mobility

In recent years, there has been significant progress in the development of electric vertical take-off and landing (eVTOL) vehicles, which are associated with urban air mobility (UAM) and advanced air mobility (AAM). It is estimated that these aircraft will replace and complement a portion of the current general aviation. An example of the increasingly widespread use of these drones can be seen in the use of radio aids verification aircraft, which are replacing traditional aircraft in this activity, or in the replacement of helicopters for inspecting high-voltage power lines.

However, beyond the drones that we are all familiar with, there are several questions arising regarding the new air mobility: How will cargo be transported? How will passengers travel? Will they use the same vehicles, or will they be specific to their needs? What will their characteristics be? Will they be autonomous or piloted? What additional services will they require? What will their propulsion methods be? What aeronautical infrastructure will they need? What will their terminals look like? What features will the support elements have? How will they integrate with other air, land, or maritime/river transport modes? And so on, we could continue with numerous questions that still have relative answers or, in some cases, no answers at all.

"You can see that the fuel of the future will be focused on the hydrogen, or rather, in green hydrogen, even though this technology is still embryonic for application in the air transport system."

The fact is that, as of today, we have more questions than answers, but this is precisely what planning is about—anticipating possible scenarios that, with a certain level of certainty, may become a reality.

In this regard, the new vehicles are still in the development phases, as is the regulatory framework itself. An example of these AAM vehicles can be seen in the following image:

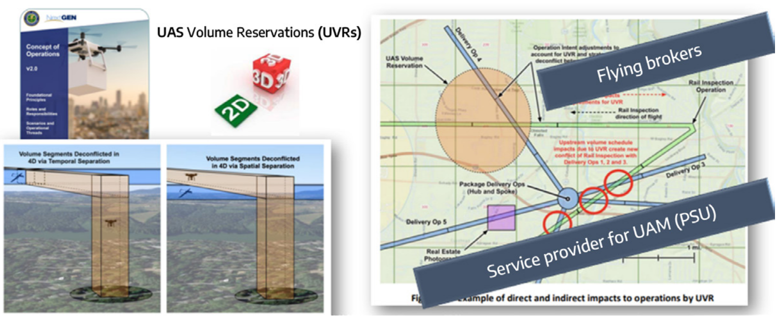
Source: ICAO + GTA UIDET "GTA-GIAI" UNLP.

Additionally, beyond what has been published by ICAO, you can observe developments and trends related to these types of aircraft and their systems on the official websites of the Federal Aviation Administration (FAA), the European Union Aviation Safety Agency (EASA), or even on the National Aeronautics and Space Administration (NASA) website.

By exploring these websites and analyzing their contents, we can say with a certain level of certainty that soon, the skies will be filled with electric aircraft of the Electric Vertical and Short Takeoff and Landing (eVTOL or eSTOL) type. These aircraft may be autonomous or piloted (either directly or remotely controlled) and will operate within controlled or uncontrolled airspace but always within their specific corridors, as per their assigned activity.

It is reasonable to assume that the network of ground infrastructure for general aviation will no longer only include traditional aerodromes and heliports but will also encompass vertiports or stolports located within aerodromes or independently situated in urban or suburban areas.

This will lead to envisioning cities where transportation will no longer be primarily 2D but 3D, utilizing different networks and subnetworks for passenger or cargo services, all in compliance with the rule of law, sustainability, and safety as fundamental pillars of specific development. An example of this can be seen in the following image:



Source: FAA.

For this transformation to become a reality, it will be necessary to integrate and strengthen various aspects, such as Big Data, 5G technology, the Internet of Things (IoT), airspace management services, multimodal transportation system management services, and infrastructure, all in alignment with the principles of Smart Cities. These Smart Cities should prioritize sustainability and inclusivity while emphasizing the integral multimodality and complementarity of transportation.

In this context, the Air Transport Group (GTA) of the "GTA-GIAI" research unit at the Department of Aerospace Engineering of the Faculty of Engineering at the National University of La Plata has been working on the development of aerial mobility networks and vertiports. Examples of these can be visualized in the following illustrative images:

Source: GTA-UNLP, 2022.

At this moment, pausing the discussion of the points, I invite the reader to consider where a vertiport for the operation of eVTOL aircraft intended for AAM could be located within an airport.

The core idea here is related to the concept of creating a complex within an airport, thereby allowing for a new mode of accessibility to the airport site using eVTOL aircraft and the corresponding infrastructure and facilities.

Furthermore, this airport vertiport will be connected to an urban network of vertiports, each with its own criteria for location and design. In both cases, the best solution and location will be determined through the analysis of variables, indicators, dimensions, and decision matrices.

Within the typical dimensions of decision-making, we will encounter the boundaries of "aeronautical operability," "economic and financial viability," "anthropic impact," "natural impact," and "social perception."

Ultimately, the final solution will depend on the perspective through which the operational context is viewed, whether it is located at an airport or within an entirely urban area. Additionally, this perspective will be shaped by various variables and constraints, including social, cultural, strategic, environmental, technical, political, economic, financial, and legal factors, among others. The determination of precedence will be a matter of political, strategic, and technical/sustainability considerations.

ICAO and Innovation at the Heart of Global Aviation Development

Finally, beyond eVTOL, UAM, and AAM, it is worth mentioning that ICAO has created a dedicated website[7] for innovation.

In this context, ICAO has launched a global competition[8] aimed at young enthusiasts, inviting them to participate and present ideas aimed at finding and developing new solutions or services that support ICAO's five SOs.

These efforts to seek and develop innovative technologies and solutions are also reflected in ICAO's "2023-2025 Activities Plan[9]" This underscores the organization's ongoing commitment to promoting innovation and advancing aviation worldwide.

CONCLUSIONS

The industry is making significant efforts to pursue technological innovation and align with the United Nations' SDGs and ICAO's SOs. It's easy to appreciate the innovations implemented in recent years that have contributed to environmental goals while keeping a focus on other SOs, such as safety.

It's also true that this is an ongoing journey, and it's in this context that eVTOL aircraft designed for both passengers and cargo within the framework of UAM and AAM are gaining momentum, soon to become a reality, even though there is still much development and certification work ahead.

Indeed, as Eric Hoffer aptly said:

> "In times of change, those who are open to learning will own the future, while those who think they know it all will be well equipped for a world that no longer exists".

Finally, I would like to close with two phrases from Albert Einstein: "We cannot solve problems by thinking the same way as when we created them" and "The mind is like a parachute; it only works when it's open."

In summary, substantial contributions have been made, but there is still much to devise and do. The ceiling of innovation only lies in our imagination.

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