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Circular Economy: A Technological Innovation Strategy for Sustainability in Air Transport

Economía circular: una estrategia de innovación tecnológica para la sostenibilidad en el transporte aéreo

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ABSTRACT

This work aims to identify innovations, technological advances, and best practices to migrate towards a circular economy in air transport. The relevance of the research lies in the contribution to the generation of circular economy knowledge in the field of administration with application in the aeronautical industry. By analyzing literature and best practices, the circular economy could be a viable solution to reduce the use of natural resources in aircraft manufacturing and airport operations. Among the main findings are innovations and technological developments in new materials, fuels, building methods, and best practices implemented at airports to obtain energy and generate less waste. It has also been identified that applying circular economy principles in this mode of transport would contribute to sustainability efforts and increase the competitiveness of organizations in the sector.

Keywords: Innovation, Sustainability, Air transport, Circular Economy, Competitiveness.

JEL code: L93, M16, O320

RESUMEN

Este trabajo tiene como objetivo identificar innovaciones, avances tecnológicos y mejores prácticas para migrar hacia una economía circular en el transporte aéreo. La relevancia de la investigación radica en el aporte a la generación de conocimiento sobre economía circular en el campo de la administración con aplicación en la industria aeronáutica. Al analizar la literatura y las mejores prácticas, la economía circular podría ser una solución viable para reducir el uso de recursos naturales en la fabricación de aeronaves y las operaciones aeroportuarias. Entre los principales hallazgos se encuentran innovaciones y desarrollos tecnológicos en nuevos materiales, combustibles, métodos de construcción y mejores prácticas implementadas en los aeropuertos para obtener energía y generar menos residuos. También se ha identificado que aplicar principios de economía circular en este modo de transporte contribuiría a los esfuerzos de sostenibilidad y aumentaría la competitividad de las organizaciones del sector.

Palabras clave: Innovación, sustentabilidad, transporte aéreo, economía circular, competitividad.

Código JEL: L93, M16, O320

INTRODUCTION

In 2015, with the Millennium Development Goals, countries, firms, and non-governmental organizations joined efforts to reduce technological gaps and extreme poverty and ensure access to health, education, and gender equity by adopting the Sustainable Development Goals (SDGs). The SDGs guide implementing actions to improve people's quality of life worldwide while mitigating global warming. (UN, 2023; COP26, 2021a; Barbier & Burgess, 2019)

Although transport modes are not a specific SDG objective, they are integrated transversally. It impacts other objectives, particularly those related to food security (facilitating the transfer and distribution of food), health (bringing health services to marginalized areas through mobile units, as well as facilitating the mobility of people), energy, and infrastructure, to name a few. It is also considered an important aspect of achieving the SDGs as a quarter of the world's energy-related greenhouse gas emissions come from transportation, and these are expected to increase substantially in the coming years. (COP26, 2021a)

According to figures issued during COP26 in 2019, worldwide transportation is considered the fourth largest pollutant emission, especially greenhouse gases (GHG), after energy, industry, and agriculture. These figures represent 15% of GHG emissions, including CO2 emissions, which contribute 23% and are responsible for consuming about 40% of the energy worldwide. GHG emissions are generated by land transport and air transport (passenger and cargo).

Air transport is an important part of the world economy due to its strong inter-industrial links with upstream and downstream sectors of aircraft production despite representing a small percentage of the value added of the member countries of the Organization for Economic Cooperation and Development (OECD) (approximately 0.03%). (OECD, 2020; COP26, 2021ba)

In context, the aviation or aeronautical industry includes activities related to airport operations, maintenance, repair and operations services, aircraft manufacturing, rental and leasing services, and refined oil production (including the blending of biofuels), among others; therefore, it requires state-of-the-art technologies, constant innovation, and skilled labor to ensure the safety of users and service providers. (Celikel, Rötger & Casas, 2022)

Individually, each activity developed in the aeronautical industry produces waste and contributes to CO2 generation; 97% of pollutants are generated during flights, 2% in ground operations, and 1% in aircraft production. (Domone et al., 2021)

According to Buticchi, Wheeler and Boroyevich (2022) and Kobeh (2008) stakeholders such as leaders of the world's economies, airlines, aircraft manufacturers, airport operators, and international regulatory bodies have joined forces to reduce the impact that aviation has on the environment, resulting in initiatives and policies for the use of new technologies to produce aircraft that generate less noise, operate with less polluting fuels, use new materials, implement new practices at airports, and modify existing infrastructure.

However, this is not enough because although there is a commitment to reduce the adverse effects of aviation, the world is also facing some geopolitical problems, such as war or trade tensions, which have had an impact on the procurement of raw materials and critical components for the manufacture of engines and aircraft assembly (AviaciónDigital, 2022). Therefore, the proposal to migrate to a regeneration and reuse economy has been outlined as an alternative to meet the SDGs and market demands.

This paper has a descriptive scope, and its objective is to identify innovations, technological developments, and best practices to migrate towards a circular economy in air transportation. The technologies and actions implemented in this mode of transport are identified by reviewing secondary sources. This work is relevant because it contributes to the generation of knowledge in the field of management on the application of the circular economy in the aeronautical industry; according to the literature review, more than 65% of the identified documents belong to the engineering field.

This research is structured as follows: First, the theoretical framework is presented from the perspective of the circular economy and its relationship with competitiveness. Another section presents the literature review on circular economy in air transport, the technologies identified as viable to contribute to the change of the economic model, and the practices that some airports have implemented. Finally, some reflections and challenges are presented.

CIRCULAR ECONOMY AND COMPETITIVENESS

Since the beginning of the Industrial Revolution, a productive system has prevailed in which goods are generated from the exploitation and transformation of raw materials, which are sold, exploited, and subsequently discarded, generating an overexploitation of natural resources and an emission of waste and pollutants. Since the world conference on climate change held in Paris (2015) and Glasgow (2021), more than 70% of raw materials have been extracted than the Earth's capacity to renew them safely. Therefore, given the depletion of natural resources, implementing a new economic model and new production systems has become crucial (Popović et al., 2022).

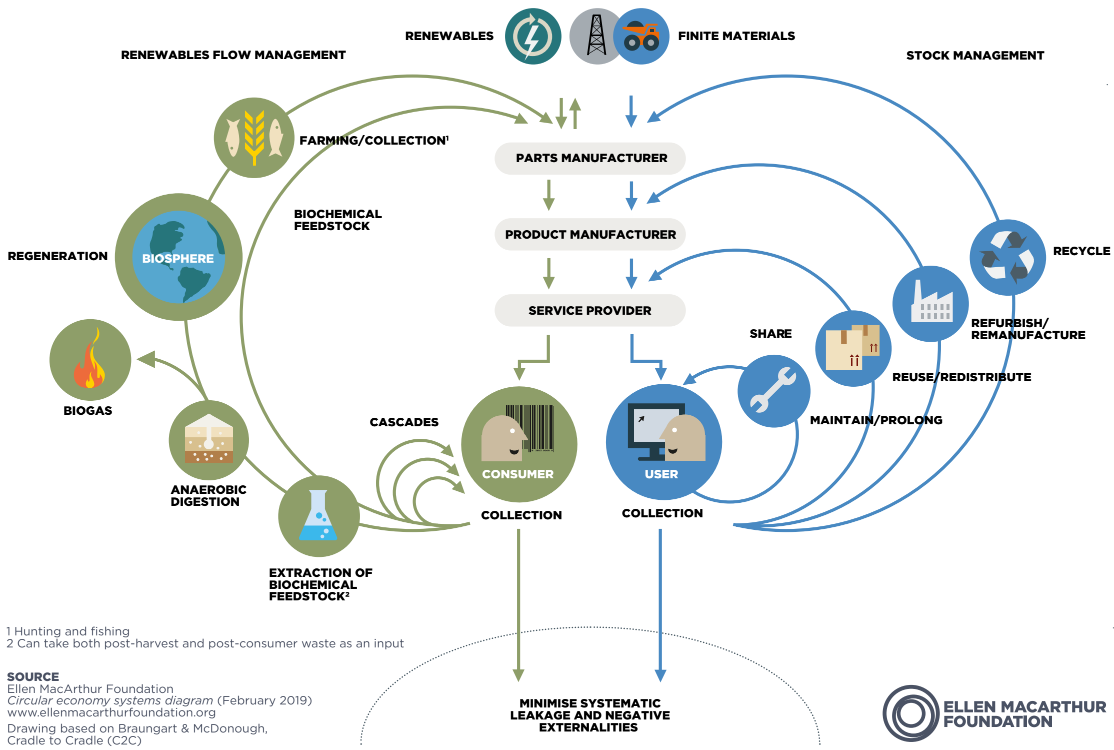
The circular economy (CE) originated with the idea of reducing the resources and inputs used in industrial production, proposing an alternative to the linear economy (extract - produce - dispose) production model that has been used to date (Hungaro et al., 2021). It was proposed to migrate towards a circular economy to minimize waste and pollution, using resources best and keeping products and materials in use for as long as possible, recovering and regenerating products and materials at the end of each useful life (MacArthur, 2013).

Although it was first used in the 1970s, the concept of CE has had a more extraordinary boom and relevance starting in the decade of the new millennium (2000), being associated with sustainable development (Korhonen et al., 2018). The circular economy is based on the following: the design of manufactured products with added value and maximum use in longer life cycles; the creation of versatile products with different uses in different periods of their useful life, seeking to ensure the reuse of the same good; the return of solid waste to the industrial sector in an orderly manner. The cost of secondary raw materials from recycling is competitive in the market, and a systemic approach to supply chain management evaluates the interconnections between the energy produced, the material extracted, and the natural environment (Hungaro et al., 2021; MacArthur, 2013).

According to MacArthur (2013), the circular economy is defined as "one that is restorative by design, and aims to keep products, components, and materials at their maximum utility and value, at all times" has three principles:

1. Waste equals food: redefining the purpose of goods at the end of their useful life by prolonging durability and minimizing impacts on ecological systems from manufacturing new products. Within a closed loop, proper maintenance, reuse, refurbishment, and recycling can extend the life cycle of products. (MacArthur, 2013)
2. Use renewable resources: By increasing renewable or waste-derived resources and energy, the circular economy model could create jobs and reduce environmental impact, including carbon emissions. (MacArthur, 2013)
3. Increasing resistance through material innovation takes care of raw material consumption and the reproduction of waste to reorient products from one manufacturing process to another. Therefore, designing a circular economy model requires combining various companies and stakeholders, which play different roles within a circular economy system. (MacArthur, 2013)

Figure 1
Diagram of the Ellen MacArthur Foundation's circular economy system



Source: Adapted from The Ellen MacArthur Foundation (2022).

Figure 1 shows a system based on the principles of the circular economy. It is known as a butterfly diagram, in which the continuous flow of materials is observed in two cycles: the technical and the biological. In the first cycle, products and materials are kept in circulation through reuse, repair, remanufacturing, and recycling strategies. In the second cycle, nutrients based on biodegradable materials are returned to the Earth System to regenerate nature (The Ellen MacArthur Foundation, 2022).

As an alternative model, circular economy principles offer operational and strategic advantages at the micro and macroeconomic levels, which, when driven by technological advances and developments, represent an excellent opportunity to influence economic development and growth systemically (Popović et al., 2022). These principles find application in different industries and sectors, including transportation, by reducing the use of "new" materials and reducing the generation of greenhouse gases in the transformation of the same; however, it requires the adoption of technology that gives new use to those parts and components whose useful life has ended, in addition to implementing the use of new materials that allow their transformation and reuse simply (Bleischwitz et al., 2017). Also, some strategies are considered to take advantage of using materials and mitigate the negative impact on society and the environment. (Potting et al., 2017)

As shown in Figure 2, the circular economy aims to reduce the use and extraction of natural resources through the application of the 9Rs: refuse, rethink (redesign), reduce, reuse, repair, renew, recycle, and recover, based on the idea that in nature everything has value and everything is used to produce value, where waste becomes a new resource (Korhonen et al., 2018). In this way, the product's life cycle is extended, waste is used, and, over time, a more efficient and sustainable production model is established. It maintains the balance between progress and sustainability. (REPSOL, 2022)

A higher level of circularity of materials in product chains means that, in principle, smaller quantities of natural resources will be needed to produce new (primary or virgin) materials. The avoided production of materials benefits the environment. In practice, however, increasing the circularity of one product chain may lead to lower circularity in another. (Korhonen, Honkasalo & Seppälä; 2018)

Figure 2. Circular economy strategies

	Strategies		
Circular economy	Smart production and use of manufacturing.	R0 Refuse	Create a product redundant.
		R1 Rethinking	Develop new uses for assets.
		R2 Reduce	Consume fewer and more efficient resources.
Increase circularity	Extend the life of parts and products	R3 Re-use	Reuse of products/components in operations.
		R4 Repair	Repair to maintain benefits.
		R5 Refabricating	Reintegrate and renew to maintain performance.
A higher level of circularity = lower natural resource requirements		R6 Remanufacturing	Operate components in a new product with the same function.
		R7 Readapt	Operate components in a new product with different function.
	Application and Material Utilities	R8 Recycle	Process materials ready for the new plant.
Linear economy		R9 Recover	Energy recovery through incineration.

Source: Own elaboration (Potting et al., 2017; Domone et al., 2021).

For the principles of a circular economy to be implemented, companies must have the necessary resources and capabilities to implement changes in their practices and products, from design to the selection of new materials that can be recycled and reused. In the first instance, this would mean a competitive advantage by reducing raw material costs. (Varaniute, Zickute & Vecerskiene, 2023)

Competitiveness is a company's capacity to create and implement competitive strategies and sustainably maintain or increase its market share. These capabilities are related to various factors, controlled or not by the companies, ranging from the technical training of personnel and managerial/administrative processes to public policies, the supply of infrastructure, and the peculiarities of demand and supply (Haguenauer et al., 1996). A company is said to have a competitive advantage when it applies a value-creation strategy that is not being applied simultaneously by any current or potential competitor (Barney, 1991, p. 102).

The circular economy is increasingly relevant to business strategies (Mishra et al., 2022), as it "opens up opportunities for companies to build competitive advantage, create new profit pools, develop resilience, and provide solutions to some of the most important problems facing businesses today" (De Angelis, 2021; Saari et al., 2022).

CIRCULAR ECONOMY IN AIR TRANSPORT

The literature review indicates that the relationship between circular economy and air transportation is an emerging topic of study. The search for information in the Scopus database, using the keywords "aviation AND circular economy" and "air transportation AND circular economy," resulted in a total of 53 articles, of which 66% belong to the engineering area of study, describing alternatives for new fuels, materials, novel designs, and best practices in the operation of aircraft and airports.

In this sense, the global value chain of the aerospace industry has the potential to be reshaped through the principles of the circular economy (ICAO, 2022), from the design of aircraft, their parts, and components to their end-of-life management and use. At its inception, the commercial aerospace industry naturally established a linear economy in which economic value is attached to products (aircraft, spare parts), with economic growth closely linked to the use of natural resources (Domone et al., 2021).

An aircraft is used during its useful life, comprising 30 years for passengers and 20 years for cargo aircraft. This operation is maintained through the purchase and changes of worn parts whose life reached its limit according to the flight hours of the aircraft (Celikel, Rötger & Casas, 2022). In the end, parts and components of the aircraft were discarded as waste. This approach was the premise that materials were cheap and labor was expensive, so the value of reuse or recycling could have been higher.

On the side of mitigating the airline industry's environmental impact, this has been focused on waste management. However, increased attention to environmental sustainability and increased legislative and social pressure on aerospace organizations have led to changes in the supply chain. Aircraft that had reached their end of life were stored at airports or in dedicated storage facilities such as the world's largest aircraft graveyard: the Aerospace Maintenance and Regeneration Group (AMARG), which is located at Davis-Monthan Air Force Base in Tucson, Arizona.

Based on the circular economy strategy, some initiatives for aircraft recycling have been developed and implemented, such as the PAMELA project promoted by Airbus. However, these are still considered incipient because there is no international regulation for aircraft end-of-life management (Dolganova et al., 2022).

In addition, the linear economy model used for aircraft production consumes large amounts of energy and is highly dependent on material resources such as titanium, steel, aluminum, aluminum alloys, and composites (often including polymers and carbon fiber) (Dolganova et al., 2022), which casts doubt on the environmental impact of air transport in 2035.

The transition from a linear to a circular economy is a proposal to optimize polluting emissions or waste related to the production and maintenance of aircraft. By recycling and reusing products instead of discarding them after use, the circular economy preserves the value of products and materials better than the current linear economy. The circular economy also helps reduce or eliminate production-related greenhouse gas emissions by minimizing the demand for materials, energy, and waste generation. These principles can be applied mainly in two areas of air transport: 1. aircraft manufacturing and 2. airport management.

AERONAUTICAL INNOVATIONS AND THE CIRCULAR ECONOMY

According to the Oslo Manual (OECD, 2018), an innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and has been made available to potential users (product) or put into use by the unit (process). However, it focuses on innovating products and improving business models and services by improving processes to make people's lives easier.

It can also be understood as the art of transforming ideas and knowledge into new products, processes, or services that are significantly better than the existing ones and, above all so that they are valued or recognized by the market. It is a determining source of competitive advantages.

Four types of innovation are identified according to the final result: 1. product, 2. process, 3. marketing, and 4. organizational (OECD, 2018). The importance of innovation within organizations lies in the fact that it not only allows them to obtain or maintain a competitive advantage through the improvement or diversification of the processes or products offered but also to deal promptly with changes and threats arising in their environment (Teece, Pisano & Shuen, 1997; Teece, 2007).

From the perspective of evolutionary economics, there is a close relationship between innovation and development. Given the decline of a linear production system, where resources are increasingly scarce, incorporating innovation activities to migrate to a circular economy is a viable alternative for companies to remain in force. This new model seeks to produce efficiently, consider the environment, and reduce waste as much as possible through reuse, where waste is no longer waste and a resource, through changes in the production and supply chain (Imbernó & Souto, 2023).

In the case of air transport, there are two significant niches of opportunity for implementing the circular economy. The first refers to the aircraft production process, which includes design and research activities, production of parts and components, sub-assembly, final assembly, and after-sales activities (such as maintenance, repair, and operations services). The second area where the circular economy could be applied is in the operation of airports.

RESEARCH METHOD

The research is descriptive. First, a literature review was conducted in the Scopus database using the keywords "circular economy" and "aerospace industry." Fourteen results were obtained, which indicates that this topic needs to be studied more. However, it has been an emerging topic of study since the first papers were published in 2016.

Among the topics analyzed are new, lighter, and less polluting materials and the adoption of renewable energies such as ethanol. Emphasis is placed on the design of parts, components, and aircraft as a starting point for implementing the principles of a circular economy.

Due to the lack of publications, secondary sources of information, such as reports from non-governmental organizations and specialized agencies, were used. Two areas, aircraft, component production, and airport operation, were identified for applying the circular economy in the aerospace industry.

The aerospace industry has implemented design initiatives for circularity, emphasizing recycling, disassembly, improvement, and reuse. It has been observed that the components and materials used by the industry can be reused by other sectors (such as furniture). The feasibility of these design processes in complex products, such as aircraft, requires attention to design for disassembly in the early stages of new product development (Rodrígues et al., 2022).

Production of aircraft and their components

As mentioned, the central axis in a circular economy model is to maintain the value of inputs and materials as long as possible through recycling and reuse, thus reducing the demand for natural resources. As shown in Figure 2, to obtain a final good, in this case, an aircraft, it is first necessary to obtain the raw material to transform into the parts and components needed for the final assembly.

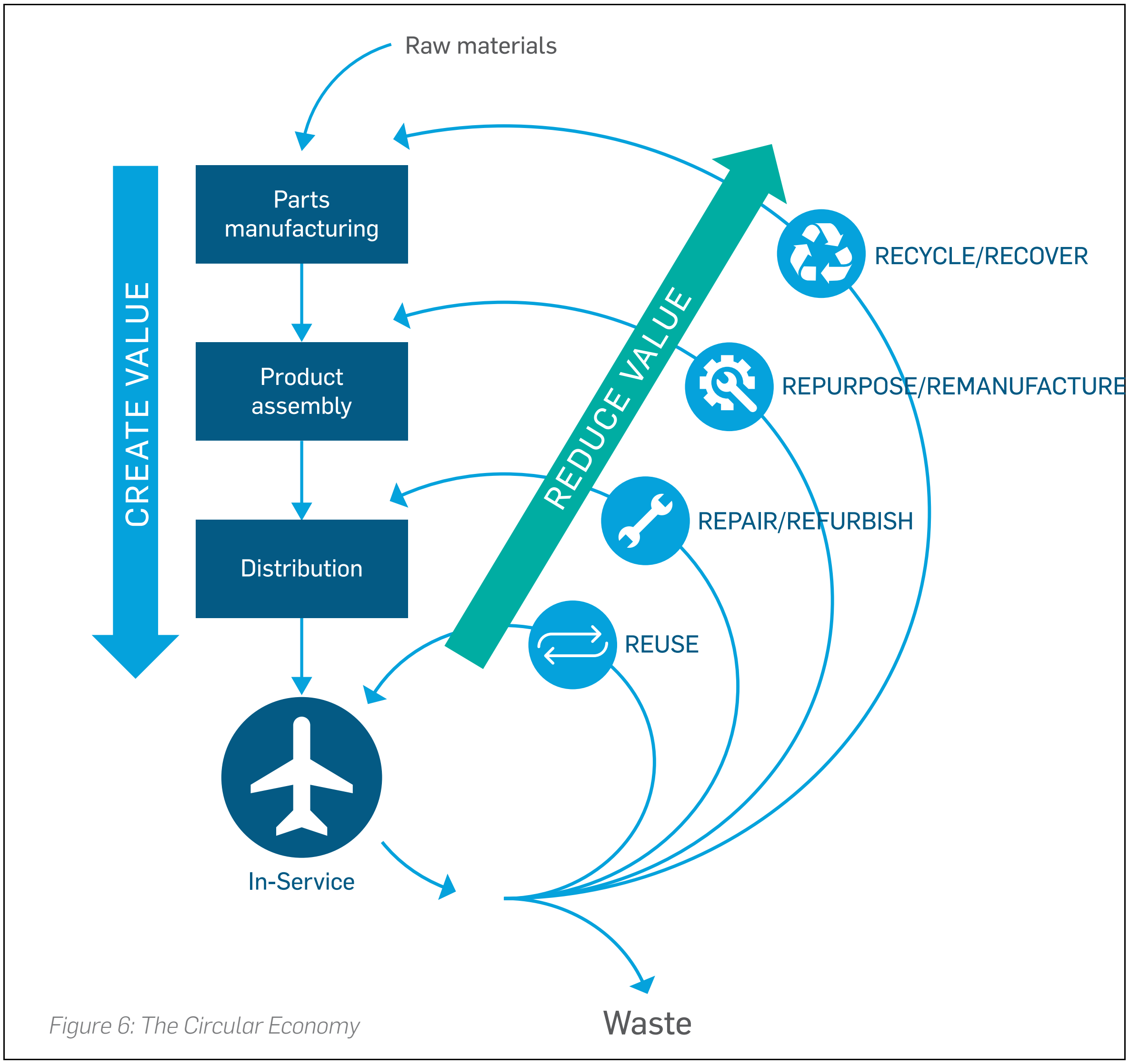
Maintenance and repair actions are necessary when an aircraft completes its life cycle (measured in flight hours) (Celikel, Rötger & Casas, 2022). In this process, parts and components are changed and discarded in the linear economy model, increasing the number of pollutants.

Under the circular economy model, parts and components are proposed to be recycled, repaired, and reused to avoid excessive waste generation. It also means profits for companies by reducing the costs of obtaining and transforming raw materials.

Figure 3 represents the production system of an aircraft, which starts with the extraction of raw materials necessary for the manufacture of parts and components. After being assembled, the aircraft is distributed and receives preventive and corrective maintenance during its useful life, which ranges between 25 and 30 years (Celikel, Rötger & Casas, 2022).

After this, the aircraft are scrapped and sent to aircraft graveyards. From the CE approach, from the design of the aircraft, the materials, and components used should be allowed to be repaired, reused, or remanufactured, either used in the same industry or in other sectors. Thus, it is intended to reduce the waste of aircraft and their components and use fewer natural resources. On the other hand, it is proposed that the lower the consumption of raw materials, the lower the costs for companies, the more competitive they will be. (Varaniute, Zickute & Vecerskiene; 2023)

Figure 3
Circular economy in the production of aircraft and aircraft components



Source: Domone et al. (2021).

However, in an industry highly dependent on technology and with high-quality standards, it is not easy to think that the migration towards a circular economy can occur without generating innovations and technological developments (Dwivedi, 2023). In this sense, some technologies that can contribute to the change in the production system were identified (see Table 1).

Table 1
Technological alternatives for a circular economy in air transport

Technology	Description	Application of the circular economy model in air transport
Additive manufacturing	They are state-of-the-art manufacturing processes, known as 3D printing, and have become popular as Rapid Prototyping tools. Currently, AM is classified as part of the Digital Manufacturing processes that have taken off with the so-called industrial revolution 4.0 and is one of the critical technologies. ASTM (American Society for Testing and Materials) proposed seven families that allow the identification of the technical principle under which each process works. These seven families are photopolymerization, powder bed fusion, binder injection, material injection, lamination, material extrusion, direct energy disposal, and hybrid.	Additive-manufactured metal parts are used in the aerospace industry for functional parts such as turbine blades, fuel injection systems, and blades. Optimizing parts can improve functionality and reduce weight. Lighter parts help reduce aircraft weight and, consequently, fuel consumption.
Digital twins	The virtual "Digital twins" model accurately reflects a physical object, process, or system. It is used to simulate and study the behavior of digital products precisely to adapt solutions to actual products efficiently.	Tests on engines and turbines. They can also be placed on operating aircraft to gather information to improve critical parts and components.
Artificial intelligence	AI is distinguished as a disruptive point of the "fourth industrial revolution"; it includes models, systems, and functions generally associated with human intelligence. Due to exponential data, AI can complement people's practices and expand their capabilities. Likewise, it allows human beings to learn faster from feedback, provides information to understand complex phenomena, and obtain benefits with less environmental and social impact.	We are designing circular products, components, and materials. AI can improve and accelerate the development of new products, components, and materials suitable for a circular economy through iterative machine learning (ML)-assisted design processes that enable rapid prototyping and testing. We are operating circular business models. AI can amplify the competitive strength of circular economy business models by combining real-time and historical data on products and users. Optimize circular infrastructure. AI can help build and improve the reverse logistics infrastructure needed to "close the loop" with products and materials by improving product sorting and disassembly, component remanufacturing, and material recycling processes.
Internet of things	Connected objects are capable of storing and connecting a huge amount of data that will later, thanks to increasingly complex software programs, be analyzed to return useful information.	Participation in the creation of smart cities, in the use of airports.

Source: Own elaboration (CIDESI, 2022; Domone et al., 2021; McKinsey Sustainability, 2019).

Developing fiber-reinforced polymers was also identified as a crucial enabler of lightweight, high-performance structures to increase efficiency in aviation (Bachmann et al., 2021). The way the industry designs and recycles aircraft is being rethought to avoid downcycling and reduce dependence on the import of precious materials such as aluminum (Webb, 2023), as well as the extraction of materials defined as critical by the European Union, among which are lithium and cobalt, and which are indispensable for the disposal of internal combustion engines. Therefore, one solution to ensure access to these materials is to apply the principles of circular economy to recover them at the end of their useful life to guarantee the supply and reduce their environmental impact (Joensuu, 2023).

GROUND OPERATIONS, THE AIRPORTS

As mentioned, several proposals exist to implement circular economy principles in the design and construction of aircraft; however, 2% of the pollution generated by air transport originates in ground operations, i.e., airports. Against this backdrop, industry specialists have issued statements stating that "Aircraft are becoming more and more modern, and an airport owes its existence to its aircraft. Accordingly, the circular economy will take on a preponderant level within a few years in air terminals" (Pereira, 2022).

Airports generate wastewater, the treatment of which can generate methane, one of the leading greenhouse gases. In addition, air conditioning and lighting systems are used in the facilities, and waste is produced in restaurants and stores. In addition, the infrastructure is used for aviation. That is, "everything related to aircraft and runway maintenance, from accidental fuel spills to the use of oils or antifreeze or the pollution produced by the vehicles used" (Pereira, 2022).

Therefore, it is of utmost importance to implement actions to reduce airports' impact on the environment and the people living near them (Modarress, 2020). Table 2 shows some actions implemented in international airports that operate under the circular economy model.

Table 2

Actions to migrate towards a circular economy at airports

Airport	Implemented actions
Heathrow Airport, London	London's Heathrow Airport implemented actions to redeploy facilities and equipment and to dismantle them during modernization work. It has also designed the new terminal, which is part of the expansion program, as a covered space in which structures and buildings can be reorganized over time to respond to commercial, safety, and security changes. By using a standardized kit of parts for building construction that can be disassembled and reused multiple times in different configurations, the terminal can avoid the traditional demolitions associated with refurbishments.

Gatwick Airport, London	It invests in waste-to-energy, converting food scraps from flights and other types of organic waste into biomass fuel to provide heating for the North Terminal.
Indianapolis International Airport, United States	They are leaning towards using low-carbon pavements and are challenging the traditional methods and materials used in their runways and taxiways.
Amsterdam Schiphol Airport	They have improved their operational resource and waste management performance in response to circular economy thinking.
Vancouver International Airport	
Portland International Airport	
Queenstown Airport	

Source: Own elaboration (Danson, 2023).

Other initiatives for airports to operate in a circular economy model include energy efficiency and greater control of aircraft take-off and landing, which will reduce emissions produced while the aircraft is on the ground.

CONCLUSIONS

Although the idea of using a production system based on the principles of circular economy has presented a more significant interest by governments, industry, and academia, being seen as an alternative to achieve environmental sustainability, little has been published on its relationship with air transportation, so the objective of this work was to identify innovations, technological developments and best practices to migrate towards a circular economy in air transportation and allow stakeholders to remain competitive in an industry that operates under the global value chain scheme.

For the aviation sector, the circular economy is an emerging concept. Although its application has yet to be widespread, using circular economy strategies can offer valuable learning opportunities for the future. Aviation is a sector expecting substantial growth, with annual global air traffic expected to double by 2035 (ICAO, 2022), with an average annual growth rate of 4.4%. According to Boeing and Airbus, the projection of new aircraft delivered by 2034 would be 38,050 and 32,585, respectively. (Boeing, 2019; Airbus, 2018)

All estimates indicate a potential increase in global aviation resource consumption, waste, and emissions generation (Celikel, Rötger & Casas, 2022). Transitioning from the linear economy to the circular economy could help reduce adverse environmental impacts and associated economic costs.

The analysis highlights the need to develop and use alternative fuels, and it is also identified that circular economy practices depend on product designs. Migrating towards a circular economy is a complex task since different stakeholders with particular functions participate in aviation, including aircraft designers and assemblers, who must emphasize using parts and components that can be reused, which would imply a significant change in its supply chain. (Hartley, Baldassarre & Kirchherr, 2023)

The primary users of aircraft are the airlines, which must implement improvements in energy consumption and waste management. As for airports, an important part is energy use and waste management, the administration of arrivals and departures, and the appropriate infrastructure that allows water to be reused, or better yet, ventilation systems without contaminating.

Due to those mentioned earlier, it is proposed that managers within organizations prepare for these changes. Adopting or developing new technologies and implementing novel practices can support this transition by promoting the continuous reuse of materials to minimize waste and the demand for additional natural resource consumption.

In general, transitions towards sustainability usually involve social, organizational, and regulatory changes and changes in consumer habits, among other things. However, these transitions usually come with technological innovations and developments. In the case of aviation, technologies such as additive manufacturing, the use of digital twins, the Internet of Things, and artificial intelligence are considered mechanisms that contribute to this transition.

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