Circular Economy in Airports ACI-LAC

Whitepaper

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Circular economy in airports ACI-LAC

White paper

Authors
Emma Paola Flores Herrera
Sergio Parra
Vivekanandhan Sindhamani
Eoghan Davis
Francesco Longo
Helena Rodriguez

Contributors
Fede Depetris
Francisco Medela
Fredy Alejandro Sanabria Amortegui
Ivan Vidal
Jorge Rosillo
Julissa Salavarria
Melina Santos
Tania Chacín
Vincent Grandjean

Collaborators
Adriana Bejarano
Alessandra Reis
Antonio Baeza
Fernando Graña
Fued Abrão Junior
Ivan Vidal
Jorge Jean Francois
Jorge Navarro
Jorge Rosillo
Keisha Mohan
Laura Becerra
Miguel Marquez
Mónica Chévez

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1 Introduction

Airports, as critical hubs of global transportation and commerce, face a unique set of challenges in today's era of heightened environmental awareness amongst the public. Circular strategies can help airports to reduce their carbon footprint, lower operating costs, and enhance their resilience in the face of resource constraints and climate change. Implementing circular strategies supports resilient economic models by decoupling economic growth from material consumption (Kennedy & Linnenluecke, 2022).

Aviation is expected to grow by 2.9% year on year between 2019 and 2050 (ICCT, 2022), and therefore, more resources will be required by airports to maintain their operations. However, resources are limited. Airports can benefit from adapting circular economic models by reducing their environmental impact, creating opportunities for new business models, and decoupling their economic growth to the availability and need for natural resources (ICAO, 2019).

With their substantial operational scale, airports have the capacity to institute comprehensive circular economy principles (waste prevention strategies, the implementation of robust waste reuse initiatives, and the establishment of efficient recycling programs) that can serve as championing models for other local businesses and organizations. Given their prominent position and influence, by setting a high standard for circular practices, airports can inspire and influence other entities to adopt similar approaches, thus fostering a more environmentally conscious and responsible community, that can reverberate throughout their local and regional spheres (Tjahjono, Ünal, & Tran, 2023).

At present, society has functioned largely on what is referred to as "linear economy", where we extract many flora & fauna resources, minerals and metal resources, use them and ultimately send them to landfill. This is what can be simply put as the "take-make-dispose" model (Karataş Yücel & Ozkan, 2020). This cycle is dependent on an end-of-life for these resources that often see them disposed of into the environment via a landfills or public waterways; where these account for 85-90% of where waste ends up in Latin America & the Caribbean (Savino, 2019). Circular economy on the other hand seeks to rectify this cycle, through having closed loop cycle where the dumping of waste materials and water into the environment is avoided, and the real value of these resources are reintroduced into the supply chain. Circular economy is defined as an economic system that prioritizes the optimisation of material use and minimisation of waste. This is done by reducing and if possible, eliminating, resource extraction and therefore waste generation.

As part of the development of the present white paper, a survey was developed across airports in Latin America and the Caribbean. From 21 surveyed airports, 16 airports have developed or are developing circular economy projects. The same survey has indicated that the biggest challenge airports are facing when it comes to implementing circular approaches in their airport related to lack of knowledge. This white paper aims to provide a comprehensive overview of how airports can strategically transition to more circular approaches, driving innovation and fostering collaboration to herald a new era in airport resource management. Relevant topics to be covered in this white paper include the transition from a traditional linear economic model to a circular one in airport construction, processes and operations, focusing on perpetual resource cycling. It provides a framework for 1) defining the scope of circular systems, 2) mapping resource flows, 3) identifying and prioritising improvement areas, and 4) detailing the implementation of actions and initiatives to realize a resource-efficient airport environment. Further, whereas circular economy encompasses energy, water and material flows this white paper will not focus on energy flows, due to the extensive coverage of energy and decarbonization guidelines, recommendations, and good practices in other documents. As such, energy topics fall outside the scope of this paper.

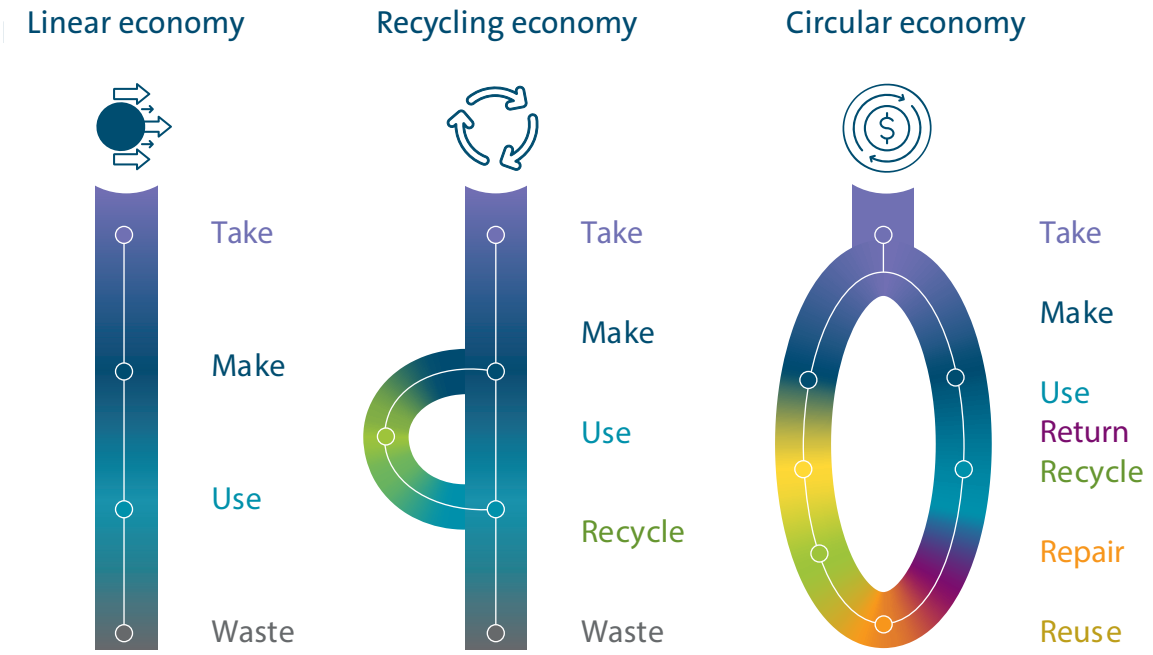

Fig.1 Linear, recycling and circular economy. Adapted from (Schaffner, 2020)

2 Implementing circular economy

In advancing towards a circular economy within airport operations, it is paramount to transition from a traditional linear economic model to one that allows for the perpetual cycling of resources at their highest utility and value. Through the 4-step process shown in Figure 2, we guide airports to evolve towards the circular economy principles.

The definition of each step of this 4-step process is summarized below:

1. **Definition of scope**, it is outlined the potential boundaries of an airport system, identifying which airport processes may undergo a transformation from linear resource use to circular resource flow.

2. **Mapping airport ecosystem's resource flows**, iit is delved into exemplifying tracking of resource inflows and outflows within the airport's ecosystem, including water and materials flows. This comprehensive mapping is a prerequisite for understanding the current state of resource utilization across various airport processes.

3. **Identification of circular initiatives**, it is identified specific areas where circular initiatives can be implemented effectively. There are some examples showcasing successful interventions in airports with focus in Latin America and the Caribbean. These examples serve as empirical evidence of the benefits and applicability of the circular economy in the airports sector.

4. **Implementation of circular initiatives**, it is spotlighted the potential opportunities for enhancing circularity and integrates case studies.

2.1 Step 1- Definition of scope and commitment

Within the broader context of implementing a circular economy at airports, it is essential to establish a clear demarcation of the airport system boundaries that delimit the flows that will be revised and improved according to circular economy principles.

Table 1 provides an overview of potential considerations, showcasing airports processes categorised in construction and operation, spanning across landside, terminal airside, and airport city areas. The table further presents detailed airport subprocesses corresponding to construction and operation processes within the distinct areas and indicates potentially involved stakeholders. Due to the diverse business model of airports, resource management within the airport is not fully centralized. For instance, the retail and F&B within the airport terminal are run by concessionaires who make independent procurement decisions. This is also applicable to the numerous offices and hotels on airport city premises. Airlines and ground handlers abide by own regulations (i.e., mandatory incineration of aircraft waste). All these activities contribute to a material footprint that is not directly controlled by the airport. When defining the scope it is therefore relevant to consider the degree of control that an airport has over the presented processes. The table correspondingly whether the airport has full control over a process, has guidance over a process (through guidelines and contractual conditions) or whether it has only influence (through communication or incentives). This organizational schema breaks down the complexity of airport into manageable segments.

Once the scope of the system is defined and before continuing to the next steps, it is crucial to get the commitment of the highest level of the airport operator management (i.e. CEO, director) in order to ensure continuity to the strategy.management (i.e. CEO, director).

Area	Airport Process		Involved stakeholders	Airport's degree of control [1]
	Design & construction	Operation		
Landside	Offices	- Fixed-based operations - Maintenance, repair, and overhaul operations - Ground handling operations - Air traffic control operations - Airline operations - Security operations - Catering - Cleaning	- Operations management - Operations employees	Control
	Storage areas and others			
	Intermodal Passenger transport facilities (incl. offices)		- Operations management - Operations employees - Passengers	Guide
	Roads			
Terminal	Offices	-Airport operation and administration (inc. governmental offices)	-Administration management -Administration employees	Control
		-Passenger services (airline counters, F&B, retail and lounges) administration	-Airline management -Airline employees -F&B, retail, lounges management -F&B, retail, lounges employees	Control/ Influence
	General areas	-Transfer and waiting	-Passengers	Influence
	Airline counters (incl. offices)	-Passenger services	-Airline management -Airline employees	Control/ Influence
			-Passengers	-Influence
	Baggage handling	-Baggage handling	-Airline/FBO/GHO management -Airline/FBO/GHO employees	-Control /Influence
	Security checkpoints	-Security processes	-Security operations management -Security operations employees	-Control /Influence
			- Passengers	-Influence
	Customs and migration	-Customs and migrations processes	-Customs and migration employees	Influence
			-Passengers	Influence
	F&B, retail, lounges	-Passenger services	- F&B, retail, lounges management - F&B, retail, lounges employees	Control
			-Passengers	Influence
Airside	Aprons	- Fix-based operations - Ground handling operations - Air traffic control operations - Airline operations - Security operations	- Operations management - Operations employees	Control/guide
	Taxiways			
	Runways			
	Hangars			
	Fuel Supply/plants	-Fuel production, storage and supply	-Operations airlines, and/or others employees	Control/Guide

Tab.1 Potential scope of an airport ecosystem

[1] The level of control- influence may vary for certain stakeholder depending on the business, contractual relations with the airport operators along with regulatory framework around the stakeholder's operations.

2.2 Step 2- Mapping airport ecosystem's flows

Once the airport ecosystem scope is defined, the next step involves a detailed mapping and quantification of the resources within the defined scope. This includes an assessment of flows that may go through the construction and operational processes within an airport. Categories of resource flows that can be mapped include construction and furnishing materials, water, consumer products, ICT products, cleaning materials, ground-support equipment and other operational equipment and materials. Each of these categories need to be further broken down into specific resources that flow into the airport ecosystem and that flow out, in the case of a linear system, as waste. In the case the airport already has some circular flows, the resource would then flow back into the airport ecosystem. An example of a resource mapping exercise in form of a Sankey diagram is show in Figure 3. A Sankey diagram is a type of visualisation that can be used to provide a comprehensive visualization approach to not only mapping but also quantifying resource flows in an airport ecosystem. In the case of this example, construction materials and water flow within construction processes while water, consumer products and materials, ICT products, equipment, and de-icing materials flow through operational processes. It is important to note, that in Sankey diagram shown in the figure below, no correlation is shown between the thickness of the lines and the quantities flowing in each stream, nevertheless when used in a real scenario, the lines thickness should indicate the quantification of the flows.

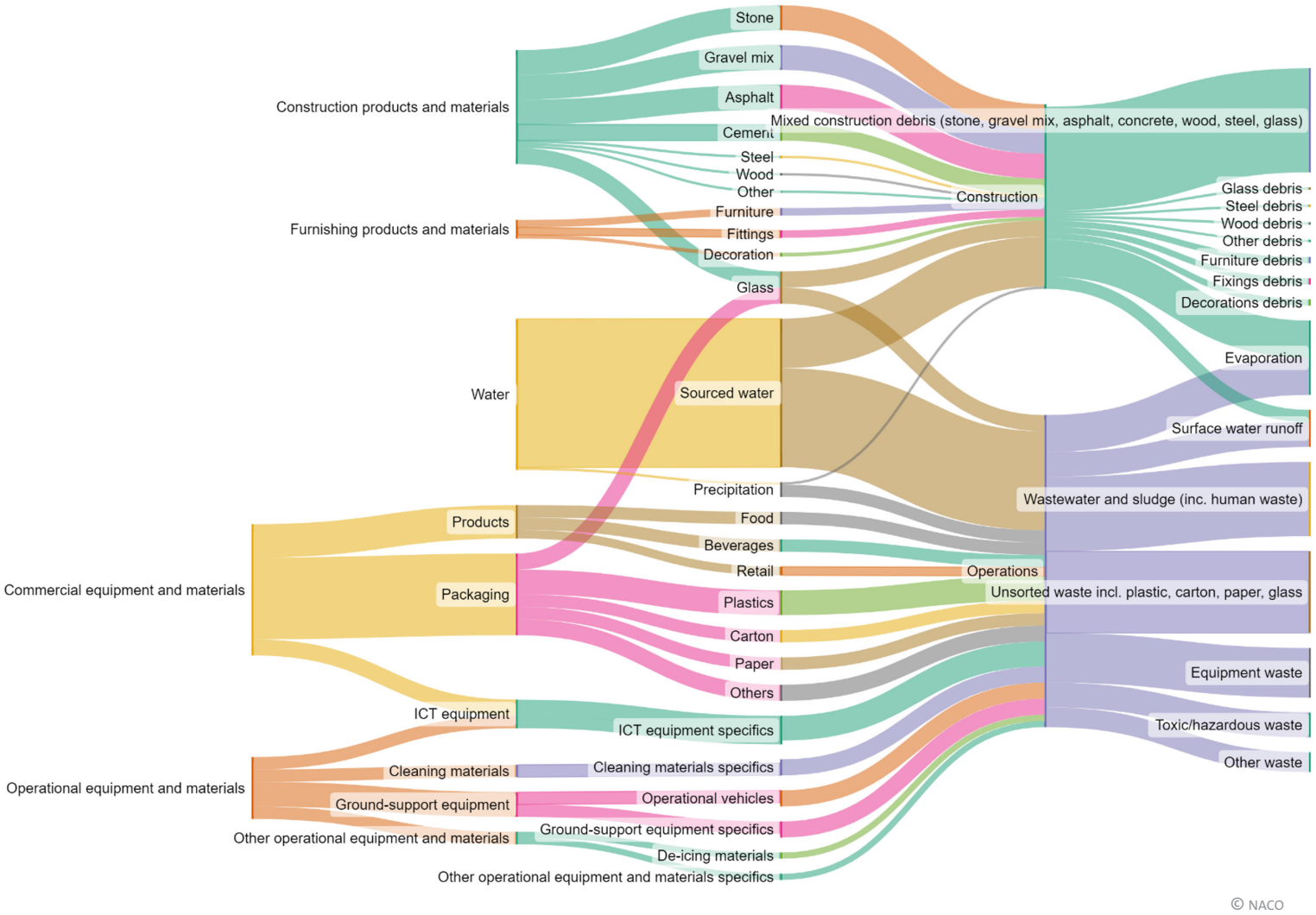

Fig.3 Example of a Sankey diagram showing resource flows within an airport ecosystem

2.3 Step 3- Identification of circular initiatives

Building on the information gathered in the previous steps, airports can then identify specific areas where circular initiatives can be implemented effectively (see Figure 4).

This step involves a careful analysis of resource flows (Sankey diagram) to pinpoint inefficiencies and opportunities for circular approaches. When addressing which improvements and initiatives to focus on as an airport, it is critical to address first those initiatives that have the highest sustainability impact, being mindful of the ease-of-implementation regarding availability of airport resources. The R-Hierarchy or R-Ladder is a useful tool for understanding hierarchy around determined (semi-)circular pathways that the airport can follow to maximise its impact. The R-ladder can be presented in a five-steps version (as presented in the ICAO Waste Management Toolkit and the ACI's Policy Handbook) or in a 10-steps version.

Table 2 presents an overview of the 10 steps and details their relation to the summarized version of the ladder. The steps are presented from top-to-bottom in hierarchical order.

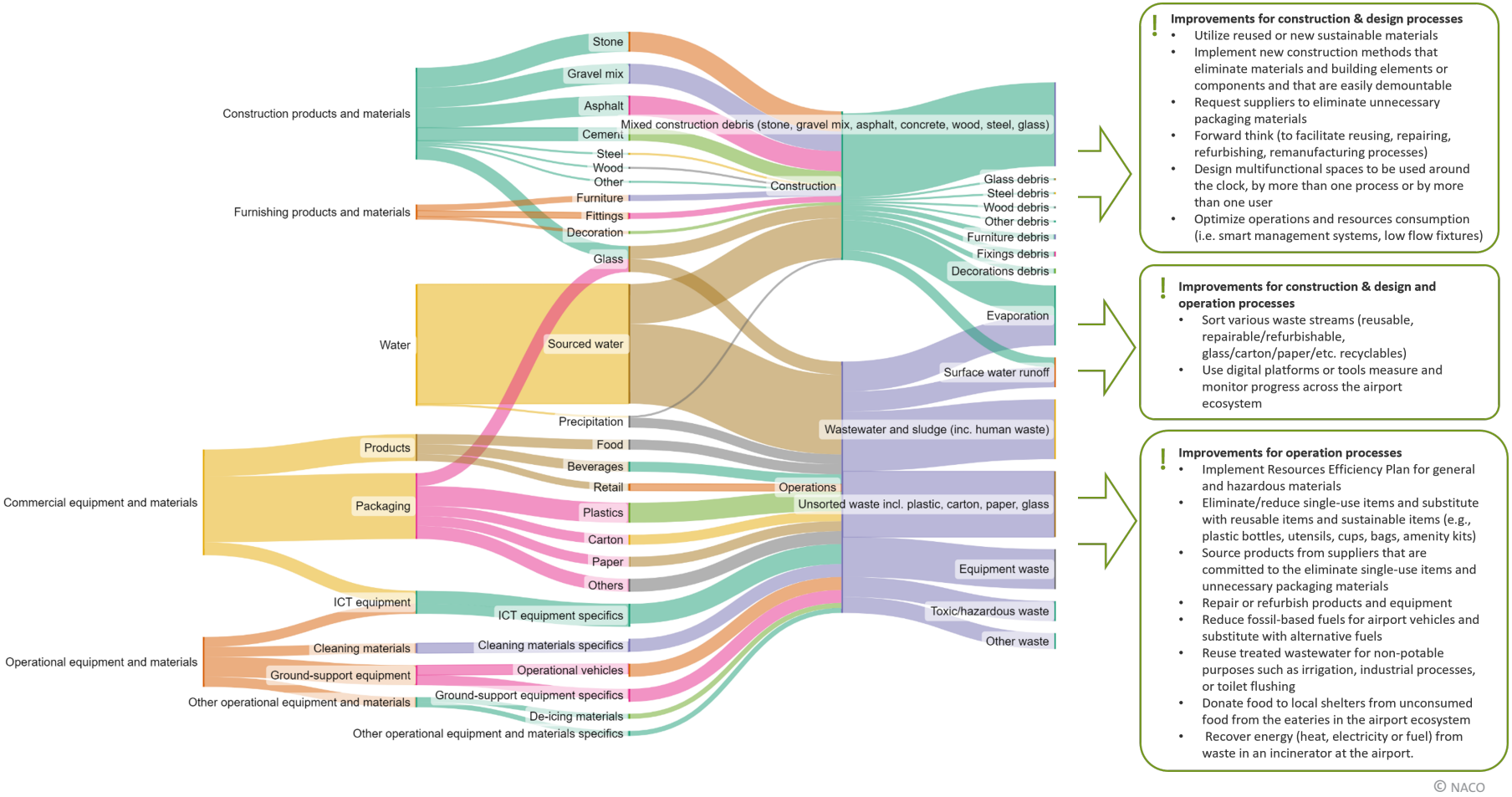

Fig.4 Example of identification of improvements- explained in detail in the next pages

An overview of potential initiatives that airports can implement according to the circular economy ladder hierarchy as presented in Table 2 (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and/or recover) along with practical implementation cases relevant to the region of Latin America and the Caribbean is presented in this section.

ICAO	10R's	Description	
Prevention	Refuse	Efficient use of products and manufacturing operations	Make product redundant by eliminating its function, or by offering the same function with completely different product
Reduction	Rethink		Make product use more effective (i.e., sharing product, so it has higher utilization rate)
	Reduce		Increase efficiency in product manufacture or decrease use by consuming fewer natural resources and materials
Reuse	Reuse	Extension of product lifecycle to several lifecycles	Reuse by another consumer of discarded product which is still in good condition and fulfills its original function
	Repair		Maintenance and repair of defective product so it can be used for its original function
	Refurbish		Restore old product and bring back up-to-date
	Remanufacture		Use parts of discarded product or its parts in a new product with the same function
	Repurpose		Use discarded product or its parts in a new product with a different function
Recycling	Recycle	Maximization of material usefulness	Process materials to obtain the same (high-grade) or lower (low-grade) quality
Recover	Recover		Incineration of material to recover its embodied energy
Disposal	Disposal		Material is sent to landfill (Not part of the 5Rs nor the 10Rs)

Tab.2 Circular economy ladder

Initiatives - Design & construction processes	Initiatives - Operational processes
▪ Utilize reused or new sustainable materials in the construction processes that eliminate unsustainable ones ▪ Implement new construction methods that eliminate materials and building elements or components ▪ Request suppliers to eliminate unnecessary packaging materials **Forward think (to facilitate reusing, repairing, refurbishing, remanufacturing processes):** ▪ Design and construction buildings that have a long lifespan (eliminating future replacements) ▪ Design and construction modular buildings that are easily demounted (eliminating need for the building elements and components that these replace) ▪ Avoid construction methods that glue or which involve chemical restructuring of the materials used	Eliminate single-use items and substitute with reusable items (e.g., plastic bottles, utensils, cups, bags, amenity kits) ▪ Substitute styrofoam, polypropylene plastic materials for sustainable materials ▪ Source products from suppliers that are committed to the eliminate single-use items and unnecessary packaging materials ▪ Eliminate fossil-based fuels for airport vehicles and substitute with alternative fuels ▪ Collaborate with airlines and ground-handlers to eliminate fossil-based fuels and substitute with alternative fuels

Case studies
Case study- Single-use plastic ban Chhatrapati Shivaji Maharaj International Airport in Mumbai, India conceptualized in 2018 and implemented in 2019, a single-use plastic ban. This ban was applied across the airport's operations, including retail, F&B, and partner airlines reaching an estimated 100% reduction of single use plastic. This target is reached through identifying alternative, practical alternatives. For example, disposable cutlery is substituted by bio-based materials made like, among others, from starch. Where possible re-usable options were chosen. (Airports Council International Asia-Pacific, 2023). **Case study- Refusal of new construction materials** Preventing the use of new materials during the construction phase was one of the corner stones of the design of Aeropuerto Ecológico Galapagos in Galápagos, Ecuador. Awarded with a LEED Gold certification, the 6000 m2 airport terminal was constructed with an estimated 80% of re-used materials from the previous terminal building. Where the use of reclaimed materials was not possible, alternative options were found, starting from locally sourced materials or, finally, from certified ecologically manufactured materials (Aeropuerto Ecológico de Galápagos, 2021), (Egere-Cooper, 2015).

Refuse

The first course of action for reducing waste production is eliminating the need the production of resources and goods at source. Through the mitigation of resource extraction, manufacturing processing, transport and distribution, excess resources and goods can be minimized. Refusal of waste involves a shift in mindset towards avoiding the use of unnecessary/non-recyclable materials, products or packaging to reduce the generation of waste.

Initiatives - Design & construction processes	Initiatives - Operational processes
Design multifunctional spaces to be used around the clock, by more than one process or by more than one user (i.e flexible piers for large and small aircrafts)	▪ Share spaces for recycling, compacting, composting, and storage facilities to intensify use of the facility ▪ Use multifunctional spaces to be used around the clock (i.e. working spaces and canteen) ▪ Optimize operations and resources consumption (i.e. smart management systems, low flow fixtures)

Case studies
Case study- Circular lightning partnership Transitioning from a linear economy to a circular economy requires rethinking standard business practices, this is what Schiphol Airport Group in the Netherlands achieved by partnering with technology company Philips. The partnership was aimed at developing a partnership for circular lighting solutions on airports. By rethinking the regular system of purchasing-using-disposing of lighting fixtures, Philips withheld the ownership of lamps and fittings, giving them access to the possibility of replacing, refurbishing, maintaining separate components otherwise not serviceable directly by Schiphol Group or external suppliers. Once the end of service was reached, Philips took the responsibility of properly recycling each element. The solution reduces 50% of energy consumption with energy-efficient LED lightning and extends 75% of the service life of the fittings, reduces maintenance costs and raw material consumption (ICAO, 2019), (Royal Schiphol Group, 2024).

Rethink

Rethink involves the shift in mindset toward maximizing the usage of a given product or material.

Initiatives - Design & construction processes	Initiatives - Operational processes
▪ -Utilize reused or new sustainable materials in the construction processes that reduce unsustainable ones ▪ Implement new construction methods that reduce materials and building elements or components ▪ Request suppliers to reduce unnecessary packaging materials **Forward think (to facilitate reusing, repairing, refurbishing, remanufacturing processes for future construction processes):** ▪ Design and construction buildings that have a long lifespan (eliminating future replacements) ▪ Design and construction modular buildings that are easily demounted (eliminating need for the building elements and components that these replace) ▪ Avoid construction methods that glue or which involve chemical restructuring of the materials used	Reduce single-use items and substitute with reusable items (e.g., plastic bottles, utensils, cups, bags, amenity kits) ▪ Substitute styrofoam, polypropylene plastic materials for sustainable materials ▪ Source products from suppliers that are committed to the eliminate single-use items and unnecessary packaging materials ▪ Reduce fossil-based fuels for airport vehicles and substitute with alternative fuels ▪ Collaborate with airlines and ground-handlers to reduce fossil-based fuels and substitute with alternative fuels

Case studies
Case study- Waste refill station The Aeropuerto Ecológico de Galápagos with the project “Baltra Libre de Plásticos”, PET waste generation was reduced by offering a free water refill station in the terminal, encouraging passengers to use their own containers. Refer to Recycle to see the case study on the pathways of the unavoidable PET waste that remained (ACI-LAC survey, 2024). **Case study- Ashes in construction** Combining the principles of reduce, recycle and recover, Corporación Quitport, in charge of the construction, administration, operation and maintenance of the Mariscal Sucre International Airport in Quito, Ecuador and AERODOM group responsible for managing and operating six airports in the Dominican Republic have been exploring waste incineration and the consequent use of ashes for concrete and “eco-blocks” production reducing the carbon-intensive cement in the mix (ACI-LAC survey, 2024).

Reduce

Reduction involves the minimizing of consumption of resources, as well as the generation of waste. The initiatives shown in the table below resemble the ones presented in for Refusal, the distinction lays in terms “eliminate” and “reduce”. In other words, when an initiative can led to 100% of the reduction of the resource, it will be considered refusal, otherwise it will be consider reduction.

Initiatives - Design & construction processes	Initiatives - Operational processes

Land use planning- minimal land reclamation
Reuse elements and components from previous construction processes (See Reduce)
	Reuse items (e.g., refillable plastic bottles, utensils, cups, bags, amenity kits)
	▪ Reuse treated wastewater for non-potable purposes such as irrigation, industrial processes, or toilet flushing.
	▪ Collaborate with other stakeholders that can reuse materials from the operational processes
	  ▪ Implement reuse networks across the airport value chain, across airport industry or across other industries
	  ▪ Donate food to local shelters from unconsumed food from the eateries in the airport ecosystem'
	  ▪ Reuse wooden pallets on cargo handling and shipping

Case studies
Case study- Second hand equipment marketplace Aeroports de Paris Airport group, operator of 26 airports in France, developed the first worldwide market place for second-hand airport equipment, releasing to the market components and vehicles that can be purchased and used by other operators. The marketplace spans from security check-points and escalators to fire fighting vehicles and runway lights. With direct and planned availability the marketplace allows other operators to purchase equipment that otherwise would be destined to disposal (Groupe ADP, 2022) (Passenger Terminal World, 2023). **Case study- Community donations** Aeropuerto Internacional de Querétaro in Mexico and Aeropuerto Merino Benítez in Chile provide donations of lost and forgotten objects at the airport or other resources that could have second life with the surrounding communities (ACI-LAC survey, 2024).

Reuse

In this case, the product has been produced but there is still an opportunity to divert it away when reused by another consumer, when it is still in good condition and it still fulfils its original function.

Initiatives - All processes
▪ Repair or refurbish furniture by using materials that are disposed of from other waste. ▪ Repair or refurbish products and equipment rather than purchasing new ones. ▪ Maintain products or restore them to their original/accepted performance.

Initiatives - Operational processes
Case study- Repurpose and remanufacture of warehouses During the summer of 2022, Brussels Airport in Belgium began a redevelopment of the central zones at Brucargo. Within this redevelopment, eight warehouses had to be disassembled. Thanks to a careful demolition and disassembly process, it was possible to achieve two targets: repurpose a 2,850 m2 steel structure, and the remanufacture of crashed concrete for flooring and outdoor paving. The salvaged steel structure is to be used by a local construction company to build a new warehouse (Brussels Airport, 2022). **Case study- Communities partnerships** The airport has ensured alliances from different actors from the private sector and local communities to achieve the reduction of waste going to landfills. El Dorado partnered with local communities specifically for the project “Plásticos por Sonrisas” to remanufacture plastic products into playgrounds (Opain, 2021).

Repair, refurbish, remanufacture and repurpose

Prevention and reduction and reuse of resources brought into the airport ecosystem is not wholly possible for many airports, which is where repair, refurbish, remanufacture and repurpose principles come into play. These principles are not broadly adopted yet, nevertheless they constitute steps to be considered prior to recycling or incinerating. Given their similarities and narrow adoption, they are presented grouped in this section:

- Repair: Maintenance and repair of defective product so it can be used for its original function.
- Refurbish- Restoration of old product to bring back up-to-date.
- Remanufacture- Use of parts of discarded product or its parts in a new product with the same function.
- Repurpose- Use discarded product or its parts in a new product with a different function.

Initiatives - All processes

- Recycle materials on-site to produce new products on-site.
- Recycle materials on-site and sell recycled material to other stakeholders.
- Set a regional recycling centre on-site and sell recycled material to other stakeholders.
- Collaborate with stakeholders to recycle materials off-site.

Initiatives - Operational processes

Case study- Water recycling
As part of its reduction-based strategy in 2009, Turin Airport in Italy also took in the management of surface waters, introducing a network of collection canals and rainwater tanks. Run-off water from the aprons is in this way treated through a hydrocarbon separation plant before being released in irrigation canals and reducing the need to water extraction from local wells and public water infrastructure (Torino Airport, 2021).

Similar projects are set in Latin America and the Caribbean region in Aeropuertos de Oriente SAS, Aeropuerto Mariscal la Mar, Aeropuerto Argentina 2000 S.A., Aeropuerto Ecológico de Galápagos, and at Aeropuerto Internacional El Dorado Luis Carlos Galán Sarmiento (ACI-LAC survey, 2024).

Case study- Plastic to uniforms and bicyles
The unavoidable waste that remained from the Aeropuerto Ecológico de Galápagos' project "Baltra Libre de Plásticos", was carefully sorted, washed and compacted before being transported to the mainland, where it is recycled as raw material to make uniforms and bicycles, which are then returned to the airport for use by staff (ACI-LAC survey, 2024).

Case study- Plastic to taxiways
Ecopetrol and El Dorado Airport have inaugurated the first section of a taxiway paved with modified asphalt that includes post-consumer recycled plastic. This innovative approach meets all the technical parameters required by the Colombian Aeronautical Regulations. The paving of this section utilized an asphalt mixture containing 338 kilograms of recycled plastic, equivalent to 200,000 plastic bags. This initiative not only repurposes one of the most environmentally damaging products but also addresses the challenge of recycling materials that are typically difficult to recover due to their low reuse rates in recycling processes. This project represents a significant step towards sustainable development and showcases how industries can contribute to environmental conservation by integrating recycled materials into their operations (Ecopetrol, 2023).

Recycling

Recycling involves processing materials to obtain the same (high-grade) or lower (low-grade) quality. There are inevitably times where waste will be generated and sent to the airports waste management system for processing. At this point, the resource or good that has been thrown away to the trash still has value and can be utilized for other purposes to generate value and contribute to a circular economy through putting these resources back into the economy. There is significant opportunity for airports in the realm of recycling, as it has been found that 75% of an airports Municipal Solid Waste (MSW) can be recycled (ICAO, 2017).

Initiatives - All processes
▪ Recover energy (heat or electricity) from waste in an incinerator at the airport. ▪ Collaborate with external parties (government or waste management industry) to recover energy (heat or electricity) from waste outside the airport ecosystem boundaries. ▪ Recover biogas or SAF from biowaste waste to biogas at the airport. ▪ Collaborate with external parties to recover biogas or SAF outside the airport boundaries.

Case studies
Case study- Biodigestion and composting In an effort to recover the embodied energy from the organic residual waste, Corporación Quiport introduced facilities aimed at the production of biogas and compost. To this aim, plant residues, food waste, and treatment plant sludge are collected. 5 biodigesters, 12 composters, and 1 dehydrator process the residues producing and output of biogas, and compost, the latter for example used for the airport's green areas. This initiative prevents the emission of more than 2.000 tons of CO_2 in the atmosphere (Corporación Quiport, 2023), (Corporación Quiport, 2024).

Recover

Continuing down the chain, some materials will not or cannot otherwise be recycled or reused. This can be due to a variety of factors, though it often comes down to the lacking surrounding infrastructures to support the earlier stages in the waste hierarchy. Waste recovery revolves around the fact that every product has embodied energy, which can be extracted instead of sending it to landfill. Waste recovery comes in the form of waste-to-energy facilities, which are also referred to as incinerators. These do have their own emissions to worry about, which is a developing topic in wider discussion in waste management circles.

2.5 Step 4- Implementation of circular initiatives

As a last step, the implementation of the circular initiatives will depend on a successful business plan. Consideration of the costs and benefits of the initiatives around the airport strategic priorities, the availability of resources and the financing options should be taken into consideration to ensure successful implementation of circular approaches. Furthermore, the degree of control that the airport has over the processes as seen in Step 1- Definition of scope and the horizon of the initiatives should be considered in the implementation development as well. Lastly, regular monitoring and feedback mechanisms should further be established to assess the effectiveness of implemented initiatives and make necessary adjustments.

An overview of the above-mentioned steps is listed below:

1. **Cost-benefit analysis and strategic prioritization of the initiatives:** The analysis may consider capital expenditure, operational expenditure, cost savings, intangible benefits such as customer experience, and societal acceptance as part of license-to-operate benefits.

2. **Goals definition and strategic prioritization**: According to the results of the cost-benefit analysis and to the strategic priorities of the airport, objectives should be elaborated, short-listed, and prioritized within the implementation horizon.

3. **Business case development:** A revenue and operational cost model and financial model, which may incorporate sustainable financing options, should be elaborated. Metrics such as Net-Present-Value (NPV) to measure success rate of investment should be included.

4. **Stakeholder engagement plan development:** A stakeholder engagement plan should guide stakeholders prioritization, communication and dissemination and the governance model around this. Intersectoral collaboration with strong alliances between airports, governments, commercial brands, tech companies, and the scientific community may be incorporated to ensure innovation keeps taking being considered.

5. **Implementation plan development:** Implementation plan development: Objectives, milestones, and actions should be incorporated into a timeline, accounting for financial and human resources availability to reach them. Financial incentives may part of this i.e. rent based on waste/sqm as well as education and training for airport employees and collaborators. Further, emerging technologies can be quite helpful to implement the circular actions (i.e. digital platforms or tools to measure, monitor and manage the airport ecosystem resource flows per process and/or stakeholder) .Documentation and presentation to decision-makers: Documentation of the business case and the implementation plan should be documented and presented to decision-makers.

6. **Documentation and presentation to decision-makers:** Documentation of the business case and the implementation plan should be documented and presented to decision-makers.

7. **Implementation and monitoring:** This last step involves executing the outlined strategies, tracking progress, and making necessary adjustments to ensure that the circular initiatives are efficiently integrated in the airport ecosystem construction and/or operations. The metrics shown in Table 3 may be assessed in collaboration between the airport operators and their business partners.

Metric	Unit	Guidance
Water consumption (footprint)	l, m3	Absolute and relative water consumption for: (a) Fresh water (green and blue), (b) Recycled and reused water (grey), and (c) Total water stored and changes in storage.
Water withdrawal	l, m3	Absolute and relative water withdrawal by: (a) Surface water, (b) Groundwater, and (c) Seawater.
Water consumption intensity	#	Water intensity per net revenue, traffic unit, passenger and/or m2 over time.
Water discharged to areas	#	Total water discharged to all areas for: a) Surface water, b) Groundwater, c) Seawater, or d) Third-party water
Water discharged by quality	l, m3	Breakdown of total water discharge to by: (a) Freshwater (≤1,000 mg/L Total Dissolved Solids), (b) Other water (>1,000 mg/L Total Dissolved Solids).
Resource inflow	tons	Resource inflows products (including packaging) and materials (specifying critical raw materials (CRM) and rare earths).
Resource inflow types	tons, %	Absolute and relative material resource inflows: (a) Raw materials, (b) Sustainably sourced biological materials and biofuels (excluding energy) with certification and cascading principal application, and (c) Reused/recycled components, intermediary products, and materials in product and packaging manufacturing.
Waste generated by recovery operation type	tons	Absolute and relative hazardous and non-hazardous waste generated by recovery operation type: (a) Preparation for reuse, (b) Recycling, (c) Recovery or (d) Disposal.
Waste directed to disposal by waste treatment type	tons	Absolute and relative hazardous and non-hazardous waste directed to disposal by waste treatment type: (a) Incineration, (b) Incineration with energy recovery, (c) Landfill, or (d) Other disposal operations.
Waste intensity	#	Waste intensity per net revenue, traffic unit, passenger and/or m2 over time.
Anticipated financial effect	$	Description and quantification of anticipated financial effects from a) Material use-related risks and opportunities and b) Waste management-related risks and opportunities.

Tab.3 Circular economy suggested metrics

3 Recommendations

To spearhead circularity in airports, Latin America and the Caribbean region may collectively agree on and set a vision for the industry. This vision would be ambitious yet achievable, aiming to transform airports into models of efficiency and sustainability. To realize this vision, it is crucial to take proactive and strategic actions to incentivize airports to adopt circular economy principles, minimizing waste generation, maximizing resource efficiency, and promoting circular practices throughout airport operations. One such action could be the implementation of a Airport Circularity Accreditation system. The Airport Circularity Accreditation could be structured around the levels of Resource mapping, Waste minimization, Third-Party integration, Systemic waste minimization, Zero-Waste, Circularity (no recovery/incineration), and Advanced circularity (no recovery/incineration and minimal recycling) and can be developed and launched in Latin America and Caribbean by Airports Council International Latin America and Caribbean (ACI-LAC).

A similar approach to the Airport Carbon Accreditation (ACA) could be followed by introducing certain key requirements at each level of accreditation. Every 5 years the requirements would be reassessed and adapted to the new circular economy reality and standards. By adhering to this system, airports can systematically reduce waste, optimize resource use, and ultimately eliminate waste entirely, moving towards a circular model where resources are used in a sustainable and efficient manner. With concerted effort and commitment, airports in the Latin America and Caribbean region can become pioneers in airport circularity, setting a global standard for sustainability in aviation.

4 Conclusion

The transition to a circular economy within the airport sector represents a fundamental shift from the 'take-make-dispose' model to a circular system focused on resource optimization and waste minimization.

A methological approach to integrating circular economy principles into airport processes, as presented in this white paper supports airports to achieve this transition. Defining the scope of an airport ecosystem must be the initial step, Table 7 serves as a framework, detailing potential considerations and categorizing airport processes into construction and operation phases, encompassing landside, terminal airside, and airport city domains. The table also presents the various stakeholders potentially involved in these processes, acknowledging the complexity and diversity of airport business models and the implications for resource management depending of the degree of control that the airport has over these processes.

Resource mapping entails evaluating the movement of resources through construction and operational phases. In a linear system, waste is the end product, whereas in a circular system, resources are reabsorbed. The Sankey diagram serves as a visual tool for mapping and quantifying the flows within the airport ecosystem.

Drawing from the accumulated data, airports should then follow the deployment of circular initiatives. This phase demands a meticulous examination of resource flows, as illustrated by a Sankey diagram, to identify inefficiencies and prospects for circular approaches. Prioritizing initiatives with the most substantial circular impact is paramount, with careful consideration of the feasibility of implementation in light of the airport's resource constraints, control over processes, and other limitations The R-Hierarchy or R-Ladder is a valuable framework for determining the hierarchy within selected (semi-)circular routes that an airport can adopt to enhance its impact. This framework can be represented in either a five-step or a ten-step model. A variety of potential initiatives per the ten-step model (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and/or recover) is delineated, along with relevant case studies from Latin America and the Caribbean.

Furthermore, the successful implementation of circular initiatives depends on a well-crafted business plan. This involves a thorough cost-benefit analysis of the initiatives, taking into account the airport's strategic priorities, resource availability, and financing options. The degree of control that the airport has over the processes, as defined in Step 1 (Definition of Scope), and the timeline of the initiatives should also be considered. Regular monitoring and feedback mechanisms are essential to assess the effectiveness of the implemented initiatives and make necessary adjustments.

Lastly, to spearhead circularity in airports, we recommend that the Latin America and the Caribbean region collectively agree on and set a vision for the industry. Realizing this vision requires proactive and strategic actions to incentivize airports to adopt circular economy principles, thereby minimizing waste generation, maximizing resource efficiency, and promoting circular practices throughout airport operations. One such action could be the implementation of an Airport Circularity Accreditation system as described in Chapter 3. This accreditation, structured around various levels from resource mapping to advanced circularity, could be developed and launched in Latin America and the Caribbean by the Airports Council International Latin America and Caribbean (ACI-LAC). By adhering to the accrediation system, airports can move towards a circular model where resources are used in a sustainable and efficient manner. With concerted effort and commitment, airports in the Latin America and Caribbean region can become pioneers in airport circularity, setting a global standard for sustainability in aviation.

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