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Sustainability in African Airports and a Just Transition

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Abstract

This study explored Airports Council International (ACI) Africa and its member airports can strengthen policy design and implementation to foster environmentally sustainable and socially just transitions. The study specifically focused on analyzing current sustainability initiatives in African airports, analyzing the potential for renewable energy integration, investigating the socio-economic impacts of sustainable practices, evaluating policy frameworks, exploring stakeholder engagement, and examining challenges and opportunities for a just transition. The study was anchored on the just transition and sustainability theory, which advocate for environmentally responsible development that ensures equity and inclusion. A comparative case study design was employed, focusing on four major African airports: Johannesburg OR Tambo (South Africa), Mombasa Moi (Kenya), and Félix-Houphouët-Boigny International Airport in Abidjan (Ivory Coast). Secondary data collection was primarily through document analysis, including policy documents, sustainability reports, and academic literature. A thematic analysis approach was used to identify patterns and themes across the data, with a focus on governance, policy, stakeholder engagement, and financial mechanisms. The study findings indicated that, while there are efforts to adopt sustainable practices, many African airports still face significant challenges, including limited funding, outdated infrastructure, and insufficient policy frameworks. Renewable energy

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adoption and circular economy practices were identified as key opportunities for reducing carbon footprints, but progress was hindered by financial and institutional barriers. The study results also highlighted the importance of stakeholder engagement in promoting sustainability, with varying levels of involvement from local communities, governments, and private sectors. Based on the study findings, it was recommended that it was crucial to enhance stakeholder engagement, prioritize renewable energy adoption and implement circular economy practices in African airports. The study recommends that the airports should focus on developing comprehensive sustainability policies, strengthening regulatory frameworks, and promoting a just transition that ensures equitable outcomes for workers and communities. The study also recommends investigating the long-term impact of renewable energy adoption on airport operations and financial sustainability since it is vital for scaling green initiatives across African airports.

Keywords: *Climate Change, Just Transition, Sustainability*

1. Introduction

Climate change and sustainability have become central agenda items for African airports as the aviation sector confronts increasing environmental, social, and economic pressures. The African aviation industry is undergoing a critical transformation as the escalating impacts of climate change, resource depletion, and social inequities compel stakeholders to rethink infrastructure development through the lens of sustainability.[1] [2] Airports, as key engines of economic development and connectivity, are at the center of this transition.

Air transport has been widely identified as a catalyst for economic growth, tourism development, and regional integration across Africa.[3] [4] Consequently, the expansion and modernization of airport infrastructure are increasingly being aligned with broader environmental and social objectives. This shift is reflected in the growing adoption of sustainability frameworks such as the Airport Carbon Accreditation (ACA) programme, through which several African airports are committing to carbon management, emissions reduction, and climate-resilient operations.[5] [6]

Despite this momentum, African airports face a distinct set of structural challenges. Many countries continue to contend with aging infrastructure, constrained financial resources, limited access to green technologies, and weak or fragmented regulatory frameworks for renewable energy integration and environmental governance.[7] [8]At the same time, the relatively early stage of aviation infrastructure development in parts of the continent presents a strategic opportunity to embed

[1] International Civil Aviation Organization (ICAO), *Environmental Report 2023: Aviation and Climate Change* (Montreal: ICAO, 2023).
[2] Airports Council International (ACI), *Sustainability Strategy for Airports Worldwide* (Montreal: ACI, 2022).
[3] African Airlines Association (AFRAA), *Aviation as a Driver of Africa's Economic Development* (Nairobi: AFRAA, 2023)
[4] World Bank, *Air Transport and Connectivity in Africa* (Washington, DC: World Bank, 2022).
[5] Airports Council International (ACI), *Airport Carbon Accreditation Annual Report* (Montreal: ACI, 2023).
[6] International Civil Aviation Organization (ICAO), *Action Plan on CO_2 Emissions Reduction* (Montreal: ICAO, 2022).
[7] World Bank, *Infrastructure Financing Constraints in Sub-Saharan Africa* (Washington, DC: World Bank, 2021).
[8] United Nations Conference on Trade and Development (UNCTAD), *Transport and Trade Facilitation in Africa* (Geneva: UNCTAD, 2022).

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sustainable design principles and low-carbon operational models from the outset, thereby avoiding the carbon-intensive development trajectories observed in more mature aviation markets.[9] [10]

Within this context, the concept of a *just transition* becomes particularly salient. A just transition emphasizes the need to balance environmental sustainability with social equity, inclusion, and economic justice, ensuring that climate action does not exacerbate existing inequalities or marginalize vulnerable communities.[11] [12] For African airports, this implies that sustainability initiatives must not only reduce environmental footprints but also promote decent work, local economic participation, and equitable access to the benefits of aviation growth.

As Africa's aviation sector continues to expand, there is a growing need for a deeper and more systematic understanding of how sustainability can be integrated into airport planning, construction, and operations while ensuring inclusive and equitable outcomes. This thesis, therefore, examined the pathways, barriers, and implications of advancing sustainability in African airports within a just transition framework, seeking to balance development imperatives with climate resilience, environmental stewardship, and social justice.

Problem Statement

Airports across Africa have been identified as vital drivers of socio-economic development, regional integration, and global connectivity.[13] [14] Yet, as climate change intensifies and structural inequalities persist, the need to align airport development with sustainability and social justice principles has become increasingly urgent.[15] While Airports Council International (ACI) Africa has recognized the importance of sustainable airport operations and has encouraged environmental best practices among its members through initiatives such as the Airport Carbon Accreditation (ACA) Programme and the African Airports Development Programme, significant gaps remain in policy frameworks, implementation strategies, financing mechanisms, and institutional support systems necessary to achieve meaningful progress.[16] [17]

[9] Schäfer, A. W., et al., "Technological, Economic and Environmental Prospects of Aviation," *Nature Energy* 4, no. 2 (2019): 160–166.
[10] Gössling, S., & Humpe, A., "The Global Scale, Distribution and Growth of Aviation," *Global Environmental Change* 65 (2020): 102194.
[11] Newell, P., & Mulvaney, D., "The Political Economy of the Just Transition," *The Geographical Journal* 179, no. 2 (2013): 132–140.
[12] International Labour Organization (ILO), *Guidelines for a Just Transition towards Environmentally Sustainable Economies and Societies for All* (Geneva: ILO, 2018).
[13] World Bank, *Air Transport and Regional Integration in Africa* (Washington, DC: World Bank, 2022).
[14] African Airlines Association (AFRAA), *Aviation as a Catalyst for Africa's Socio-Economic Development* (Nairobi: AFRAA, 2023).
[15] Intergovernmental Panel on Climate Change (IPCC), *AR6 Working Group II: Impacts, Adaptation and Vulnerability* (Geneva: IPCC, 2022).
[16] Airports Council International (ACI) Africa, *Sustainable Airports Development Strategy for Africa* (Montreal: ACI, 2021).
[17] Airports Council International (ACI), *Airport Carbon Accreditation Annual Report* (Montreal: ACI, 2023).

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Many African airports continue to face challenges in adopting and enforcing environmental policies that align with international climate objectives, including carbon emissions reduction, biodiversity protection, and climate resilience enhancement.[18] [19] At the same time, the socio-economic dimensions of airport development, including displacement, labour conditions, and community engagement, are often inadequately addressed within planning and regulatory processes.[20] [21] As a result, airport expansion can inadvertently exacerbate existing social inequities and environmental vulnerabilities, undermining broader sustainable development objectives.[22]

Despite ACI Africa's efforts to promote sustainability through training, advocacy, and benchmarking tools such as Airport Carbon Accreditation, the lack of cohesive, continent-wide policy integration and uneven adoption of sustainability standards among member airports continue to limit progress.[23] Currently, ACI Africa has approximately 70 members across 53 countries, collectively managing more than 260 airports.[24] However, only 23 airports in Africa have achieved Airport Carbon Accreditation, representing the lowest level of participation globally and underscoring the significant gap in implementation.[25] Furthermore, there remains limited empirical research on how African airports can transition toward sustainability in a manner that is not only environmentally sound but also socially equitable, ensuring that no groups or communities are disproportionately burdened or excluded from the benefits of aviation development.[26] [27]

This thesis, therefore, sought to critically examine how ACI Africa and its member airports can strengthen policy design and implementation frameworks to foster environmentally sustainable and socially just transitions. In doing so, it addresses the urgent need for actionable, context-sensitive policy recommendations that integrate environmental stewardship with social equity in the African aviation sector.

Purpose of the Study

To assess how ACI Africa and its member airports can strengthen policy design and implementation frameworks to foster environmentally sustainable and socially just transitions.

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[18] International Civil Aviation Organization (ICAO), *Environmental Report: Aviation and Climate Change* (Montreal: ICAO, 2023).
[19] United Nations Environment Programme (UNEP), *Greening Aviation Infrastructure in Developing Regions* (Nairobi: UNEP, 2021).
[20] Salgado, M., & Rhoades, D. L., "Social Sustainability in Airport Infrastructure Development," *Journal of Air Transport Management* 89 (2020): 101892.
[21] Flyvbjerg, B., *Survival of the Unfittest: Why the Worst Infrastructure Gets Built* (Oxford: Oxford University Press, 2014).
[22] Sovacool, B. K., et al., "Energy Justice and Infrastructure Development," *Energy Research & Social Science* 21 (2016): 1–5.
[23] Airports Council International Africa, *Capacity Building and Sustainability Programmes Report* (Montreal: ACI, 2022).
[24] Airports Council International Africa, *Annual Activity Report* (Montreal: ACI, 2023).
[25] Airports Council International, *Global Airport Carbon Accreditation Status Report* (Montreal: ACI, 2024).
[26] Newell, P., & Mulvaney, D., "The Political Economy of the Just Transition," *The Geographical Journal* 179, no. 2 (2013): 132–140.
[27] International Labour Organization (ILO), *Guidelines for a Just Transition towards Environmentally Sustainable Economies and Societies for All* (Geneva: ILO, 2018).

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Research Objectives

The objectives of the study were to;

1. Conduct a comprehensive literature review on sustainability practices in the aviation sector, with a focus on African airports.
2. Perform case studies of selected African airports to evaluate their sustainability initiatives and outcomes.
3. Analyze policy documents and regulatory frameworks to identify barriers and facilitators of sustainable practices in the aviation sector.
4. Develop a set of recommendations for enhancing sustainability in African airports, considering the principles of a just transition.

Significance of the Study

The value of this study is in three-folds: theory, policy, and practice. Airports are both significant sources of greenhouse gas emissions and critical engines of economic growth, making sustainability in aviation an urgent priority, particularly for Africa, which is disproportionately affected by climate change. This study examines how African airports can reduce their carbon footprint while advancing economic development, tourism, and trade. Anchored in the principle of a just transition, it explores how sustainability initiatives can be designed to promote social equity and deliver tangible benefits to marginalized communities without deepening existing inequalities. The findings will inform aviation policy and practice by identifying effective, context-appropriate sustainability strategies aligned with national and regional development goals. By highlighting the role of technological innovation and locally tailored solutions, the study positions African airports as potential leaders in sustainable aviation, with insights that are relevant not only regionally but also to other developing economies navigating the balance between growth and environmental responsibility.

2. Literature Review

Concept of Sustainability in Aviation

The global aviation sector is at a pivotal juncture in its response to the climate crisis. Central to its sustainability agenda is the commitment to achieve net-zero carbon emissions by 2050, a target aligned with international climate frameworks such as the Paris Agreement. To this end, the industry's decarbonization roadmap foregrounds Sustainable Aviation Fuels (SAFs), hydrogen propulsion, electric aircraft, and incremental technological improvements in fuel efficiency. However, the practical viability of these pathways, particularly their scalability and affordability, remains the subject of ongoing debate.[28] This uncertainty has sparked a broader conversation about the role of policy interventions and behavioural change in reducing aviation's environmental footprint. The emergence of the flygskam (Swedish for "flight shame") movement exemplifies a shift in public sentiment, urging individuals to reconsider their flying habits in light of

[28] IATA, Global outlook for air transport – Deep change, (2024); Sharmina M., Edelenbosch Y., Wilson C., Freeman R., Gernaat J., Gilbert P., Larkin A., Littleton W., Traut M., van Vuuren P., Vaughan E., Wood R. & Le Quéré C., "Decarbonising the critical sectors of aviation, shipping, road freight and industry to limit warming to 1.5–2°C, Climate Policy. 21 (4): at 455–474 (2021)

environmental concerns.[29] In response, several national governments have adopted regulatory measures aimed at limiting aviation growth and encouraging modal shifts to lower-emission transport systems.[30] At the international level, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), adopted by the International Civil Aviation Organization (ICAO), seeks to stabilize net carbon emissions from international aviation at 2020 levels. Under CORSIA, airlines are required to offset emissions exceeding this baseline through approved carbon credit mechanisms. Although voluntary during its pilot and first phase (2021–2026), the scheme becomes mandatory for most ICAO member states from 2027 onward.[31]

For African airports, the sustainability agenda presents both a challenge and an opportunity. While the continent's aviation sector contributes a relatively small share to global emissions, it is projected to grow significantly in coming decades. This growth trajectory raises pressing questions about how African states and airport operators can align with global decarbonization goals without compromising their developmental and connectivity imperatives. Here, the principle of a just transition becomes particularly relevant. A just transition in the African aviation context demands that sustainability efforts not only address environmental outcomes but also safeguard social equity, economic inclusion, and capacity-building. This entails ensuring that climate policies are adapted to local realities, such as limited infrastructure, constrained financing, and workforce development needs, while promoting access to sustainable technologies and global climate finance mechanisms. As African airports begin to incorporate environmental management systems, renewable energy solutions, and green infrastructure initiatives, there is an urgent need for context-sensitive regulatory frameworks and inclusive planning approaches. These should be guided not only by international best practices but also by principles that promote resilience, equity, and long-term sustainability.

The Just Transition Framework

Aviation decarbonization is an urgent global imperative, yet its implementation must consider the unequal starting points and dependencies across regions. For African economies, many of which are in early or intermediate stages of development, air transport plays a pivotal role in regional connectivity, trade facilitation, tourism, and access to essential services. Accordingly, climate mitigation policies in aviation must be designed to avoid compounding existing vulnerabilities. A Just Transition framework provides a critical lens through which to assess and mitigate these risks, ensuring that sustainability efforts in African aviation do not come at the expense of social and economic resilience. This framework raises several pressing questions for African airport policymakers and regulators: Socio-economic repercussions:

a) How do carbon-reduction policies in the Global North - such as carbon pricing, flight bans, or Sustainable Aviation Fuel (SAF) mandates impact African economies that rely heavily on inbound tourism and exports?

[29] Coffey H., Flygskam: What is the flight-shaming environmental movement that's sweeping Europe? The Independent (2020)
[30] International Transport Forum, Decarbonising aviation: Exploring the consequences, International Transport Forum Policy Papers, No. 140, OECD Publishing, Paris (2024)
[31] ICAO Assembly Resolution A39-3, Consolidated statement of continuing ICAO policies and practices related to environmental protection – Global Market-based Measure (MBM) scheme (2016)

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b) Feasibility of economic diversification: What viable pathways exist for African regions whose economic structures are tightly linked to aviation? Can policy reform, capacity building, and investment in non-aviation sectors offer alternatives?

c) Strengthening local and regional demand: Given Africa's rapidly growing population and expanding middle class, how can airports and airlines be repositioned to support domestic and intra-African tourism in alignment with the African Continental Free Trade Area (AfCFTA) and Single African Air Transport Market (SAATM) goals?

The Just Transition imperative is particularly pronounced for African airports due to several structural challenges:

a) Geographical remoteness: Many African countries, particularly landlocked or island states, depend on air transport for access to global markets, making them uniquely exposed to aviation shocks.

b) Economic dependence on aviation-linked sectors: Historical trade patterns and limited infrastructure alternatives have created a reliance on aviation for employment and national income.

c) Environmental vulnerability: African countries are among the least responsible for global emissions but face disproportionate risks from climate change, including drought, flooding, and rising sea levels, which also threaten airport infrastructure itself.

d) Institutional and financial fragility: Many airport operators in Africa lack the fiscal autonomy and technical capacity to adapt quickly to decarbonisation pressures without international support or concessional financing.

A Just Transition in African aviation, therefore, calls for an integrated and regionally tailored governance approach. This includes aligning national aviation strategies with sustainable infrastructure investment, strengthening regulatory frameworks to encourage climate resilience, and ensuring international climate policies do not inadvertently penalize the continent's development trajectory. It also requires multilateral cooperation to unlock climate finance, technology transfer, and capacity-building support for airport authorities and aviation regulators. Ultimately, African airports must not only decarbonise, but do so in a way that safeguards livelihoods, promotes inclusive development, and secures the continent's connectivity in an increasingly carbon-constrained world.

Global Trends in Airport Sustainability

Achieving Net Zero

This section explores the strategic role of airport operators in achieving net-zero emissions, focusing on economic instruments and supportive measures that incentivise low-carbon operations.

The Role of Airport Operators in Decarbonizing Aircraft Emissions

Airport operators are increasingly pivotal in the broader aviation ecosystem's transition toward net-zero emissions. While aircraft emissions are predominantly under the control of airlines and manufacturers, airport operators can exert meaningful influence through targeted economic

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mechanisms. A prominent strategy involves incentivising the use of Sustainable Aviation Fuel (SAF). For instance, in 2022, Heathrow Airport integrated a SAF incentive into its landing charge structure, thereby financially rewarding airlines that use SAF. Similarly, Schiphol Airport introduced a €15 million fund to support SAF uptake, while Swedavia, the Swedish airport operator, launched a SAF Incentive Programme subsidising up to 50% of the premium cost associated with neat SAF for eligible applications.[32]

The extent to which airport operators can influence aircraft emissions often depends on their operational scope. In Norway, for example, AVINOR functions both as the airport operator and the Air Navigation Service Provider (ANSP). This dual role allows it to manage Standard Instrument Departure (SID) and Arrival Routes (STARs), thereby enabling greater optimization of air traffic flows to reduce fuel burn and associated emissions.[33]

Moreover, the effectiveness of SAF adoption is contingent upon external variables, such as political will, economic incentives, and regulatory frameworks, which shape the overall feasibility of low-carbon aviation initiatives. Jurisdictional variations often determine the pace and scale of such transitions.[34] (Figure 1)

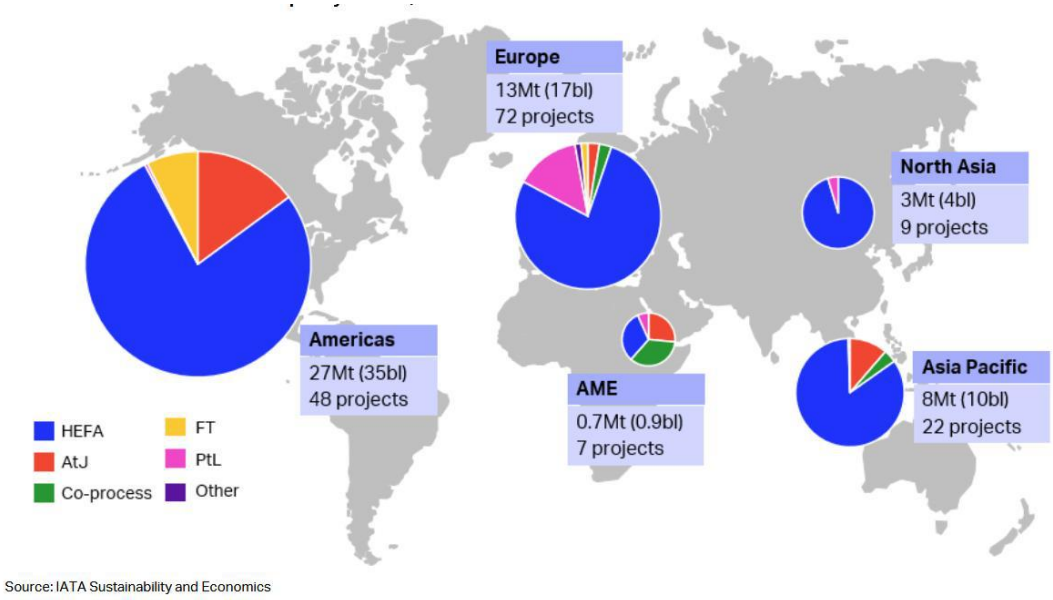

Figure 1: Total Renewable Fuel Capacity In 2030, Million Tonnes

Supporting Measures to Reduce Aircraft and Ground Emissions

This subsection discusses complementary strategies that facilitate emission reductions, focusing on aircraft fleet renewal, retrofit programmes, propulsion innovations, and enabling infrastructure.

[32] Swedavia Airports, Swedavia – Sustainable Aviation Fuel (SAF) Incentive Programme, (2024)

[33] ACI Europe, Guidance on airports' Contribution to net zero aviation: Reducing scope 3 and supporting the implementation of destination 2050, (2022)

[34] id

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Fleet Renewal and Retrofitting of In-Service Aircraft

Aviation decarbonization is significantly enhanced through the introduction of newer, fuel-efficient aircraft and retrofitting existing fleets with low-emission technologies. Airport operators can support this process through a variety of non-coercive mechanisms, such as:

a) Promoting air operators with modern, low-carbon fleets;
b) Evaluating and adopting differentiated airport charges based on noise, NOx, and CO_2 emissions to incentivise cleaner operations; and
c) Integrating environmental performance into slot allocation frameworks, thereby encouraging greener operations.

However, the implementation of such measures presents challenges:

a) Airport operators are not direct customers of aircraft or engine manufacturers, restricting their ability to influence product specifications.[35]

b) Ensuring consistent use of environmentally prioritised slots is difficult, especially if airlines switch to higher-emission aircraft after allocation. Further, care must be taken to avoid discrimination against carriers with legacy fleets.[36]

c) Legal uncertainties, data reliability, and overlap with existing emission schemes often hamper such efforts.[37]

Despite these limitations, alternative financial approaches exist. Notably, cost-sharing mechanisms, such as Swedavia's SAF Incentive Programme, offer a viable path to supporting airline decarbonisation without encountering the legal and operational complexities of charge modulation.[38]

Aircraft Propulsion and Energy Systems

Emerging propulsion technologies, particularly electric and hydrogen-powered systems, represent a transformative frontier in airport sustainability. Leading this innovation is AVINOR, which has committed to fully electrifying Norwegian domestic aviation by 2040, with hybrid-electric aircraft expected to enter service by 2025. Key AVINOR initiatives include:

a) Collaborations with stakeholders such as SAS to acquire the Pipistrel Alpha Electro, facilitating research on operational feasibility, noise reduction, and required infrastructure;

b) Waiving landing charges for general aviation traffic until 2025 and establishing foundational infrastructure for aircraft charging; and

c) Participation in the "GreenFlyway 2.0" programme aimed at fostering zero-emission air mobility in diverse regions.[39]

[35] id
[36] id
[37] id; see also, ACI Europe, Information on the use of modulations of airport charges for environmental reasons, (2020)
[38] id
[39] See, https://www.greenflyway.se/ accessed on 23 December 2024

Elsewhere, Heathrow, the Manchester Airports Group and Stuttgart Airport have implemented similar measures, including the waiver of landing charges for zero-emissions aircraft, to promote early adoption of clean technologies.[40]

The long-term transition to liquid hydrogen (LH_2) propulsion, anticipated to become operational by 2035 through initiatives like Airbus's ZERO project demands robust infrastructural planning. In this regard, the GOLIAT (Ground Operations of Liquid hydrogen Aircraft) project exemplifies proactive foresight. The consortium, comprising leading aerospace firms, airports, and research institutions across Europe, seeks to address key enablers for hydrogen aviation:

a) Developing scalable LH_2 refueling technologies for future commercial aircraft;

b) Demonstrating safe small-scale ground operations for hydrogen-powered aircraft;

c) Establishing standardization and certification pathways for LH_2 use in airports; and

d) Assessing the technical and economic viability of a hydrogen value chain within the airport ecosystem.[41]

Hydrogen holds vast potential due to its high energy density and near-zero carbon footprint. Yet, the transition is not without significant hurdles. Safety protocols, regulatory frameworks, cost considerations, and the maturity of supply chains all require comprehensive evaluation. Ensuring a just and equitable transition, particularly for developing countries, will necessitate tailored capacity-building strategies, international cooperation, and targeted financial support.[42]

Sustainability Challenges in African Airports

Efforts to reduce air travel, particularly in response to global climate imperatives, present complex challenges for vulnerable economies. In many African contexts, the intersection of economic, social, and environmental considerations creates a multifaceted policy landscape.

Measures aimed at curbing aviation-related carbon emissions, such as:

a) the introduction or escalation of aviation-specific taxes and environmentally based airport charges;

b) the inclusion of aviation emissions in carbon trading markets;

c) and regulatory capacity constraints on airport and flight operations are often justified by their environmental benefits. However, their implementation tends to generate disproportionate socio-economic impacts on regions highly dependent on aviation connectivity.[43]

Many African economies rely heavily on international air travel to sustain tourism, trade, and diaspora links. Policies that suppress air travel demand, particularly for leisure, risk destabilizing inbound tourism markets and constraining outbound travel, with adverse consequences for employment, foreign exchange earnings, and broader economic resilience.

[40] ICAO, Greenhouse Gas Management and Mitigation at Airports, Eco Airport Toolkit at 14 (2022)
[41] Middleton I., Innovative aviation liquid hydrogen project launched, Airbus 16 May 2024
[42] id
[43] id

While strategies such as increased flight taxes or capacity limits may contribute to carbon reduction goals, they can also restrict access to global markets and reduce opportunities for economic development. These unintended consequences highlight the critical importance of designing regulatory frameworks that are not only environmentally sound but also socially and economically equitable.[44]

A just transition in the aviation sector, particularly in the African context, requires a holistic approach that integrates climate objectives with the developmental needs of affected regions. Policymakers must therefore balance the urgency of environmental action with the practical realities of economic vulnerability. By embedding sustainability principles within a framework that recognizes regional disparities, it is possible to develop aviation policies that are both environmentally responsible and developmentally just.

Policy and Regulatory Frameworks (Global, Regional, and National)

Globally, policy and regulatory frameworks play a pivotal role in shaping airport sustainability, investment strategies, and service quality. International case studies reveal that light-handed regulatory approaches, characterized by transparency, performance monitoring, and flexibility, can stimulate infrastructure development while maintaining competitive and efficient operations. These models offer valuable lessons for African airports navigating a just transition toward sustainable growth.

Australia and New Zealand offer compelling examples of effective light-handed economic regulation. In Australia, the regulatory model emphasizes performance monitoring over direct price control, enabling airports to set charges through commercial negotiation under competitive market constraints. This framework has supported over AUD 8 billion in airport infrastructure investment between 2002 and 2019. Over the same period, Sydney Airport experienced a substantial increase in passenger volumes, from 28 million to more than 44 million, underscoring the model's capacity to drive both growth and service quality. New Zealand's regime similarly prioritizes transparency and accountability. The Commerce Commission monitors performance and publishes benchmarking reports, ensuring operators remain responsive to users while retaining pricing autonomy. Auckland Airport benefited from this environment, investing NZD 1.2 billion in capital projects over five years and increasing passenger numbers from 14 million in 2012 to over 21 million in 2019.[45]

In Japan, a dual approach is evident. The Civil Aviation Bureau within the Ministry of Land, Infrastructure, Transport and Tourism regulates aeronautical charges to ensure high service standards and operational efficiency. At the airport level, facilities such as Kansai International and Itami operate under a light-handed, dual-till framework, allowing for the strategic use of both aeronautical and commercial revenues. These fosters improved service delivery while ensuring financial viability and operational autonomy.[46]

Latin America has adopted hybrid regulatory frameworks that balance service quality with financial sustainability. In Brazil, major airports operate under a dual-till system managed by private concessionaires, with oversight from the National Civil Aviation Agency. This

[44] id
[45] Cheglatonyev S., Airport Economic Regulation: Achieving Sustainable Equilibrium, October 2024
[46] id

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arrangement encourages investment and ensures alignment with national development goals. Similarly, in Mexico, the Federal Civil Aviation Agency regulates privately operated airports under a dual-till model, mandating high service standards and operational efficiency while allowing flexibility in non-aeronautical revenue generation.[47]

In Europe, a wide spectrum of regulatory intensity exists. Airports operating under light-touch regimes often report improved consumer outcomes, efficient investment cycles, and more agile responses to market demands. Conversely, airports subject to stricter price-cap regulation, where regulators must approve charges and investments, frequently encounter protracted approval processes and legal challenges. Such friction can undermine timely infrastructure upgrades and delay sustainability transitions.[48]

The experiences of Australia, New Zealand, Japan, Latin America, and Europe demonstrate that flexible, transparent, and performance-oriented regulatory frameworks can unlock substantial infrastructure investment, improve service delivery, and support sustainable airport operations. These lessons are particularly salient for African airports, which face distinct challenges including constrained public funding, evolving regulatory institutions, growing passenger demand, and the imperative of aligning with global sustainability and decarbonisation targets. As African states pursue a just transition in aviation one that balances environmental responsibility with social equity and economic development, there is a critical need to recalibrate regulatory frameworks to incentivize investment, enhance resilience, and enable long-term sustainability. Understanding and adapting successful elements of international regulatory models, while accounting for local socio-economic and institutional contexts, can serve as a foundational step toward building a more sustainable, efficient, and inclusive airport system across the continent.

A 'Just' Transition Defined: Strategies for Sustainable Development

A just transition refers to the process of shifting towards environmentally sustainable, low-carbon economies in a manner that is equitable, inclusive, and leaves no one behind. According to the United Nations, a just transition must be grounded in the principles and goals of the 2030 Agenda for Sustainable Development, promoting investment and policy frameworks that ensure equitable and inclusive outcomes.[49]

Crucially, there is no one-size-fits-all blueprint for implementing a just transition. Rather, it demands a context-specific, dynamic approach that integrates diverse perspectives across sectors and disciplines.[50] It must consider both the intended benefits and potential unintended consequences of decarbonization and sustainability policies. A genuinely just transition balances short-term socio-economic needs with long-term environmental goals, ensuring that intergenerational equity remains a central tenet of sustainable development.[51]In the context of international transport, particularly aviation, the imperative for a just transition becomes even more complex. The COVID-19 pandemic underscored the sector's vulnerability to global shocks, with significant socio-economic repercussions. Historically, the expansion of air connectivity and

[47] id
[48] id
[49] Committee for Development Policy, A globally just transition: Perspectives from the Committee for Development, Policy Note (2023)
[50] id
[51] Broekema G. et al, supra note 12

declining airfare costs have played a pivotal role in reducing global inequality, enhancing access to opportunities in education, health, trade, and tourism, particularly in developing regions. To ensure a just transition, it is essential to explore solutions that simultaneously mitigate environmental impacts and create opportunities. [52]

For African airports, the challenge lies in adopting sustainability measures that do not hinder but rather enhance development gains. A just transition in this context entails designing solutions that mitigate environmental harm while catalysing economic growth, job creation, and improved access. It requires a fine-tuned balance between climate responsibility and the urgent need to accelerate socio-economic transformation on the continent. In this regard, African airport governance and policy must embrace a just transition framework that promotes climate resilience, inclusivity, and innovation.

A 'Just' Transition in Aviation

In the evolving discourse on sustainable aviation, the concept of a just transition has gained prominence, particularly in addressing the sector's multifaceted environmental impacts, namely, aviation noise, degradation of local air quality, and contributions to climate change. Central to this transition is the notion of "building back better," a principle increasingly embedded in international aviation recovery strategies post-COVID-19. ICAO has been instrumental in steering this transformation. During the 2019–2022 triennium, ICAO's Air Transport Bureau's Environment Branch advanced a notably ambitious environmental agenda. This agenda is intricately aligned with 14 of the 17 UN SDGs), reflecting the sector's commitment to global sustainability imperatives.[53]

By integrating the SDGs into its strategic planning, ICAO reinforces the aviation sector's contribution to the UN's Agenda 2030 for Sustainable Development, a comprehensive global framework for achieving social equity, economic development, and environmental protection. Within this framework, a just transition is not merely a technical or regulatory shift; it represents a broader systemic change. It ensures that environmental progress in aviation is pursued in a way that is inclusive, equitable, and sensitive to the needs of all stakeholders, including vulnerable communities and developing regions, particularly in Africa, where aviation is both a catalyst for development and a source of environmental concern.

One policy proposition is the carbon solidarity contribution; a levy applied at the point of sale by airlines. Unlike blanket aviation taxes, this mechanism could be differentiated based on the traveller's region of origin, ensuring that passengers from less developed countries are not unduly burdened. The funds generated could then support clean energy transitions in vulnerable economies, helping to reduce domestic energy costs and improve business competitiveness.[54] This reflects a distributive justice approach, ensuring that the costs and benefits of climate action are equitably shared.

Accelerating fleet renewal and aircraft innovation represents another vital pathway. The introduction of the next-generation aircraft, characterized by 10–15% improvements in fuel efficiency, reduced particulate emissions, and quieter operations, offers immediate environmental

[52] id
[53] ICAO, Innovation for a green transition, Environmental Report (2022)
[54] Broekema G. et al, supra note 12

gains. Policy incentives, such as accelerated depreciation allowances for airlines that commit to renewing their fleets, could expedite adoption.[55] Complementing these efforts, international carbon-reduction mechanisms, such as the Paris Agreement's Article 6 Crediting Mechanism, offer opportunities to mitigate emissions not covered by CORSIA.[56]

The use of high-integrity offset standards, such as Gold Standard carbon projects, for emissions not covered by CORSIA could ensure environmental integrity while upholding fairness in international climate governance.[57]

Ultimately, advancing a just transition in aviation requires policy frameworks underpinned by evidence-based research. A nuanced understanding of the interlinked economic, environmental, and social effects of aviation policies is essential. By adopting a holistic and equity-centred approach, government and industry can co-create a future in which the benefits of sustainable aviation are broadly shared, [58] ensuring that no region or community is left behind.

3. Methodology

Research Design

This thesis adopted a Critical Realist research philosophy, which was well-suited to examine the complexities of sustainability in African airports within the framework of a just transition. Critical Realism acknowledges that reality consists of multiple layers; the empirical, what is observed, the actual events that occur, and the real underlying structures and mechanisms that shape events.[59] This philosophical stance enabled critical examination of sustainability challenges, as it allowed for the exploration of structural and systemic barriers that influence sustainability efforts in African airports.

A Critical Realist approach helped to identify context-dependent underlying causal mechanisms, such as economic policies, regulatory frameworks, and institutional governance, that impact the success of sustainable transition strategies in airports. By using this philosophy, this thesis aspired to provide more than just a descriptive analysis of sustainability efforts and instead uncover the underlying socio-economic, political, and environmental factors that shape outcomes. This perspective aligned with the primary analytical method, secondary data analysis, as it allowed for the interpretation of policy documents, sustainability reports, and case study findings to shed light on both the explicit and implicit influences on airport sustainability.

Data Collection Methods

Given the research philosophy, this study employed a Comparative Case Study design, supplemented by Document Analysis, to examine sustainability initiatives in selected African airports. This approach allowed for an analysis of different airport contexts framed by the

[55] id
[56] UNFCCC, Rules, modalities and procedures for the mechanism established by Article 6, paragraph 4, of the Paris Agreement, Decision 3/CMA of 8 March 2022
[57] Gold Standard, Announcing gold Standard for the Global Goals, (2016)
[58] id
[59] Bhaskar, Roy. "On the possibility of social scientific knowledge and the limits of naturalism." *Journal for the Theory of social Behaviour* (1978).

dependent underlying causal mechanisms, while uncovering patterns and variations in sustainability implementation.

Comparative Case Study Approach

The study examined three major African airports:

1. Johannesburg OR Tambo International Airport (South Africa)
2. Mombasa Moi International Airport (Kenya)
3. Félix-Houphouët-Boigny International Airport in Abidjan, (Ivory Coast)

These cases were selected based on their varying levels of sustainability adoption, regulatory environments, and socio-economic conditions. By comparing these cases, the study highlighted best practices, barriers, and opportunities for a just transition within African aviation. The case study method is useful for understanding how policies, governance structures, and sustainability initiatives vary across different airports and how these factors influence the just transition process. The case study method offers a robust approach for exploring the complex and context-dependent dynamics for a just transition.

Particularly useful for examining how policies, governance structures, and sustainability initiatives differ across airports, and how these institutional and organizational variations shape pathways. By enabling in-depth, contextualized analysis, the case study approach facilitates a nuanced understanding of the interplay between local conditions and broader systemic forces, thereby shedding light on the diverse expressions and challenges of implementing a just transition in different airport settings.

Document Analysis

Since the study relied primarily on secondary data, Document Analysis was the core data collection method. This involved a systematic procedure for reviewing or evaluating documents, which was used to provide context, generate questions, supplement other types of research data, track change over time and corroborate other sources.[60] Document analysis included both quantitative and qualitative components: the approach presented can be used with either set of methods, but emphasizing the qualitative with respect to sustainability in African airports, to include:

Policy documents: National, Regional & Global aviation policies, Environmental regulations, Global agreements such as ICAO's CORSIA framework.

1. Sustainability reports: Airport annual sustainability reports, Carbon footprint assessments, ACI's Airport Carbon Accreditation
2. Academic and industry literature; Research papers, Case studies, best practice reports
3. Financial and investment reports; Funding strategies for green infrastructure, Public-private partnerships in sustainable aviation.

The Document Analysis approach allowed for a critical evaluation of existing policies, initiatives, and their impact on sustainability transitions. By applying a thematic analysis framework, the study systematically identified and interpreted recurring patterns within the data, allowing for the extraction of key themes relevant to the just transition in the aviation sector. Core themes such as

[60] Bowen, Glenn A. "Document analysis as a qualitative research method." *Qualitative research journal* 9, no. 2 (2009): 27-40.

governance structures, financing mechanisms, stakeholder engagement practices, and the adoption of low-carbon technologies were analyzed across the selected case studies. This approach enabled not only the identification of commonalities and divergences among cases but also facilitated a deeper understanding of the institutional and contextual factors that influence these dimensions. Through cross-case comparison, the thematic analysis contributed to a richer, more nuanced account of how various actors navigate the complex terrain of sustainability transitions in airport contexts.

Justification for Data Collection Methods

The combination of Comparative Case Study and Document Analysis within a Critical Realist framework ensured a holistic understanding of sustainability transitions in African airports. This design was justified because:

1. It accommodates the complexity of sustainability challenges by recognizing the influence of political, economic, and institutional structures.

2. It allows for in-depth cross-case comparisons to uncover both unique and shared challenges across different airports.

3. It effectively utilizes secondary data, ensuring a rigorous and structured analysis of available information while avoiding the challenges of primary data collection constraints.

By using this research design, the study aims to provide evidence-based recommendations for policy enhancements, investment strategies, and governance reforms necessary to achieve a just transition in African airports.

Sampling Techniques

The sampling strategy employed in this study is designed to support the Critical Realist research philosophy and the Comparative Case Study approach. Under Critical Realism, the goal is to explore not only observable outcomes but also the underlying structures and mechanisms that shape sustainability transitions. As such, sampling is not intended to achieve statistical representativeness but rather to facilitate analytical generalization, enabling rich, contextual insights into the workings of sustainability in African airports. Given that the research relied on secondary data, sampling was implemented at two levels:

1. Selection of Case Study Sites (Airports)
2. Selection of Documents for Analysis

These sampling processes were guided by purposive and criterion-based techniques, ensuring that the cases and data sources selected were relevant, information-rich, and contextually diverse.

Case Selection – Comparative Case Study Sampling

The selection of case study airports followed a purposive sampling strategy, intended to capture diversity across several dimensions relevant to the research objectives. Four airports were chosen for detailed analysis:

1. Johannesburg OR Tambo International Airport (South Africa)
2. Mombasa Moi International Airport (Kenya)
3. Casablanca Mohammed V International Airport (Morocco)

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The selection criteria included:

- Geographical Representation: The airports are located in different regions of Africa - Southern, Eastern, Northern, and Eastern again (due to economic and strategic contrast) - offering a continent-wide perspective on sustainability challenges and practices.
- Institutional and Policy Variability: These airports operate within different national regulatory and governance frameworks, providing opportunities to explore how institutional arrangements and state policies influence sustainability outcomes.
- Diversity in Sustainability Practices: The airports demonstrate varying degrees of engagement with sustainability initiatives - from airports with internationally recognized green certifications (e.g., ACI's Airport Carbon Accreditation) to those at earlier stages of environmental integration. This variation helps to highlight best practices as well as constraints.
- Socio-Economic Contexts: Each airport is embedded in a unique socio-economic setting, from more industrialized economies like South Africa to emerging economies such as and Kenya. This range enables an analysis of how resource availability, economic priorities, and public investment affect sustainable aviation efforts.

This purposive selection ensured that the cases were both comparable and contrasting, supporting the study's aim of uncovering the causal mechanisms and structural dynamics that shape the sustainability transition across different African contexts. Furthermore, the sampling enhanced the explanatory power of the research by enabling cross-case thematic analysis, highlighting both commonalities and divergences in sustainability "flight paths".

Document Selection – Sampling for Document Analysis

Given the reliance on secondary data, the study also employed purposive and criterion-based sampling for Document Analysis. The documents selected are those most relevant to understanding sustainability strategies, policy frameworks, and institutional practices affecting African airports.

Types of documents included:

- Policy and Regulatory Documents: These include national aviation policies, environmental and climate change regulations, civil aviation authority reports, and international agreements such as ICAO's CORSIA framework. These documents provide the formal, institutional context for sustainability practices.
- Sustainability and Environmental Reports: These consist of airport-issued sustainability or environmental performance reports, ACI's Airport Carbon Accreditation documentation, carbon footprint assessments, and energy efficiency initiatives. These reports offer insights into operational sustainability strategies and their evolution over time.
- Academic and Industry Literature: Peer-reviewed journal articles, case studies, consultancy white papers, and industry association publications (e.g., ACI Africa, ICAO, UNEP) are used to complement institutional data with broader theoretical and practical insights.
- Financial and Investment Reports: Documents covering funding models, public - private partnerships, donor-supported projects, and government investment strategies in sustainable aviation infrastructure are analyzed to understand the financial dimension of sustainability transitions.

- Relevance: The content must directly relate to sustainability, aviation, just transition, governance, or infrastructure in an African context.
- Credibility and Source Authenticity: Preference is given to official publications by recognized bodies such as ICAO, ACI, UNEP, national governments, or reputable academic publishers.
- Timeframe: Most documents were published within the last 10–15 years, ensuring the analysis reflects recent developments and current practices.
- Availability and Accessibility: Documents that are publicly available or accessible through academic libraries and institutional repositories were prioritized for transparency and replicability.

This structured document sampling strategy supports thematic coding and analysis, allowing for the identification of patterns, contradictions, and gaps in sustainability efforts. The combination of varied document types ensures a multi-dimensional perspective, essential for analyzing the interplay between technical, institutional, and socio-economic drivers in the just transition of African airports.

Justification of Sampling Techniques

The choice of purposive sampling was grounded in the qualitative, interpretive nature of this study and aligns with the Critical Realist commitment to explanatory depth rather than empirical generalization. Specifically, this approach is justified on the following grounds:

1. Relevance to Research Objectives: The selected cases and documents are directly aligned with the study's focus on just transitions and sustainability in African aviation, enabling meaningful analysis of causal mechanisms and contextual variations.

2. Depth over Breadth: Given the complex, layered nature of sustainability transitions, a small number of well-chosen cases provide richer insights than a large sample with shallow engagement.

3. Comparative Power: By selecting cases with both similarities and differences, the study facilitates comparative insights that illuminate how context influences sustainability outcomes.

4. Access and Feasibility: The reliance on secondary data ensures the research is feasible within time and resource constraints, while still allowing for systematic, rigorous analysis.

On the whole, the sampling strategy enhances the credibility, relevance, and depth of the findings. It supports the overarching aim of the thesis: to uncover the institutional, political, and economic mechanisms influencing sustainability transitions in African airports and to provide context-sensitive recommendations for advancing a just and sustainable future in African aviation.

Data Analysis Approach

The data analysis in this study is guided by a Critical Realist framework, which supports a layered understanding of the empirical (what is observed), the actual (what occurs), and the real (the underlying mechanisms and structures that shape events). This ontological and epistemological orientation is the foundation of the study's aim: not simply to describe sustainability initiatives at African airports but to uncover the deeper, often obscure structures such as governance systems, regulatory frameworks, and socio-economic contexts that influence sustainability transitions.

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Given the reliance on secondary data and a Comparative Case Study approach, the analysis follows a qualitative, interpretive, and thematic strategy. The process involves multiple stages of engagement with the data, including document review, thematic coding, pattern identification, and cross-case synthesis.

Thematic Analysis Framework

The core analytical method employed in this thesis is thematic analysis, which enables systematic identification, organization, and interpretation of patterns and themes across volumes of textual data. Thematic analysis is particularly suitable in this context because it allows for the exploration of both manifest content (explicit information) and latent content (underlying meanings and assumptions) a key objective in Critical Realist research. This study follows Braun and Clarke's[61] six-phase approach to thematic analysis:

- Familiarization with the Data: All selected documents were read thoroughly to gain an in-depth understanding of the material. Initial impressions, recurring topics, and points of interest were noted to inform early thinking about possible themes.
- Generating Initial Codes: The data were systematically coded to identify relevant extracts. Codes were developed both inductively (emerging from the data) and deductively (informed by theoretical constructs such as "just transition", "institutional capacity", "stakeholder engagement", and "policy alignment").
- Searching for Themes: Related codes were grouped into candidate themes. For example, codes such as "green financing gaps", "regulatory inconsistencies", and "political will" were clustered under broader themes like Governance and Institutional Structures or Economic and Financial Mechanisms.
- Reviewing Themes: The themes were reviewed across individual cases and the entire dataset to ensure coherence, consistency, and relevance. At this stage, cross-case comparison began to take shape, highlighting how themes appeared similarly or differently across airports.
- Defining and Naming Themes: Final themes were clearly defined and refined to ensure they accurately captured the essence of the data. Themes were aligned with research questions and theoretical constructs within the Critical Realist framework.
- Writing up: Analytical findings were contextualized within the broader literature and theoretical framework. Each theme supported by evidence drawn from multiple documents and cases, illustrating the interplay between local and systemic factors in shaping airport sustainability transitions.

Analytical Focus Areas

To ensure a focused and consistent analysis across the selected airports, the following analytical domains were emphasized:

- Governance and Institutional Structures: Assessment of how different institutional arrangements and governance capacities support or hinder sustainability efforts.

[61] Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

- Policy Frameworks and Regulatory Compliance: Examination of the influence of national, regional, and global policy instruments such as ICAO's CORSIA or national climate strategies on airport practices.
- Economic and Financial Mechanisms: Analysis of the availability and structure of funding, including public-private partnerships, donor support, and green financing tools.
- Stakeholder Engagement and Participation: Evaluation of how airports engage local communities, civil society, and environmental actors in shaping and implementing sustainability initiatives.
- Technological and Operational Innovations: Documentation of low-carbon technologies and energy-efficient infrastructure deployment, along with barriers to their adoption.

These themes were used as categories and comparison points across cases, allowing the study to track both convergence and divergence among the selected airports.

Cross-Case Comparison and Causal Layering

To operationalize the Critical Realist, focus on causal mechanisms, the analysis employed

cross-case comparison and causal layering to identify not just what varies across cases, but

why those differences exist.

- Cross-Case Comparison: The selected airports were compared across key themes, revealing how varying political economies, policy ecosystems, and institutional strengths lead to differing levels of sustainability adoption.
- Causal Layering: Inspired by Bhaskar's (1978) stratified ontology, causal analysis occurred at three levels:
  - Empirical – observable outcomes (e.g., energy efficiency projects, carbon accreditation status)
  - Actual – events and processes (e.g., implementation of sustainability plans, delays in project rollout)
  - Real – deeper structures (e.g., financing capacity, regulatory rigidity, governance culture)

This multi-level analysis enabled the research to move beyond surface-level description and toward explanatory depths, providing runway guidance on the enduring challenges and enabling conditions for a just sustainability transition in African aviation.

4. Findings and Discussions

Across the globe, airports are investing in cleaner technologies and reducing emissions for every layer of their operations. According to ACI World statistics (Haldane Dodd, 2025), 592 airports in 89 countries joined the Airport Carbon Accreditation program, which is more than half of global passenger traffic, collectively cutting emissions by 550,000 tonnes of CO^2 (Figure 2)

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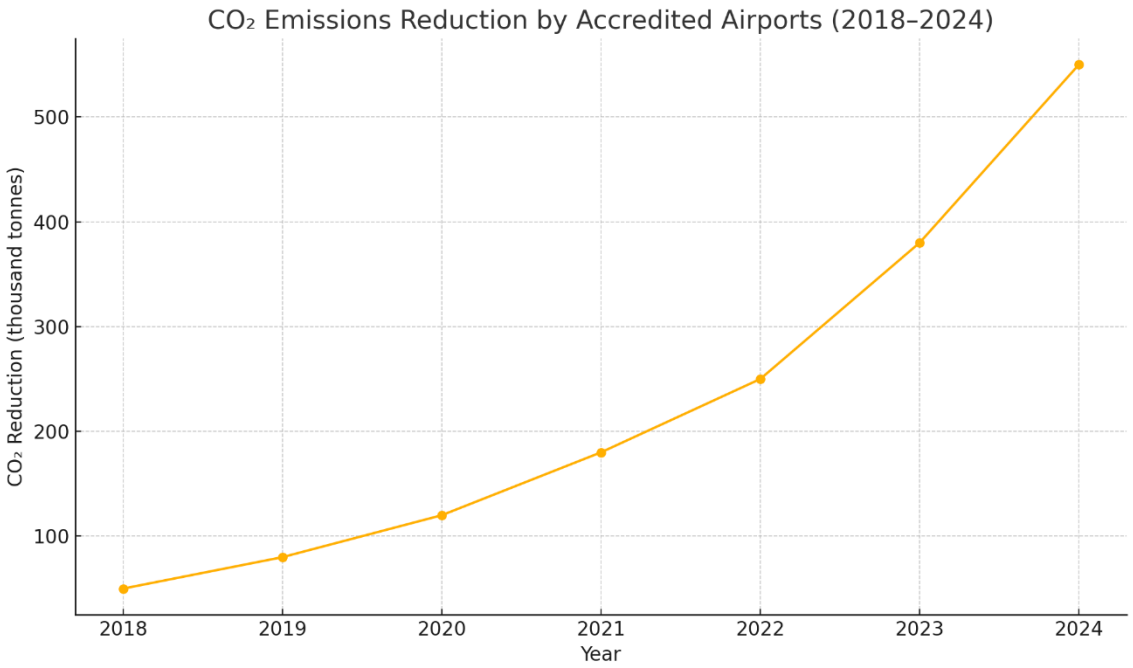

Figure 2: CO2 Emissions Reduction by Accredited Airports (2018-2024)

Examples of innovation include Amsterdam Schiphol, which partnered with Engie and Phillips to ensure long-term energy savings and reduced material waste. Athens Airport is heading toward 100% solar electricity; Cochin Airport is already fully powered by solar energy and Galapagos Airport uses only renewable energy sources both wind and solar-generated. In this chapter, we will see the initiatives African airports have and or are putting in place in an effort to ensure sustainability.

Current Sustainability Initiatives in African Airports

Several African airports have been implementing sustainability initiatives to reduce their environmental impact and promote sustainable practices. Amsterdam Schiphol, Athens, Cochin, and Galapagos airports represent global benchmarks for sustainability with renewable energy use, circular waste strategies, and green building designs. Similarly, African airports like Cape Town International and Felix Houphouët-Boigny have made strides in carbon management, energy efficiency, and waste reduction, often in collaboration with international organizations and local communities. Here are some notable examples:

1.Green Building Standards: Many airports are adopting green building standards for new constructions and renovations. The concept of a "green airport" was first introduced by the U.S.-based Clean Airports Partnership (CAP) in 2005 as part of the Green Airport Initiative (GAI) program. It focuses on seven dimensions of an airport's environmental footprint and produces an environmental report with specific recommendations for the airport's green development. Airports Council International (ACI) has also established the Green Airport Recognition (GAR) and Airport Carbon Accreditation (ACA) programs to measure the achievements of airports' green transition efforts through the classification of environmental themes and certification levels. This includes

using sustainable materials, energy-efficient systems, water conservation measures and sustainable design principles.

2. Solar Energy Projects: Airports like Cape Town International Airport in South Africa (S. Africa, n.d.) have invested in solar energy projects to power airport operations. These initiatives not only reduce reliance on fossil fuels but also lower operational costs.

3. Waste Management Programs: Airports are increasingly focusing on waste reduction and recycling programs. For example, Nairobi's Jomo Kenyatta International Airport has implemented waste segregation and recycling initiatives to minimize landfill contributions.

4. Sustainable Transportation: Many airports are promoting sustainable transportation options for passengers. This includes electric vehicle charging stations, partnerships with public transport systems, and incentives for using eco-friendly transport options. In November 2023 Kenya Airports Authority partnered with two local transportation companies to launch electric commuter buses into Jomo Kenyatta International Airport.

5. Carbon Offset Programs: Some airports and airlines are introducing carbon offset programs that allow travelers to offset their carbon emissions from flights. The goal of offsetting programs is not to reduce the harmful gasses produced while flying, but rather to invest in projects that reduce emissions elsewhere. This can include investing in local environmental projects or renewable energy initiatives. The airlines that operate into Africa that have Carbon Offset Programmes include Kenya Airways, Emirates and British Airways. Kenya Airways the national carrier for Kenya, whose hub airport is Jomo Kenyatta International Airport, has teamed up with Wildlife Works to allow passengers offset carbon emissions from every flight.

6. Biodiversity Conservation: Airports are also engaging in biodiversity conservation efforts. For instance, some airports are creating green spaces and wildlife habitats around their facilities to support local ecosystems. Eldoret International Airport has put 700 acres of land under an afforestation programme with 280,000 Eucalyptus trees.

7. Water Conservation: Airports are implementing water-saving technologies, such as rainwater harvesting systems and water-efficient fixtures, to reduce water consumption.

8. Community Engagement: Many airports are working with local communities to promote sustainability initiatives. This can include educational programs, community clean-up events, and partnerships with local organizations focused on environmental conservation.

Sustainable Aviation Fuel (SAF): Some African airports are exploring the use of sustainable aviation fuels to reduce the carbon footprint of air travel. This is still in the early stages but represents a significant step towards greener aviation. In May 2023

Kenya Airways became the first African airline to use SAF for a long-haul flight, using Eni Sustainable Mobility aviation fuel.

10. Regulatory Compliance and Reporting: Airports are increasingly aligning with international sustainability standards and reporting frameworks, such as the Airport Carbon Accreditation program, ISO 14001, World Health Organization Air Quality Standards, to track and improve their environmental performance.

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These initiatives reflect a growing recognition of the importance of sustainability in the aviation sector, particularly in the context of climate change and environmental degradation. As awareness and technology continue to evolve, more airports across Africa are likely to adopt similar practices.

Energy Efficiency and Renewable Energy Adoption

Energy efficiency and renewable energy adoption at airports are critical components of sustainability initiatives aimed at reducing carbon footprints and operational costs. Here are some key aspects and examples of how airports are implementing these strategies:

Energy Efficiency Initiatives

1. LED Lighting: Many airports are replacing traditional lighting with energy-efficient LED systems. This not only reduces energy consumption but also lowers maintenance costs due to the longer lifespan of LEDs.

2. HVAC Systems: Airports are upgrading heating, ventilation, and air conditioning (HVAC) systems to more energy-efficient models. Smart thermostats and automated systems help optimize energy use based on occupancy and weather conditions.

3. Building Insulation: Improved insulation in terminal buildings helps maintain temperature, reducing the need for heating and cooling. This can significantly lower energy consumption.

4. Energy Management Systems: Airports are implementing advanced energy management systems that monitor and control energy use in real-time, allowing for better efficiency and identification of areas for improvement.

5. Smart Technology: The use of smart technology, such as occupancy sensors and automated lighting controls, helps reduce energy use in less-frequented areas of the airport.

Renewable Energy Adoption

1. Solar Energy: Many airports are investing in solar power installations. For example:

- Cape Town International Airport: This airport has a significant solar photovoltaic (PV) installation that generates a substantial portion of its energy needs. (S. Africa, n.d.)
- Kigali International Airport: In Rwanda, the airport has also embraced solar energy, with plans for further expansion of solar facilities.

2. Wind Energy: Some airports are exploring wind energy as a renewable source. While less common, there are pilot projects in various regions assessing the feasibility of wind turbines near airport facilities.

3. Geothermal Energy: Airports in regions with geothermal resources are considering geothermal heating and cooling systems to reduce reliance on fossil fuels.

4. Sustainable Aviation Fuel (SAF): While not a direct renewable energy source for airport operations, the adoption of SAF is crucial for reducing the carbon footprint of air travel. Airports are working with airlines and fuel suppliers to facilitate the use of SAF.

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5. Energy Storage Solutions: To complement renewable energy sources, airports are investing in energy storage systems, such as batteries, to store excess energy generated during peak production times for use during high-demand periods.

Case Studies

- Hamad International Airport (Qatar): Although not in Africa, it serves as a leading example of energy efficiency and renewable energy adoption. The airport has implemented a range of energy-saving measures and has a large solar power installation. (Hamad Int) (Hamad Sustainability Report, 2021/2022).
- Addis Ababa Bole International Airport (Ethiopia): The airport has integrated energy-efficient technologies and is exploring renewable energy options to enhance its sustainability profile.
- Nairobi Jomo Kenyatta International Airport (Kenya): The airport has made strides in energy efficiency and is exploring solar energy projects to reduce its carbon footprint.

Challenges and Future Directions

While many airports are making progress in energy efficiency and renewable energy adoption, challenges remain, including:

- Initial Investment Costs: The upfront costs of implementing energy-efficient technologies and renewable energy systems can be significant, though they often lead to long-term savings.
- Regulatory and Policy Frameworks: Supportive policies and regulations are essential to encourage investment in sustainable practices.
- Technological Advancements: Continued innovation in energy-efficient technologies and renewable energy systems will be crucial for airports to meet their sustainability goals.

As the aviation industry continues to evolve, the focus on energy efficiency and renewable energy adoption will likely intensify, driven by regulatory pressures, stakeholder expectations, and the need to combat climate change.

Waste Management and Circular Economy Approaches

Waste management and circular economy approaches in African airports are increasingly

important as they aim to minimize waste generation, promote recycling, and enhance

resource efficiency. Here are some key aspects and examples:

Waste Management Initiatives

1. Waste Segregation: Airports are implementing waste segregation practices to separate recyclables, organic waste, and general waste at source. This helps improve recycling rates and reduces landfill contributions.

2. Recycling Programs: Many airports have established partnerships with local recycling companies to ensure that recyclable materials, such as plastics, paper, and metals, are processed appropriately. For example, Cape Town International Airport has a robust recycling program that includes the collection of various materials.

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3. Composting: Some airports are adopting composting initiatives for organic waste generated by food services. This not only reduces waste sent to landfills but also produces valuable compost that can be used in landscaping.

4. Education and Awareness: Airports are conducting awareness campaigns for passengers and staff to promote responsible waste disposal and recycling practices. This includes signage and informational materials throughout the airport.

5. Digital Solutions: The use of digital platforms to track waste generation and management can help airports identify areas for improvement and optimize waste handling processes.

Circular Economy Approaches

1. Resource Recovery: Airports are exploring ways to recover valuable materials from waste streams, such as metals from old equipment or construction materials from renovations, to be reused in new projects.

2. Sustainable Procurement: Airports are increasingly adopting sustainable procurement practices, prioritizing products and services that minimize environmental impact and support circular economy principles.

3. Collaboration with Stakeholders: Engaging with airlines, concessionaires, and local communities to develop joint waste management and circular economy initiatives can enhance overall effectiveness. For instance, partnerships can lead to shared recycling facilities or joint educational campaigns.

4. Innovative Waste-to-Energy Solutions: Some airports are investigating waste-to-energy

technologies that convert waste into energy, reducing landfill use while generating renewable energy.

Examples of African Airports

- Cape Town International Airport (South Africa): This airport has implemented comprehensive waste management and recycling programs, achieving significant reductions in waste sent to landfills. (S. Africa, n.d.)
- Nairobi Jomo Kenyatta International Airport (Kenya): The airport has initiated waste segregation and recycling efforts, focusing on reducing plastic waste and promoting sustainable practices among stakeholders.
- Addis Ababa Bole International Airport (Ethiopia): The airport is exploring circular economy principles by focusing on resource recovery and sustainable procurement practices.

5. Conclusion

The integration of waste management and circular economy approaches in African airports is essential for promoting sustainability, reducing environmental impact, and enhancing operational efficiency. As these initiatives continue to evolve, they will play a crucial role in the broader context of sustainable aviation and environmental stewardship.

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Water Conservation and Management

Water conservation and management at African airports are critical due to the continent's varying water availability and the increasing demand for sustainable practices. Airports are implementing several strategies to reduce water consumption and improve water management, which is essential for both environmental sustainability and operational efficiency.

Key Water Conservation and Management Strategies

- Rainwater Harvesting: Many airports are installing rainwater harvesting systems to collect and store rainwater for non-potable uses, such as irrigation and toilet flushing. This reduces reliance on municipal water supplies.
- Water-Efficient Fixtures: Airports are upgrading to water-efficient fixtures, such as low-flow faucets, toilets, and urinals, to minimize water usage in terminals and restrooms.
- Irrigation Management: Airports with landscaping are adopting smart irrigation systems that use sensors to optimize watering schedules based on weather conditions and soil moisture levels, reducing water waste.
- Greywater Recycling: Some airports are exploring greywater recycling systems that treat and reuse water from sinks and showers for irrigation or toilet flushing, further conserving water resources.
- Monitoring and Reporting: Implementing water management systems that monitor water usage in real-time helps airports identify areas for improvement and track progress toward conservation goals.

Examples of Water Conservation Initiatives

- Cape Town International Airport (South Africa): The airport has implemented rainwater harvesting systems and water-efficient fixtures, significantly reducing its overall water consumption. (S. Africa, n.d.)
- Nairobi Jomo Kenyatta International Airport (Kenya): The airport has focused on improving irrigation practices and installing water-efficient fixtures to enhance water conservation efforts.
- Addis Ababa Bole International Airport (Ethiopia): The airport is exploring greywater recycling and rainwater harvesting to improve its water management practices.
- Eldoret International Airport: EIA has a water recycling initiative, which ensures that all the water used is treated and channeled back into circulation. This they have achieved by leading rainwater through drains to a central water holding point or Dam, where the water is treated and reused.

The integration of waste management, circular economy principles, water conservation, and carbon-reduction strategies in African airports is essential for advancing sustainability, improving operational efficiency, and minimizing environmental impacts. Through innovative technologies and resource-efficient practices, airports can reduce waste, lower water consumption, and cut greenhouse gas emissions, thereby strengthening environmental stewardship within the aviation sector. Collectively, these measures position African airports as key contributors to sustainable aviation and align their operations with broader regional and global climate and environmental goals.

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Carbon Footprint and Greenhouse Gas Emissions

The carbon footprint and greenhouse gas (GHG) emissions at African airports are critical issues as the aviation sector contributes significantly to global emissions. In 2023 aviation accounted for 2.5% of global energy-related emissions. In aviation, the majority of scope 1 emissions originate from jet fuel, with 99% of these being CO2. Understanding and managing these emissions is essential for aligning with international climate goals and promoting sustainable aviation practices.

Key Factors Contributing to Carbon Footprint and GHG Emissions

1. Aircraft Operations: The primary source of emissions at airports comes from aircraft during takeoff, landing, and taxiing. The type of aircraft and the efficiency of operations play a significant role in determining emissions levels.

2. Ground Support Equipment (GSE): Vehicles used for ground handling, such as baggage tugs, fuel trucks, and maintenance vehicles, contribute to emissions, especially if they rely on fossil fuels.

3. Energy Consumption: The energy used in airport facilities, including terminals, lighting, and HVAC systems, contributes to the overall carbon footprint. Airports that rely on non-renewable energy sources have higher emissions.

4. Passenger and Cargo Transport: Emissions from passenger transport to and from the airport, as well as cargo transport, also contribute to the overall carbon footprint.

Initiatives to Reduce Carbon Footprint and GHG Emissions

1. Carbon Management Programs: Many airports are participating in carbon management programs, such as the Airport Carbon Accreditation program, which helps them measure, manage, and reduce their carbon emissions.

2. Sustainable Aviation Fuels (SAF): Some airports are exploring the use of SAF, which can significantly reduce lifecycle GHG emissions compared to conventional jet fuels.

3. Renewable Energy Adoption: Airports are investing in renewable energy sources, such as solar and wind, to power their operations, thereby reducing reliance on fossil fuels.

4. Energy Efficiency Improvements: Upgrading infrastructure and implementing energy-efficient technologies can lower energy consumption and associated emissions.

5. Public Transportation Initiatives: Encouraging the use of public transport and electric vehicles for passenger access to airports can help reduce emissions from ground transportation.

Examples of African Airports Addressing Carbon Footprint

- Cape Town International Airport (South Africa): The airport has implemented a carbon management program and invested in renewable energy projects, significantly reducing its carbon footprint. (S. Africa, n.d.)
- Nairobi Jomo Kenyatta International Airport (Kenya): The airport is working on improving energy efficiency and exploring the use of sustainable aviation fuels to lower GHG emissions.

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- Addis Ababa Bole International Airport (Ethiopia): The airport has initiated programs to monitor and reduce its carbon emissions, focusing on energy efficiency and renewable energy sources.

Challenges And Opportunities for A Just Transition

Social and Economic Implications of Sustainability in African Aviation

The social and economic implications of sustainability in African aviation are critical as the continent seeks to balance growth in the aviation sector with environmental stewardship and social equity.

Economic Implications

Growth of the Aviation Sector:

The aviation industry is a significant contributor to Africa's GDP and job creation. Despite the challenges, the importance of sustainable aviation practices can enhance this growth by attracting more tourists and business travelers who prioritize environmentally friendly options. According to IATA the continent is poised to grow significantly with over 260 million passengers expected in 2035. (see Figure 3).

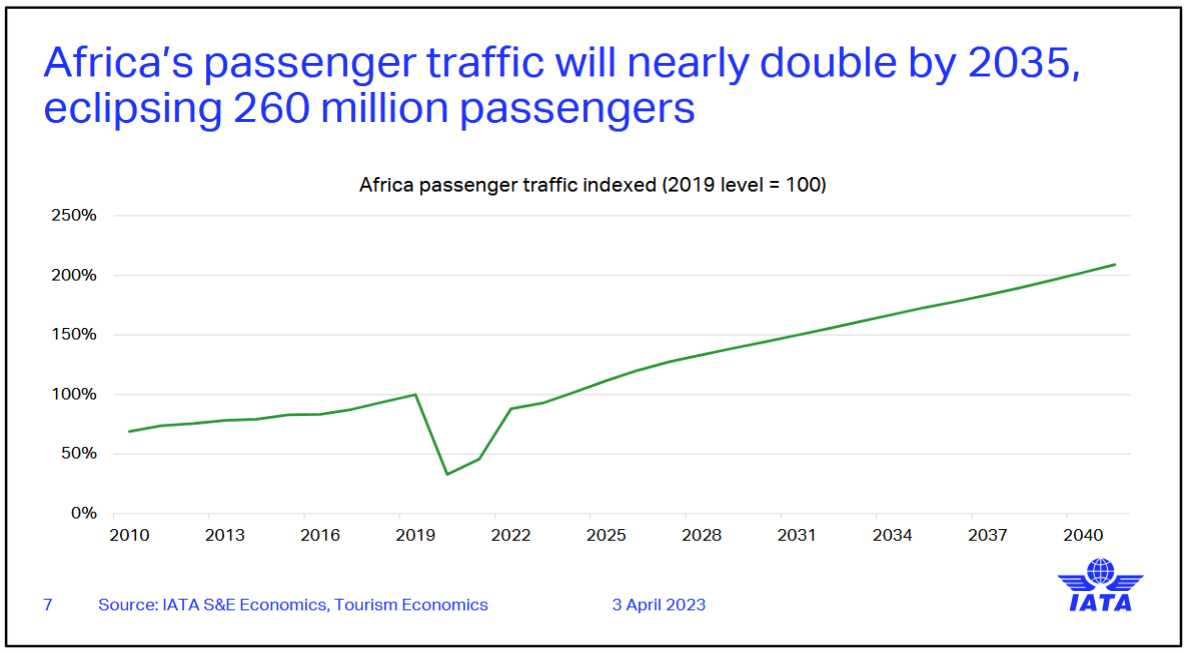

Figure 3: Projected Passenger Growth in African Aviation (2020-2035)

Africa's passenger traffic will nearly double by 2035, eclipsing 260 million passengers (134 million for 2022 to 263 in 2035). Eastern, Central/Western Africa to bring further contribution to overall traffic growth in the region. This surge in air travel necessitates investment in green technologies and infrastructure to balance economic growth with sustainability. Investments such as electric aircraft and sustainable aviation fuels (SAFs), can stimulate economic development and innovation.

Cost Efficiency:

Implementing sustainable practices can lead to long-term cost savings for airlines through improved fuel efficiency, reduced operational costs, and lower carbon taxes or penalties. Airlines that adopt sustainable practices may benefit from incentives and subsidies from governments and international organizations aimed at reducing carbon emissions.

Infrastructure Development:

Sustainable aviation requires investment in infrastructure, such as green airports and efficient air traffic management systems. African nations, airport authorities, and regional organizations are increasingly recognizing that modernizing aviation infrastructure offers an opportunity not just to boost connectivity, traffic and economic development, but also to address the challenges of climate change. Development of renewable energy sources to power airport operations can also contribute to energy security and reduce reliance on fossil fuels. Kigali's new Bugesera Airport has been designed as Africa's first green airport aiming for LEEDs certification.

Market Competitiveness:

Africa is home to over 18% of the world's population. As global demand for sustainable travel increases, African airlines that adopt sustainable practices may gain a competitive edge in the international market. Airlines that prioritize sustainability can enhance their brand reputation and attract environmentally conscious consumers.

Social Implications

Job Creation and Workforce Development:

The transition to sustainable aviation can create new job opportunities in sectors such as renewable energy, aircraft maintenance, and sustainable tourism. Currently Africa creates 7.7 million jobs within the Aviation industry and contributes 63billion dollars to the GDP. Training and reskilling programs will be essential to prepare the workforce for new roles in a greener aviation industry. Africa is also home to the world's youngest population, thus in the 21st century the growth in the working age population will originate from this continent (Figure 4)

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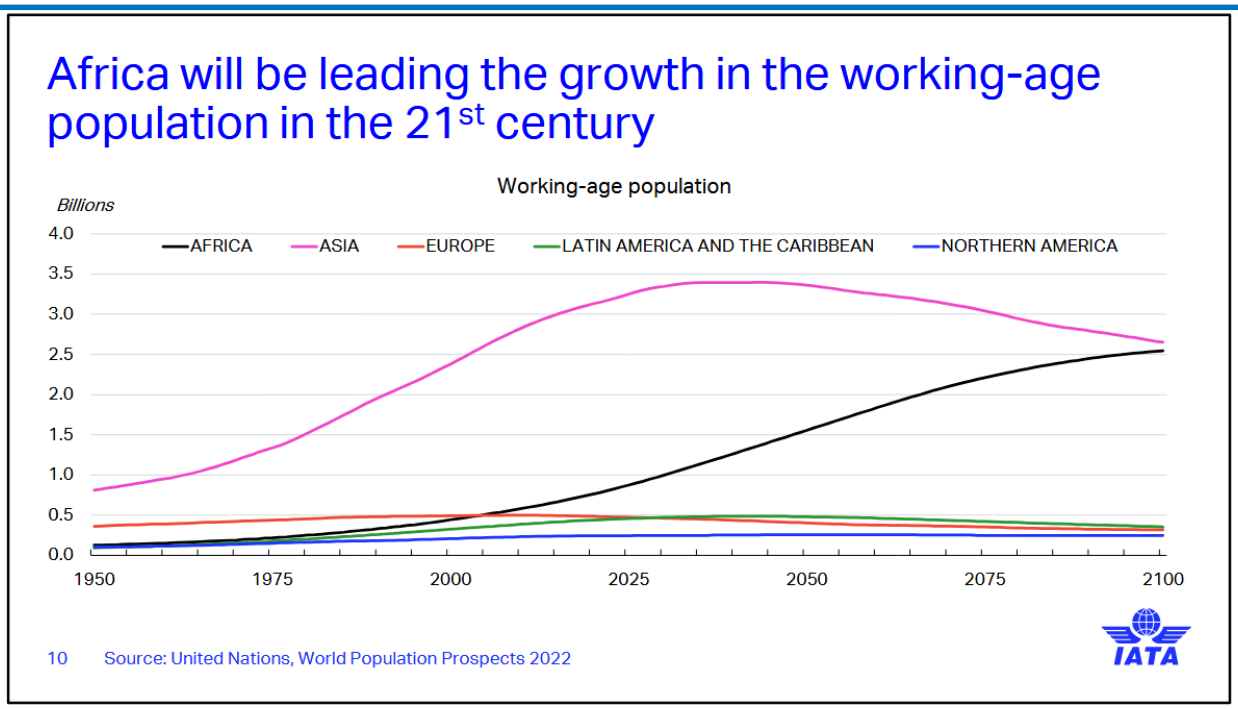

Figure 4: Working Age Population

Community Engagement:

Sustainable aviation practices can foster stronger relationships between airlines and local communities, particularly in areas affected by tourism. Engaging communities in decisionmaking processes can ensure that their needs and concerns are addressed, leading to more equitable outcomes. Several African airports have implemented exemplary community engagement programs that foster sustainable development, enhance local livelihoods, and build trust between airport authorities and surrounding communities A notable example are the initiatives that Airport Company of South Africa has implemented across its airport networks. These include the Learner/Teacher Development Program: Implemented in East London and Port Elizabeth, this program offers Saturday and holiday classes in subjects like Mathematics, Physical Science, and Accounting for Grades 10–12 students.

Teachers also receive capacity-building training. 'Words in Colour' Reading Room: Established at Nooitgedacht School in Cape Town, this initiative provides a specialized reading room equipped with phonetics-based teaching materials to accelerate literacy among disadvantaged learners. Community-Based Ecosystem Adaptation (CEBA) Project: In partnership with Wildlands Conservation Trust, this project in the Tongaat River catchment area focuses on environmental conservation while providing skills training and income-generating opportunities to local communities. (S. Africa, n.d.)

Social Equity:

A just transition to sustainability must consider the needs of marginalized communities that may be disproportionately affected by environmental changes and economic shifts. Ensuring access to affordable and sustainable travel options can enhance mobility for underserved populations, promoting social inclusion.

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Health and Well-being:

Reducing emissions and noise pollution from aviation can lead to improved air quality and public health outcomes, particularly in urban areas near airports. Sustainable tourism practices can promote the conservation of natural resources and biodiversity, contributing to the overall well-being of communities.

Cultural Preservation:

Sustainable aviation can support responsible tourism that respects local cultures and traditions, helping to preserve cultural heritage while promoting economic development. Airlines can play a role in promoting cultural exchange and awareness through sustainable tourism initiatives.

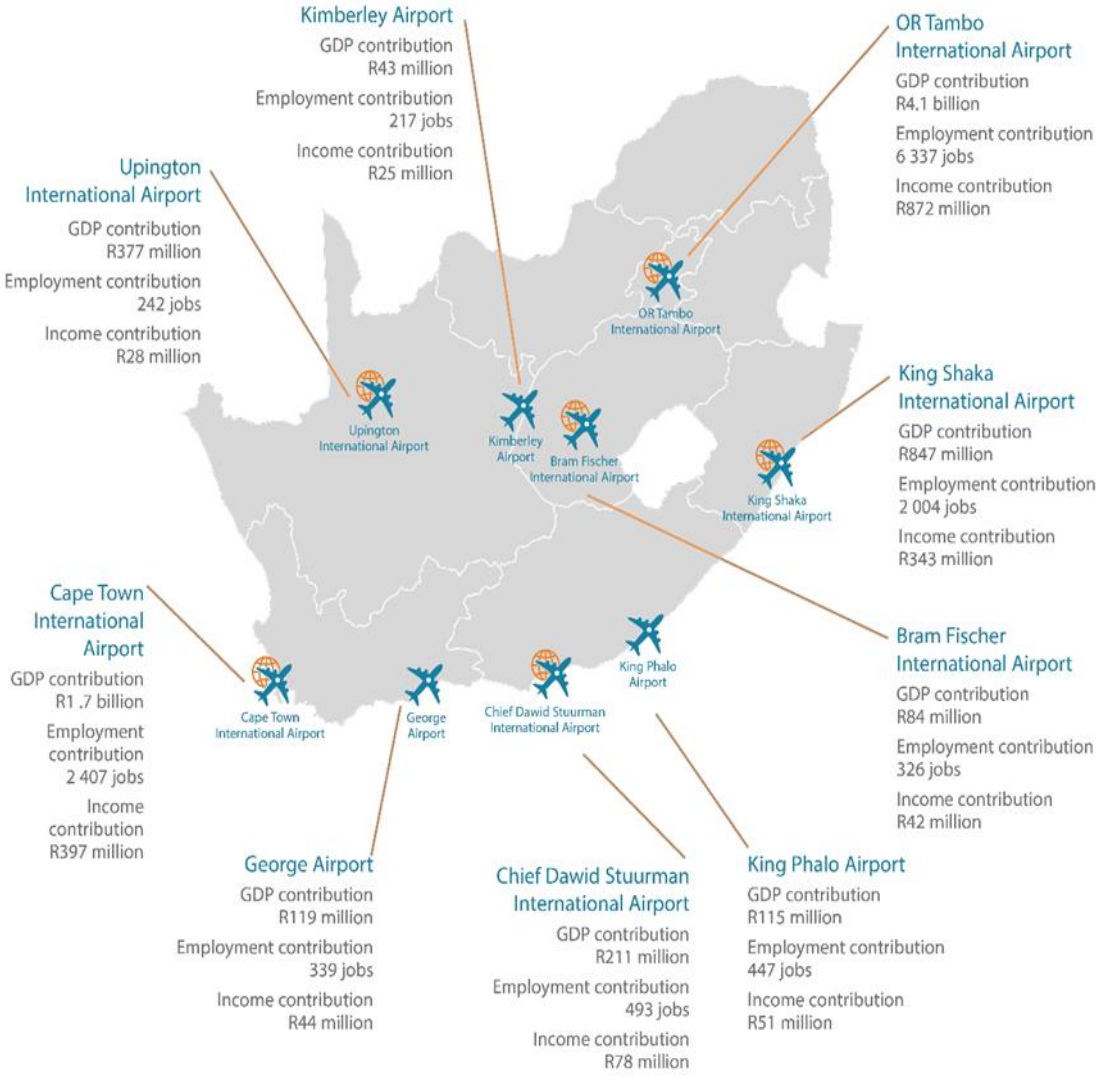

Figure 5: Socio-economic Impact of Airport Company of South Africa

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Employment and Workforce Transition Challenges

The aviation industry is undergoing significant changes due to technological advancements, environmental regulations, and shifts in consumer preferences, which present both opportunities and challenges for employment and workforce transition.

Employment and Workforce Transition Challenges in Aviation

Job Displacement:

Automation and digitalization are leading to the displacement of traditional jobs, particularly in areas such as ticketing, check-in, and baggage handling. Workers in these roles may face unemployment or the need to transition to new positions.

Skills Gap:

The shift towards sustainable aviation technologies and practices requires a workforce with new skills, such as expertise in renewable energy, data analytics, and advanced engineering. Many current employees may lack these skills, necessitating retraining and upskilling programs.

Training and Education:

Developing effective training programs to equip the workforce with the necessary skills for emerging roles in sustainable aviation is crucial. This requires collaboration between airlines, educational institutions, and governments to create relevant curricula. ACI through its African Airports Development Programme is supporting African Airports to gain excellence in management, operations and affordable capacity building through sharing of experience and expertise in the African continent.

Economic Disparities:

The transition to a more sustainable aviation sector may disproportionately affect workers in lower-skilled positions, often in developing regions. Ensuring equitable access to training and job opportunities is essential to avoid widening economic disparities.

Health and Safety Concerns:

The COVID-19 pandemic has highlighted the importance of health and safety in aviation. As the industry recovers, there may be a need for new protocols and training related to health standards, which can impact workforce dynamics. The ACI Public Health and Safety Accreditation provides airports with an assessment that evaluates how aligned their public health and safety measures are with ACI and ICAO best practice consistent with the Collaborative Arrangement for the Prevention and Management of Public Health Events in Civil Aviation (CAPSCA).

Regulatory Changes:

New regulations aimed at reducing carbon emissions and promoting sustainability may require airlines to adapt their operations and workforce structures, leading to further changes in employment patterns.

Cultural Resistance:

There may be resistance to change from employees accustomed to traditional practices and technophobia. Effective change management strategies will be necessary to facilitate a smooth transition to new technologies and practices.

Addressing the carbon footprint and greenhouse gas emissions at African airports is central to advancing sustainability in the aviation sector and aligning airport operations with global climate goals. Beyond environmental gains, sustainability in African aviation carries significant social and economic implications, offering opportunities for economic growth, job creation, and improved social equity if pursued deliberately and inclusively. A just transition will require coordinated action among governments, airlines, communities, and other stakeholders to ensure that the benefits of sustainability are broadly shared. Central to this transition is proactive workforce planning through retraining and upskilling initiatives that enable equitable access to emerging green aviation jobs, thereby building a resilient workforce capable of adapting to the evolving demands of a low-carbon aviation sector.

Policy and Governance Barriers

There are several policy and governance barriers that hamper the development of the aviation industry. Below are some of the barriers:

Regulatory Fragmentation:

Different countries have varying regulations and standards for aviation safety, security, and environmental impact, leading to inconsistencies that complicate international operations and compliance. Although ICAO has instituted standards for its member nations of which they must adhere to, recommended practises remain just that, recommended. Nations will implement the recommended practises based on their financial capability. The ICAO Council at the third meeting of its 232nd Session on 10 June 2024 approved the Second Edition of the Global Aviation Security Plan (GASeP) (Doc 10118). Several African countries are yet to develop a security policy on this and include it in their National Civil Aviation Security Plan (NCASP). It is also important to note that Air transport (economic) Provisions are not covered under the ICAO annexes, although there are policies and guidance materials.

Lack of Coordination:

Insufficient collaboration between national and regional aviation authorities can hinder the development of cohesive policies that address global challenges, such as climate change and safety standards.

Inadequate Infrastructure Investment:

Many African nations face challenges in securing funding for necessary infrastructure improvements, which can limit the capacity and efficiency of aviation systems. African governments have several competing concerns for their limited resources such as health, education and simply the provision of clean drinking water. ICAO recommends that all profits from the aviation industry and reinvested back into that industry. In some countries these funds go back to central government where they fund non-aviation related activities.

Bureaucratic Inefficiencies:

Lengthy approval processes for new routes, aircraft, and technologies can stifle innovation and slow down the adoption of sustainable practices, as most African airports are 100% government owned. Thus, all budgets are approved by the exchequer and international loans for infrastructure and facility development require sovereign guarantee.

Environmental Regulations:

While necessary for sustainability, stringent environmental regulations can impose significant costs on airlines and airports, particularly in developing regions where financial resources are limited. In Kenya the National Environmental Management Authority must approve all development projects before implementation.

Political Instability:

Political uncertainty can disrupt aviation operations and deter investment, making it difficult to implement long-term policies and strategies. In Africa, 37African countries have undergone civil unrest. For some countries such as Somalia, Sudan and DR Congo, they continue to have periods on instability. Also, in most African countries, national elections more often than not are characterised by civil unrest.

Limited Stakeholder Engagement:

A lack of involvement from key stakeholders, including airlines, airports, and local communities, in the policy-making process can lead to policies that do not address the needs and concerns of all parties.

Economic Barriers:

Economic constraints can limit governments' ability to invest in aviation infrastructure and technology, impacting the overall growth and sustainability of the sector. This is due to the fact that aviation standards are evolving at a very fast rate especially with regard to Safety, Security and airport operations. While specific figures can vary, depending on the size and existing infrastructure of the airport, a rough estimate for implementing comprehensive safety and security standards in African countries could range from $10 million to over $100 million.

The social and economic implications of sustainability in African aviation are deeply interconnected, with sustainable practices offering pathways to economic growth, job creation, and social equity while addressing the pressing challenges of climate change. Achieving a just and inclusive transition requires proactive workforce strategies, including retraining, upskilling, and equitable access to emerging employment opportunities, supported through collaboration among governments, educational institutions, and industry leaders. At the same time, effective policy and governance frameworks are essential to overcome regulatory inefficiencies and ensure a safe, resilient, and environmentally responsible aviation sector. Addressing persistent investment and financial constraints through improved access to capital, infrastructure development, regulatory streamlining, and economic stability will be critical, underscoring the need for coordinated action among governments, financial institutions, private investors, and international partners to unlock the full potential of African aviation.

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Investment and Financial Constraints

Investment and financial constraints in Africa's aviation industry continue to be an ongoing concern. Many airlines and airport operators across the continent face limited access to affordable capital, hindering their ability to upgrade infrastructure, expand fleets, or invest in safety and technology enhancements. This is exacerbated by high operational costs, currency volatility, and inconsistent government support, which deter both domestic and foreign investors. Moreover, limited financial instruments tailored to the aviation sector, along with underdeveloped capital markets in many countries, restrict the flow of long-term funding. These challenges significantly impact the industry's growth potential and its ability to compete in the global aviation market.

Limited Access to Capital:

Many African airlines and airports face significant challenges in securing financing due to the perceived risks associated with the region, including political instability, economic uncertainty, and currency fluctuations. These concerns make international lenders and investors wary, often resulting in higher borrowing costs, restrictive loan conditions, or limited access to capital altogether. For airlines, this hampers efforts to modernize fleets, adopt advanced technologies, and expand route networks. Similarly, airports struggle to invest in critical infrastructure upgrades, safety systems, and capacity enhancements needed to meet growing demand and international standards. The combined effect is a financial bottleneck that undermines the competitiveness of Africa's aviation sector, restricts growth opportunities, and impedes the delivery of efficient, safe, and high-quality air services across the continent.

High Operational Costs:

The aviation sector in Africa faces persistently high operational costs, which significantly impact the financial sustainability of both airlines and airport operators. In 2021, jet fuel and oil alone accounted for approximately 32.2% of total operating expenses for African carriers. These high input costs erode profit margins and discourage long-term investment, making it difficult for airlines to build financial resilience or pursue strategic initiatives such as fleet modernization, route expansion, or digital transformation. Additionally, these financial pressures reduce the attractiveness of the sector to external investors, who view the high-cost base as a barrier to sustainable growth.

Infrastructure Deficiencies:

Inadequate airport infrastructure and air traffic management systems can hinder operational efficiency and safety, discouraging both domestic and foreign investment. Upgrading these facilities requires significant capital, which is often lacking. African governments face other issues that require immediate attention, such as poverty eradication, housing, clean water supply to its citizens, affordable health and education.

Regulatory Barriers:

Complex regulatory environments can create additional costs and delays in obtaining necessary permits and licenses, further complicating investment efforts. This can deter potential investors who seek a more streamlined process. In Kenya for example regulations require approval from the Minister of Transport an act of Parliament and then being gazette for them to become law.

Economic Challenges:

Economic downturns, exacerbated by events like the COVID-19 pandemic, have led to reduced passenger demand and revenue for airlines, making it difficult to attract investment. Recovery efforts require substantial financial resources that may not be readily available. Another significant challenge is that African Airlines often face higher operational costs, especially when it comes to fuel. Fuel in Africa is more expensive due to lack of refineries, which adds to operational costs. IATA in its report has shared that jet 1A fuel is 12% higher in Africa than other regions.

Competition from Other Modes of Transport:

In some regions, competition from road and rail transport can limit the market for air travel, making it less attractive for investors. Airlines must demonstrate a clear value proposition to secure funding.

Need for Sustainable Investments:

As the aviation industry moves towards sustainability, there is a growing need for investments in green technologies and practices. However, the initial costs can be prohibitive, and access to green financing options is often limited.

Addressing the investment and financial constraints in Africa's aviation industry requires a multifaceted approach, including improving access to capital, enhancing infrastructure, streamlining regulations, and fostering a stable economic environment. Collaborative efforts among governments, financial institutions, and private investors are essential to unlock the potential of the aviation sector in Africa.

Emerging Opportunities for Green Growth

Emerging opportunities for green growth in African aviation are significant due to the continent's unique challenges and potential for sustainable development, driven by a growing awareness of climate change, technological advancements, and international commitments to reduce carbon emissions.

Sustainable Aviation Fuels (SAFs):

The development and use of SAFs can significantly reduce the carbon footprint of aviation. Africa has abundant biomass resources that can be converted into sustainable fuels, creating local jobs and reducing dependency on imported fossil fuels.

Renewable Energy Integration:

Airports can harness solar, wind, and other renewable energy sources to power operations, reducing energy costs and emissions. This can also position airports as leaders in sustainability within their communities.

Electric and Hybrid Aircraft:

Investment in electric and hybrid aircraft technology presents an opportunity for regional airlines to reduce operational costs and emissions, particularly for short-haul flights, which are prevalent

in Africa. In Kenya Safarilink and Yellowings Air Services are partnering with Surf Air Mobility and Textron to electrify their Cessna Grand Caravan aircraft by 2027.

Green Airport Initiatives:

Implementing green building standards and practices at airports can enhance energy efficiency, reduce waste, and improve the overall environmental impact of airport operations. ACI Airport Carbon Accreditation programme champions this. Felix – Houphouet- Boigny International Airport in Ivory Coast is the first African Airport to achieve Airport Carbon accreditation Level 4+. Similarly, Enfidha – Hammametin Tunisia has achieved level 4. The airports under the global Accreditation programme have collectively reduced over 1 million tonnes of CO2: -1,037,292 CO2e (-14.8%) in the world. The number of accredited airports rose to 558 across 87 countries - with 70 airports joining the programme for the first time and 132 progressing to a higher level of carbon management. This shows the increased commitments that Airports are putting in place to reduce their carbon footprint (ACI Accreditation Report, 2024)

Carbon Offsetting Programs:

Airlines and Airports can engage in carbon offsetting initiatives, allowing them to invest in

environmental projects that mitigate their carbon emissions, such as reforestation and renewable energy projects. In 2016 following the Paris agreement, ICAO formed the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). This is ICAO's effort to reduce carbon footprint for the Aviation sector. Currently over 50 airlines have introduced offset programs either integrated into their web-sales engines or to a third-party offset provider. These programs are aimed at passengers and companies that wish to understand the CO2 impact from flying, and who want to be directly contributing to carbon offset projects in different parts of the world, while reducing their impact from flying. CORSIA pilot phase began on 1st January 2021 and is set to become mandatory for all countries in 2027.

Public-Private Partnerships (PPPs):

Collaborations between governments and private investors can facilitate funding for green initiatives, infrastructure development, and technology adoption, leveraging resources and expertise from both sectors. One of the first airports in Africa to embrace the PPP model is the Felix Houphouët Boigny Abidjan International Airport (ABJ). The government of Cote D'Ivoire transferred the airport to a private operator AERIA in 1966. In 2010, the government of Côte d'Ivoire confirmed its confidence in the concession and renewed it for another 20 years. Egis, via its subsidiary dedicated to airports operation, is a 35.05% shareholder in AERIA, and is the operating partner. The government of Rwanda and Qatar Airways have also signed an investment partnership for Rwanda's new International Airport Bugesera. This will see Qatar Airways take 60% stake in the project which is valued at 1.3 billion US$. The new airport has been designed with a capacity for 7 million passengers in phase 1 and 14 million in phase 2 to be completed in 2032.

Sustainable Tourism Development:

Promoting eco-friendly tourism can drive demand for sustainable aviation practices, encouraging airlines to adopt greener operations while supporting local economies and conservation efforts.

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Regulatory Support and Incentives:

Governments can play a crucial role in accelerating the transition to a more sustainable aviation industry by implementing supportive regulatory frameworks and offering targeted incentives. By introducing policies that encourage the adoption of sustainable practices, authorities can reduce the financial burden on airlines and airport operators. Incentives such as tax breaks, grants, or subsidies for investments in SAFs, electric ground support equipment, or renewable energy infrastructure can make sustainability initiatives more economically viable. In addition, streamlined regulatory approval processes for green technologies and clear emissions reduction targets can offer greater predictability and encourage private sector investment. Such support not only helps reduce the environmental impact of aviation in Africa but also aligns the sector with global climate commitments and enhances its long-term competitiveness.

The aviation sector in Africa has a unique opportunity to lead in green growth by leveraging its natural resources, fostering innovation, and aligning with global sustainability goals. By embracing these opportunities, African aviation can contribute to economic development while addressing environmental challenges.

Case Studies of African Airports

Johannesburg OR Tambo International Airport (South Africa)

Oliver Tambo International Airport (ORTIA), operated by Airports Company South Africa (ACSA), is the continent's busiest aviation hub and a critical component of South Africa's economy and tourism infrastructure. In recent years, ORTIA has emerged as a focal point for ACSA's sustainability agenda, implementing a comprehensive program that addresses a wide array of environmental and operational challenges. These efforts encompass strategic initiatives spanning energy, emissions, waste, water, biodiversity, and community engagement.

The sustainability programme at ORTIA is underpinned by three major goals:

1. Environmental Stewardship – Reducing the ecological footprint of airport operations.

2. Social Responsibility – Enhancing socio-economic development through employment, education, and partnerships.

3. Economic Resilience – Improving infrastructure and operational efficiency to ensure long-term viability.

These align with both the United Nations Sustainable Development Goals (SDGs) and the International Civil Aviation Organization's (ICAO) standards on airport environmental management.

Energy Efficiency and Renewable Integration

ORTIA has invested in energy-efficient lighting, HVAC systems, and Building Management Systems (BMS). The airport integrated recycled asphalt (RA) into its pavement projects, reducing material usage and energy consumption during resurfacing operations.[62]

[62] Makgoka, M., J. E. Grobler, H. Marais, and D. Bakker. "Environmentally sustainable use of recycled Asphalt at or Tambo International Airport." (2014).

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Carbon Management and Climate Resilience

Dube and Nhamo[63]analyze ORTIA's involvement in the Airport Carbon Accreditation Programme, a voluntary initiative promoting carbon neutrality in the aviation sector. Additionally, flood risks are being tackled via infrastructural upgrades to deal with extreme weather patterns, as detailed in recent work on climate-induced events at the airport.[64]

Waste Reduction and Materials Reuse

Environmental sustainability is further supported through recycling initiatives, including sorting of waste at the source and reusing construction materials. Projects have emphasized lifecycle thinking in design and procurement.[65]

Biodiversity and Wildlife Hazard Management

Robinson, Mearns and McKay[66] stress the airport's efforts to balance operations with the preservation of wildlife habitats in proximity to ORTIA. This includes land-use planning and avian hazard management strategies.

Community Engagement and Economic Development

ORTIA has played a critical role in transforming the surrounding Ekurhuleni region into an "aerotropolis", with the aim of integrating urban and economic planning around the airport.[67] The airport's projects support local procurement, entrepreneurship, and training.

When compared to airports like Cape Town International or Kruger Mpumalanga International, ORTIA leads in terms of integrated sustainability metrics but still lags behind top-tier global airports that have achieved net-zero carbon status. The need for a more aggressive renewable strategy is evident.

The sustainability programme at Oliver Tambo International Airport illustrates a dynamic and multi-faceted approach to green airport operations. From recycled infrastructure materials to regional economic integration and biodiversity conservation, ORTIA is carving a path toward sustainability in African aviation.

Mombasa Moi International Airport (Kenya)

Moi International Airport (MIA), located in Mombasa and operated by Kenya Airports Authority (KAA), serves as Kenya's second-largest airport and a crucial regional hub. In recent

[63] Dube, Kaitano, and Godwell Nhamo. "Private Sector Sustainable Development Goals' Localisation: Case of Kruger Mpumalanga International Airport, South Africa." In *Sustainable Development Goals for Society Vol. 2: Food security, energy, climate action and biodiversity*, pp. 177-189. Cham: Springer International Publishing, 2021.
[64] Makuyana, Tawanda, and E. du Plessis. "A model for accessible tourism human capital development for physical impaired persons in South Africa." *ISCONTOUR* (2023): 142-158.
[65] Bowker, Geoffrey C., Karen Baker, Florence Millerand, and David Ribes. "Toward information infrastructure studies: Ways of knowing in a networked environment." In *International handbook of internet research*, pp. 97-117. Dordrecht: Springer Netherlands, 2010.
[66] Robinson, Lance, Kevin Mearns, and Tracey McKay. "Oliver Tambo International Airport, South Africa: Land-use conflicts between airports and wildlife habitats." *Frontiers in Ecology and Evolution* 9 (2021): 715771
[67] Christian M. Rogerson, "The Aerotropolis and Airport City: Johannesburg's OR Tambo International Airport," *Urban Forum* 29, no. 2 (2018): 205–223.

https://doi.org/10.53819/81018102t2542

years, MIA has emerged as a focal point for sustainable innovation in African aviation. Central to its transformation is the "Solar-at-Gate" initiative a pioneering pilot in East Africa designed to decarbonize on-ground airport operations. This essay examines MIA's sustainability programmes across energy, emissions, operations, biodiversity, and socio-environmental engagement.

Moi International Airport (MIA), has reinforced its environmental commitment through ISO 14001:2015 certification and advancement to Level 3 Optimisation in the Airport Carbon Accreditation program. The ISO certification highlights MIA's adherence to sustainable practices in waste, energy, water, and pollution management.[68] Under the carbon accreditation program, MIA achieved a 23.63% reduction in emissions, reflecting KAA's broader strategy to map third-party emissions and collaborate on environmental improvements, aiming for net-zero emissions by 2050 (Airport Carbon Accreditation, n.d.).[69]

Core Sustainability Initiatives

Solarization of Airport Operations

A landmark initiative at MIA is the integration of solar photovoltaic (PV) systems. MIA deployed solar energy to power aircraft ground operations, significantly reducing reliance on aircraft auxiliary power units (APUs), which emit high levels of CO_2 during turnaround processes.[70] This initiative is estimated to reduce over 1,300 tonnes of CO_2 annually.[71] The solar facility has generated 737,014.86kWh annually on average with a total power generation of 2,092,959.8 kWh for the airport. Thus, it has reduced on average 704.225 tonnes of CO2 annually. This project demonstrates a concrete solution to reduce aviation carbon dioxide emissions.

Energy and Operational Efficiency

The airport has improved energy performance by modernizing its lighting systems with LED technology and introducing energy-efficient HVAC systems. These upgrades are managed through Building Management Systems (BMS) that optimize energy consumption patterns, as detailed in studies on infrastructure performance at MIA.[72]

Sustainable Infrastructure Development

Olang'o, Mwea and Gichaga[73] assessed the performance of the newly constructed Port ReitzMoi International Airport access road, which incorporates climate-resilient materials and reduces

[68] Kenya Airports Authority (KAA), *Sustainability and Environmental Management Report 2024/2025* (Nairobi: Kenya Airports Authority, 2025)
[69] id
[70] Baxter, G. (2022). Mitigating aircraft auxiliary power unit carbon dioxide (CO2) emissions during the aircraft turnaround process from the use of solar power at the airport gate: the case of Moi International Airport, Kenya. *Int J Environ Agric Biotechnol*, *7*(1), 014-022.
[71] id
[72] Mwangi, Isaiah Gichohi, and Johnbosco Mutuku Kisimbi. "Critical Success Factors Influencing the Performance of Infrastructure Projects in The Aviation Industry in Kenya; A Case of Moi International Airport." *Journal of Entrepreneurship and Project Management* 5, no. 2 (2020): 93-11.
[73] Olang'o, Mildred, Sixtus Mwea, and Francis Gichaga. "Pavement Performance Testing of the Newly Constructed Port Reitz and Moi International Airport, Mombasa Access Road". *East African Journal of Engineering* 5 (1) (2022): 142-55.

traffic congestion and emissions. The integration of such infrastructure is vital for improving airport access while minimizing environmental degradation.

Environmental Impact Assessment and Monitoring

KAA, in collaboration with NEMA and international partners, has mandated Environmental and Social Impact Assessments (ESIAs) for all infrastructure upgrades. These assessments guide construction activities to limit impacts on biodiversity, air quality, and local communities.[74]

Stakeholder Engagement and Community Development

Programmes at MIA also emphasize social sustainability. Njuguna and Mwaura[75] report that KAA's 5-year tactical plan includes educational outreach, skills development, and procurement from local enterprises to strengthen community ties.

Implementation Framework and Strategic Challenges

The successful roll-out of sustainability initiatives at MIA hinges on robust project management frameworks. Ndamwe[76] emphasized the critical role of project capabilities budgeting, stakeholder alignment, and monitoring in maintaining sustainable terminal infrastructure.

However, challenges persist:

- Financial Constraints: Capital-intensive renewable infrastructure often requires international financing.
- Maintenance and Technical Expertise: Limited availability of specialized staff can hinder operational sustainability.
- Policy Gaps: National aviation sustainability policy is still evolving.

Comparative Insights

When benchmarked against other African airports (e.g., Oliver Tambo in South Africa), MIA stands out in solar innovation but lacks in comprehensive carbon reporting and biodiversity initiatives. There is potential for partnerships to enhance climate adaptation frameworks, similar to those implemented in Southern Africa.[77]

Moi International Airport's sustainability programme reflects Kenya's strategic pivot toward greener infrastructure. Through solar energy deployment, stakeholder integration, and performance monitoring, MIA provides a replicable model for other mid-size international airports in Africa.

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Felix-Houphouet-Boigny International Airport (Ivory Coast)

Félix-Houphouët-Boigny International Airport in Abidjan, Ivory Coast, has set a new standard by becoming the first African Airport to successfully upgrade to Airport Carbon Accreditation programme Level 4+, only 51 airports worldwide have achieved this certification. To achieve this accreditation the airport committed to total reduction of its scope 1 and 2 emissions. The airport has implemented several innovative measures to reduce its carbon footprint, including the use of LED lighting and air conditioning systems within its international terminal building, renovating apron lighting, and upgrading key facilities and infrastructure such as the runway and passenger terminal. It has also embarked on shortening takeoff and landing times turnaround times. The Airport joined the ACA programme in 2015 and two years later it had achieved level 3+

One of its most ground-breaking projects is a collaboration with Soil.is on mangrove restoration, this involves restoring four land, including restoring the vegetation of 83 hectares of runway strips, training gardeners in agro-ecological practices, restoring 2.63 hectares of degraded mangroves and converting 810 tonnes of bio-waste into compost each year.[78] Using digital technology which is an innovative soil management programme to enhance soil carbon sequestration, tailored to the local environment and community needs.

Lessons Learned and Best Practices

Carbon accreditation programs in African airports are essential for promoting sustainability and reducing greenhouse gas emissions in the aviation sector. (Figure 5)

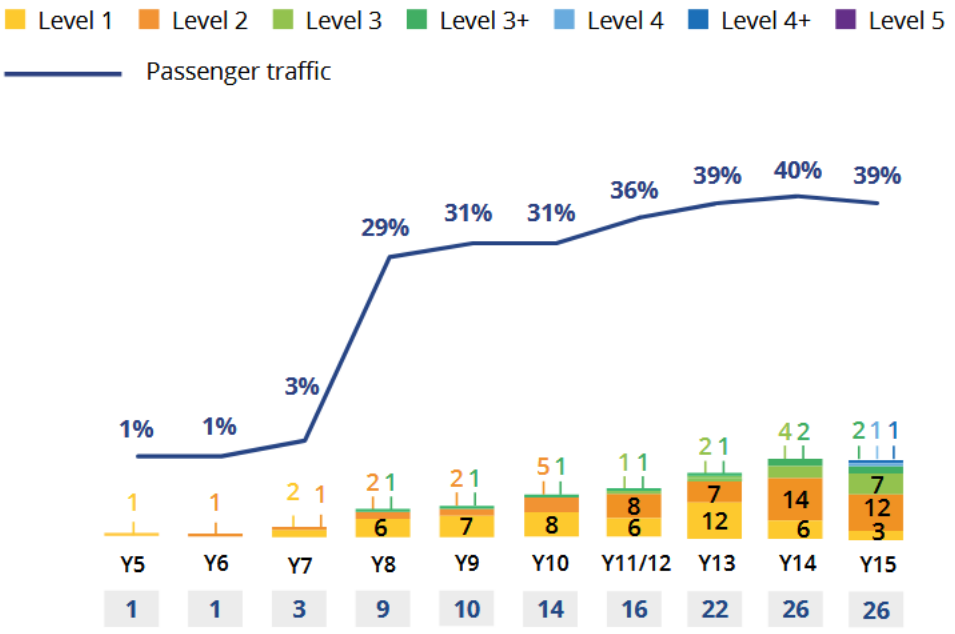

Figure 6: Accredited Airports over time – Africa

[78] Airport-Carbon-Accreditation-Annual-Report-2023-2024

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Sustainability in African airports has emerged as a strategic priority as the aviation sector seeks to reduce environmental impacts while advancing economic growth and social responsibility. Key lessons from emerging practices highlight the importance of integrated, holistic planning that embeds environmental, social, and economic considerations into airport master plans. Effective stakeholder engagement-through early collaboration, awareness, education, and capacity building-enhances ownership, implementation success, and community relations. Robust data collection and management systems, supported by appropriate technologies, are essential for accurate emissions tracking and informed decision-making. Sustainability initiatives are most effective when tailored to local contexts, with realistic, incremental goals that reflect airport size, location, infrastructure, and resource constraints. Supportive regulatory frameworks, clear compliance and reporting standards, and a willingness to exceed minimum requirements further strengthen accountability and leadership. Finally, financial viability remains critical, requiring innovative funding partnerships, sound cost–benefit analyses, and adaptable, low-cost solutions that enable African airports to pursue sustainability without compromising operational or developmental priorities.

6. Policy Recommendations and Roadmap for A Just Transition

The aviation industry underpins global trade, tourism, and cultural exchange but poses significant climate challenges. While responsible for only 2–3% of global CO_2 emissions, its climate impact is amplified by non-CO_2 effects such as NOx emissions and contrail formation. Achieving the Paris Agreement goals is particularly complex for aviation due to its international nature, reliance on fossil jet fuels, and technological constraints. This chapter advances a just transition framework that balances environmental sustainability, economic feasibility, and social equity, and proposes policy recommendations and a strategic roadmap for sustainable aviation transport management informed by legal frameworks, empirical evidence, and contemporary scholarship.

Policy and Regulatory Recommendations

Effective policy and regulatory frameworks are central to a sustainable aviation transition. Internationally, ICAO governs aviation under the Chicago Convention, with Annex 16 addressing environmental protection, though historically with limited emphasis on greenhouse gas reductions. The introduction of CORSIA marked progress by aiming to cap net CO_2 emissions from international aviation at 2020 levels, yet its reliance on carbon offsetting, phased voluntarism, and exemptions for many developing countries raise concerns about equity, consistency, and its capacity to drive deep decarbonization (Stibbe et al., 2020). In contrast, regional and national instruments have demonstrated stronger regulatory ambition. The EU's inclusion of aviation in its Emissions Trading System, upheld by the European Court of Justice, illustrates how enforceable regional measures can internalize carbon costs and fill gaps left by global mechanisms. At the national level, binding aviation-specific targets, sustainable aviation fuel mandates, and comprehensive regulation of non-CO_2 impacts, noise, and land use are essential. Embedding environmental and social impact assessments, transparency requirements, and adaptive regulatory oversight ensures accountability, equity, and responsiveness to technological and scientific advances, thereby sustaining momentum toward long-term aviation decarbonization.

Role of Governments and Private Sector

The aviation sector's sustainability transition demands coordinated action between governments and industry, anchored in clear legal frameworks. Governments, under the UNFCCC and Paris

Agreement, must legislate, invest in green infrastructure, and drive innovation. The UK's Jet Zero Strategy exemplifies this, setting net-zero aviation by 2050 through funding SAF, hydrogen research, and zero-emission aircraft, while providing regulatory certainty that spurs private investment.

Private actors-airlines, manufacturers, fuel producers, airports-are vital in execution. They adopt science-based targets, modernize fleets, optimize flight planning, and expand SAF use, with production doubling in 2024 and set to more than double again in 2025. Airbus and Boeing advance electric and hydrogen aircraft, though commercial viability depends on supportive policy.

Public-private partnerships, formalized through binding agreements, ensure accountability and innovation, while mandatory ESG disclosures strengthen transparency. Coordinated policymaking across ministries and multi-stakeholder bodies aligns aviation decarbonization with broader economic and social goals.

Investment and Financing Strategies

The transition to sustainable aviation is capital-intensive, requiring vast resources for technology, infrastructure, and workforce retraining. To attract private investment, governments must provide clear and predictable legal frameworks that reduce risk and incentivize sustainable finance. Under Article 9 of the Paris Agreement, developed countries are obligated to mobilize climate finance, supported by national laws enabling green bonds, climate-aligned loans, and other instruments with strict transparency standards.

The EU's SFDR and Taxonomy Regulation set benchmarks for defining sustainable investments, curbing greenwashing and guiding aviation projects such as SAF facilities, green airports, and low-carbon aircraft. Corporate initiatives like KLM's SAF Program pool demand to lower costs and stimulate production, complemented by subsidies and policy incentives. In emerging economies, innovations such as Malaysia's Green Sukuk Framework demonstrate culturally relevant financing models that could support aviation infrastructure.

Carbon pricing schemes generate vital revenues that should be earmarked for retraining, community development, and research to ensure a just transition. Mandatory climate-related financial disclosures, as advanced by the TCFD, enhance transparency and align capital flows with resilience goals. Recent proposals-from COP28's Global Solidarity Levies Task Force to the IMF's call for pricing aviation and shipping emissions-highlight the scale of potential funding, with estimates of up to US$200 billion annually to drive global climate finance.

Skills Development and Workforce Adaptation

A just transition in aviation requires robust workforce adaptation to prepare employees for green technologies and sustainable practices. The ILO emphasizes integrating social protection, retraining, and active labor market policies to prevent worker exclusion. International human rights instruments, notably the ICESCR, provide the legal basis by guaranteeing the right to work and vocational training, obliging states to safeguard aviation workers against displacement while enabling skill upgrades.

Practical initiatives such as Lufthansa Technik's Green Skills program in Germany demonstrate how collaboration with schools, unions, and technical institutes can deliver training in sustainable aircraft maintenance, SAF handling, and energy-efficient operations. In developing countries,

frameworks like Kenya's Climate Change Act (2016) and TVET Act (2013) support government-backed retraining in emerging technologies such as electric propulsion and digital air traffic management.

National labor regulations should require aviation employers to adopt just transition plans with clear retraining timelines, social protection measures, and inclusion strategies. Governments can reinforce these efforts through grants, tax credits, and procurement incentives. Crucially, inclusivity must be embedded: gender-sensitive training, anti-discrimination protections, and outreach to marginalized groups ensure broader participation in green aviation jobs and a fairer transition.

Community Engagement and Stakeholder Participation

Community engagement is central to achieving socially just and environmentally sustainable aviation. International frameworks such as the Rio Declaration and the Aarhus Convention enshrine public rights to information, participation, and legal remedies, ensuring aviation projects do not marginalize communities or deepen inequalities.

San Francisco International Airport's Community Roundtable illustrates how institutionalized participation builds trust and legitimacy. By bringing together local groups, environmental organizations, and government agencies, it enables dialogue on issues like noise, air quality, and expansion, leading to more responsive governance.

Where formal structures are limited, environmental impact assessment laws provide entry points for public involvement. Nigeria's EIA Act mandates hearings and consultations before major projects, empowering communities to shape outcomes and negotiate safeguards.

Community Benefit Agreements further strengthen accountability by legally binding airports or developers to commitments such as local employment, noise reduction, and social infrastructure investment. These agreements ensure benefits are equitably shared and grievances addressed.

Environmental justice requires accessible redress systems, legal aid, and citizen science initiatives that amplify marginalized voices. Governments and airport authorities should invest in capacity-building so communities can monitor air quality and noise independently, fostering empowerment and sustained participation in aviation's green transition.

7. Conclusion and Future Research Directions

The overarching objective of this thesis was to examine the intricate challenges and opportunities involved in steering the aviation sector toward sustainable transport management by integrating environmental law, policy frameworks, financial mechanisms, labor considerations, and community engagement. This interdisciplinary exploration has yielded several critical insights that advance both academic understanding and practical policymaking in sustainable aviation.

At the international level, the study revealed that while the International Civil Aviation Organization (ICAO) remains the primary institution governing aviation emissions, its current regulatory framework is insufficient for addressing the sector's rapidly escalating climate impacts. The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), adopted by ICAO, represents the first global market-based measure targeting aviation emissions. However, the voluntary nature of early implementation phases, coupled with significant participation

exemptions for developing countries, weakens its potential impact. Furthermore, CORSIA's reliance on carbon offsetting, primarily through land use and forestry projects, has attracted critical scrutiny in the literature for issues surrounding additionality, leakage, permanence, and the challenge of truly achieving carbon neutrality through offsets alone.

The research further revealed that the international legal architecture governing aviation emissions lacks binding, enforceable mechanisms that mandate substantial emission reductions within clear timelines, thereby limiting the sector's contribution to the global climate targets enshrined in the Paris Agreement. This structural gap underscores the need for reforms to enhance ICAO's governance capacity or for complementary regional and national regulatory actions.

At the regional level, the European Union's Emissions Trading System (EU ETS) and emerging regulatory initiatives such as the ReFuelEU Aviation Regulation provide instructive examples of more stringent and legally binding measures aimed at reducing emissions and fostering sustainable aviation fuel (SAF) deployment. These measures demonstrate that binding regional policies can effectively push airlines and fuel suppliers toward decarbonization, particularly when backed by clear legal mandates and enforcement mechanisms. However, the thesis highlighted significant challenges related to extraterritorial application, as these regional regulations apply to flights into and out of EU airports, provoking legal debates around jurisdiction, sovereignty, and compliance burdens imposed on third countries. This points to a broader dilemma in international environmental law regarding the harmonization of competing legal regimes and the balancing of environmental protection with state sovereignty and economic equity.

National case studies further illustrate the role of states as key actors in translating international and regional commitments into actionable policy frameworks. The United Kingdom's Jet Zero Strategy exemplifies a comprehensive approach that combines clear regulatory frameworks, investment in research and development, support for SAF scaling, and workforce adaptation policies. Such national strategies underscore the importance of coherence and alignment across policy domains - including transport, energy, environment, and labor - to facilitate sustainable aviation transitions.

Finance emerges as a crucial enabler of sustainable aviation transitions. The thesis analysed innovative financing mechanisms such as green bonds issued by airports, sustainability-linked loans, and carbon pricing revenues reinvested in SAF production and technology innovation. Amsterdam Schiphol Airport's issuance of green bonds to fund sustainability infrastructure illustrates how financial markets can be leveraged for environmental objectives, provided robust legal frameworks ensure transparency, accountability, and the prevention of greenwashing. The study further demonstrates that without clear legal standards governing the use and reporting of sustainability-linked finance, the risk of superficial compliance threatens the sector's credibility and the mobilization of capital necessary for decarbonization.

In parallel, workforce adaptation emerges as a pivotal component of a just transition. The aviation sector's heavy reliance on highly skilled labor, combined with anticipated technological disruptions, necessitates comprehensive retraining programs, social protection measures, and inclusive labor policies. The thesis integrated international labor law frameworks-such as the ILO's Guidelines for a Just Transition-highlighting the legal obligations of states and employers to protect workers' rights and promote equitable access to green jobs. This focus addressed a

notable gap in aviation sustainability research, which often marginalizes social dimensions in favor of technical and environmental concerns.

Finally, community engagement and participatory governance are underscored as essential for the legitimacy, equity, and effectiveness of sustainable aviation policies. The thesis presented the San Francisco International Airport Community Roundtable as a best practice model where institutionalized stakeholder participation leads to better environmental outcomes and enhanced social acceptance. Similarly, Nigeria's Environmental Impact Assessment (EIA) Act mandates public consultation in airport developments, demonstrating how legal mechanisms can empower affected communities and embed environmental justice principles. These examples illustrated that social license to operate is critical, and legal frameworks must mandate and facilitate meaningful participation to ensure that the benefits and burdens of aviation transitions are equitably shared.

In sum, the findings reveal that sustainable aviation transport management requires an integrated approach that bridges binding international and regional legal frameworks, coherent national policies, innovative finance aligned with rigorous sustainability standards, robust labor protections, and empowered community participation. Only through such a comprehensive and just transition can the sector realistically meet its climate commitments while supporting social equity and economic viability.

Contributions to Knowledge

This thesis makes significant contributions to interdisciplinary scholarship on sustainable aviation and just transitions by bridging environmental law, aviation management, finance, labor studies, and community governance. It advances understanding of international aviation governance by critically assessing ICAO's regime, the EU ETS, and national strategies such as the UK Jet Zero plan. The analysis highlights structural limits in international law-rooted in the Chicago Convention and ICAO's mandate, that constrain efforts to address aviation's climate externalities, exposing tensions between sovereignty, non-discrimination, and environmental protection.

By integrating financial law perspectives, the thesis offers novel insights into regulating sustainable finance instruments. It underscores the need for clear definitions, accountability, and standardized reporting to ensure that green bonds, sustainability-linked loans, and carbon markets deliver genuine environmental benefits, addressing concerns about greenwashing amid the rapid growth of ESG investing.

The incorporation of labor law and just transition frameworks fills a critical gap in aviation sustainability research. Drawing on ILO guidelines and human rights principles, the thesis establishes a normative foundation for workforce adaptation policies that protect labor rights and promote equitable access to green jobs, ensuring environmental goals align with social justice. Finally, the study enriches environmental justice scholarship by demonstrating how participatory governance-through mechanisms like San Francisco International Airport's Community Roundtable and Nigeria's EIA law, enhances transparency, legitimacy, and equitable outcomes. These case studies provide valuable models for embedding social license principles in aviation policy.

Future Research Directions

This thesis lays a foundation for sustainable aviation but highlights key areas for future research. CORSIA offsets need rigorous empirical evaluation to test real carbon outcomes and governance integrity. Socio-economic studies should assess workforce retraining, social protection, and labor transitions across diverse contexts. Emerging technologies like hydrogen and electric aircraft demand integrated legal and technical analysis to ensure equitable diffusion. Governance innovations-digital platforms, blockchain transparency, and justice frameworks-require pilot testing for inclusivity and accountability. Sustainable finance research must expand to blended finance, green sukuk, and disclosure regimes, especially in developing economies. Finally, the impacts of COVID-19 and global shocks on aviation sustainability call for longitudinal studies to build resilient, adaptive governance.

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