Airport Operations and Sustainability in Operation: Evaluating the Experiences of CIAL (Cochin International Airport Ltd), Kochi in Sustainable Practices and the Road Ahead

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Abstract

Cochin International Airport Limited (CIAL), situated in Kerala, India, has gained international acclaim as the first airport in the world to operate entirely on solar power, establishing a groundbreaking standard in sustainable aviation infrastructure. Established in 1999 and functioning through a public-private partnership model, CIAL has developed into the third busiest airport in India regarding international traffic. CIAL's approach to sustainability is fundamentally based on the tenets of Green Supply Chain Management (GSCM), which it implements across various operational areas, such as green procurement, environmentally conscious infrastructure design, the use of renewable energy, and management of waste and water. The airport emphasizes environmentally friendly purchasing by engaging with green-certified suppliers and sourcing energy-efficient materials and technologies. Its terminals and other structures are designed to optimize natural light and ventilation, further decreasing energy usage. Additionally, CIAL runs advanced effluent treatment facilities and recycling operations, utilizing reverse logistics and promoting circular economy principles. In addition to its operational initiatives, CIAL has adeptly leveraged its sustainability accomplishments as a strategic component of its branding. By branding itself as a trailblazer in green aviation, the airport has set itself apart in the competitive aviation sector. It consistently communicates its environmental credentials through public relations efforts, signage throughout the airport, collaborations in tourism, and digital channels, increasing its attractiveness to eco- conscious travelers, investors, and global organizations. CIAL has also garnered significant accolades, including the prestigious "Champions of the Earth" award in 2018, enhancing its global standing as a leader in sustainability. The airport's prominence in sustainability discussions, its case studies featured in academic and industry publications, and its participation in international climate forums further magnify its reputation. Through this comprehensive strategy integrating eco-friendly operations with purposeful communication CIAL not only minimizes its ecological impact but also exemplifies how sustainability can serve as a fundamental value, a competitive edge, and an influential story within the worldwide aviation sector. The research paper was written as a case study was developed using qualitative data derived from primary and secondary sources. An extensive review of secondary data sources

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from websites, newspaper archives and previous research was done to understand the documented evidence of sustainability linked initiatives, followed by in-depth interviews with relevant officials at CIAL to gather primary insights and undisguised observation of actual activities within the framework of sustainability theories. The study draws on rich description of the sources of evidence and tries to identify relevant themes or tenets related to the analytical framework of choice. Through triangulation and presentation of evidence, future scope, directions and avenues of improvement regarding sustainability frameworks and their scope is suggested.

***Key words:** sustainable supply chain management, green supply chain practices, sustainability performance, carbon emissions, energy efficiency, zero waste philosophy.*

Introduction

Sustainability has become an essential priority for both businesses and governments around the world, particularly in sectors with considerable environmental impacts such as aviation. The increasing need to address climate change, resource exhaustion, and ecological damage has forced organizations to rethink their operational structures. This study explores how sustainable practices can be effectively implemented through green supply chain methods, using Cochin International Airport Limited (CIAL) as a specific example. Recognized as the world's first completely solar-powered airport, CIAL showcases a successful combination of operational effectiveness and environmental preservation. Its sustainability efforts extend beyond energy creation and influence its entire supply chain, establishing a benchmark for sustainable airport management globally. CIAL's initiatives are also evaluated within the context of broader national and international sustainability goals. On a global scale, the airport's practices align with the United Nations Sustainable Development Goals (SDGs) especially those related to clean energy, sustainable infrastructure, and climate action. At the national level, its initiatives support India's Nationally Determined Contributions (NDCs) under the Paris Agreement, aimed at reducing emissions intensity and enhancing renewable energy capacity.

Background of the Study

Airports and airlines are progressively implementing green supply chain strategies to lessen their ecological impact while improving operational efficiency and adhering to regulations. Without sustainable measures, aviation's carbon emissions are anticipated to increase significantly. Airports contribute to various types of environmental pollution due to the extensive and intricate nature of their operations. A significant concern is air pollution, mainly arising from emissions generated by aircraft engines, ground support equipment (GSE), and vehicle traffic within airport grounds. These emissions release pollutants like carbon dioxide (CO_2), nitrogen oxides (NOx), sulphur oxides (SOx), and particulate matter, all of which exacerbate global warming and degrade air quality. Noise pollution results from the loud noises produced by aircraft during take-off, landing, and taxiing, which can greatly affect the health and well-being of nearby communities. Water pollution happens when de-icing fluids, fuel spills, and runoff from maintenance and cleaning processes contaminate local water bodies, harming aquatic ecosystems. Soil pollution is another issue, arising from leaks or mishandling of fuels, lubricants, and other chemicals used in airport operations. Furthermore, airports produce large

amounts of solid and hazardous waste, which includes catering waste, single-use plastics, packaging materials, maintenance debris, and electronic waste (e-waste), all needing efficient disposal and recycling methods to avoid long-term environmental damage

Established in 1999 and functioning through a public-private partnership model, CIAL has developed into the third busiest airport in India regarding international traffic. Its shift towards becoming a model of sustainability began in 2015 with the installation of a solar photovoltaic (PV) plant with a capacity of 12 MWp, which has since expanded to over 40 MWp. This significant initiative greatly lessened the airport's reliance on fossil fuels and resulted in the elimination of thousands of tonnes of carbon dioxide emissions yearly. This step illustrates how an airport can achieve growth while being ecologically responsible. CIAL's approach to sustainability is fundamentally based on the tenets of Green Supply Chain Management (GSCM), which it implements across various operational areas, such as green procurement, environmentally conscious infrastructure design, the use of renewable energy, and management of waste and water. The airport emphasizes environmentally friendly purchasing by engaging with green-certified suppliers and sourcing energy-efficient materials and technologies. Its terminals and other structures are designed to optimize natural light and ventilation, further decreasing energy usage. Additionally, CIAL runs advanced effluent treatment facilities and recycling operations, utilizing reverse logistics and promoting circular economy principles.

CIAL has also garnered significant accolades, including the prestigious "Champions of the Earth" award in 2018, enhancing its global standing as a leader in sustainability. The airport's prominence in sustainability discussions, its case studies featured in academic and industry publications, and its participation in international climate forums further magnify its reputation. Through this comprehensive strategy integrating eco-friendly operations with purposeful communication CIAL not only minimizes its ecological impact but also exemplifies how sustainability can serve as a fundamental value, a competitive edge, and an influential story within the worldwide aviation sector.

Objectives of the Study

To examine the impact of green supply chain practices on the sustainability performance of organizations.

To identify key green supply chain practices adopted in CIAL.

To identify and evaluate the organization's existing supply chain processes to identify areas where sustainability can be integrated or improved.

Design of the study

This study utilizes a mixed method research methodology to understand the different aspects of the green supply chain practices. It used both primary and secondary data to gather comprehensive and insightful information. Primary data was collected through structured interviews with key the employees. These interviews will provide firsthand insights into how green supply chain practices are integrated and managed at Cochin International Airport Limited (CIAL). In addition to interviews, secondary data will be obtained from a variety of sources, including existing case studies, the official website of CIAL, news reports, and industry magazines. These sources helped contextualize the findings, offer supporting evidence, and highlight publicly available information about CIAL's sustainability initiatives. On-site observations were also be carried out to directly examine real-time implementation of sustainable practices, such as solar power systems and waste management units.

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Ultimately, the mixed-methods framework will blend qualitative and quantitative findings, employing surveys to collect operational data and interviews to obtain stakeholder perspectives. The data will be triangulated to offer a holistic view of how sustainability practices impact airport operations, with the goal of providing valuable insights for enhancing sustainability initiatives and operational efficiency at airports.

On review of the methodological writings and research articles employing the same, the following were given as the rationales for doing mixed method research:

Triangulation: Improves the credibility of findings by combining qualitative and quantitative data to validate and corroborate results.

Completeness: Seeks to deliver a more comprehensive and balanced insight into the research subject by employing various methods.

The study was structured as follows

Conduct of an extensive review of secondary data sources, such as websites, newspapers, and previous studies.

Performing in-depth interviews with relevant officials to gather primary insights.

Use observational analysis to examine sustainability activities within the framework of relevant theories.

Reviewed media coverage and previous academic research to supplement the study.

Conducted qualitative analysis based on key themes or tenets of the selected analytical framework.

Apply a mixed-method approach, utilizing triangulation to integrate findings from primary and secondary data sources, ensuring comprehensive analysis.

To enable the research to be available in article format, only he fifth step was discussed in detail based on step two, as otherwise the article would be too long to be considered.

Review of the literature

The article “The Role of Green Supply Chaisn Management Practices in Achieving Sustainable Performance in the Aviation Industry” by F. Sahar, N. Kadri, and F.Nordin (2022) looks into how the aviation sector can become more environmentally responsible by adopting green practices in their supply chain. With the aviation industry facing growing pressure due to its environmental impact, the study highlights Green Supply Chain Management (GSCM) as a smart, forward-thinking solution that not only helps the planet but also boosts overall business performance. The authors break GSCM down into five key areas that matter most for aviation companies: green procurement, green manufacturing, green distribution, green packaging, and reverse logistics. Green procurement means buying materials and services that are eco-friendly, and making sure suppliers also share the same sustainability values. Green manufacturing focuses on producing goods in ways that cut down on waste, energy use, and emissions. Green distribution is about managing logistics like transportation and storage in ways that reduce the carbon footprint. Then there’s green packaging, which involves using packaging materials that are sustainable, recyclable, or biodegradable. Finally, reverse logistics deals with the responsible return, reuse, or recycling of used products and materials. Based on data collected from professionals

in the aviation industry, the study finds that companies that actively apply GSCM practices tend to see significant improvements in their sustainability performance. This doesn't just mean doing better for the environment it also includes economic gains and social benefits. Going green helps reduce costs, boosts efficiency, and strengthens a company's reputation with customers and stakeholders. In the end, the authors encourage aviation companies to make GSCM a core part of how they do business. Embracing green practices isn't just about compliance or public image it's a practical move toward long-term growth and resilience in a world that's becoming increasingly focused on sustainability.

Sundarakani, B., Yusliza Mohd Yusoff and Govindan, K. (2021) explores how green initiatives can be practically implemented in airport operations using the Green Supply Chain Management (GSCM) framework, all while being guided by the well-known SCOR (Supply Chain Operations Reference) model. What makes this study especially valuable is its combination of academic depth and real-world application. The research also highlights the key drivers and barriers to implementing GSCM in airports. These include internal factors like management support and external pressures like government regulations and community expectations. The authors thoughtfully show how aligning operational performance with environmental priorities can lead to a win-win situation for both the planet and airport stakeholders. The article explains how airports can transition into greener, more sustainable hubs through innovation, collaboration, and strong leadership.

Through the article Green Supply Chain Management Practices in Aviation Sector – A Case Study Approach," K. S. Ranjith and S. Vijayakumar (2020) explore how the aviation sector is beginning to take sustainability earnestly by adopting Green Supply Chain Management (GSCM) practices. Acknowledging the considerable environmental consequences of the industry, the authors delve into how airports and aviation service providers are shifting towards more environmentally friendly operations through practical case studies. The research indicates that collaboration is vital for the effective execution of GSCM. It involves not only the airlines airport authorities, suppliers, service providers, and even passengers all play a part in fostering a sustainable aviation framework. The authors illustrate how these various stakeholders are starting to collaborate to weave environmental considerations into everyday operations. Several eco-friendly practices discussed in the article include environmentally aware procurement, where businesses prioritize sourcing from suppliers who adhere to environmental standards. On the operational front, airports are transitioning to electric vehicles, conserving both water and energy, and enhancing ground operations to be more efficient and less harmful to the environment. Waste management constitutes another major focus, with airports implementing improved recycling systems and utilizing resources more efficiently. The article also underscores the significance of adhering to environmental laws, both at local and international levels, to guarantee enduring sustainability. What distinguishes this research is its hands-on, case-oriented methodology. It does not merely illustrate theoretical models but sheds light on what is presently unfolding in the industry.

Vyas and Sharma (2021) investigate how the implementation of Green Supply Chain Management (GSCM) practices is affecting the operational performance of airports in India. Their investigation underscores the increasing need for the aviation industry to reconcile economic advancement with ecological responsibility, particularly in light of the rising environmental scrutiny airports are subjected to. The authors examine five fundamental aspects of GSCM: green purchasing, green manufacturing, eco-design, green distribution, and reverse logistics. They contend that when airports embrace these sustainable practices, they not only aid in creating a healthier planet, but also experience a noticeable enhancement in operational efficiency. The research is based on data gathered from Indian airports

and employs structural equation modeling to draw inferences. Their results strongly indicate a beneficial association between green practices and enhanced performance indicators such as cost reduction, service quality, and adherence to environmental regulations. Vyas and Sharma highlight that adopting green practices is not merely about regulatory compliance or public perception it is also a calculated strategy that can provide airports with a competitive advantage.

The research by Chao, C.C. and Hsu, C.W., (2014), 'Sustainable development of airport operations: A case study of Taiwan Taoyuan International Airport' examines the increasing significance of Green Supply Chain Management (GSCM) within the aviation sector and its essential role in promoting sustainability while sustaining operational efficiency. As the aviation industry faces mounting pressure to diminish its ecological footprint, the study highlights various environmentally friendly initiatives that airports and airlines are implementing to achieve greener operations. A significant emphasis of the research is on how airports incorporate sustainable practices throughout their supply chains. This encompasses the use of renewable energy, like solar energy projects, waste management initiatives such as recycling and composting, and water conservation measures including rainwater. To assess and enhance these eco-friendly practices, the study examines the implementation of the SCOR (Supply Chain Operations Reference) model. This structure assists airports in monitoring key performance indicators (KPIs) such as the reduction of carbon footprints, energy efficiency, and resource optimization. Furthermore, the research highlights the significance of technology such as IoT (Internet of Things), AI (Artificial Intelligence), and blockchain in improving transparency, traceability, and effectiveness in green supply chain management. Nevertheless, despite the evident advantages of GSCM, the study recognizes several substantial challenges.

6.Theoretical frameworks for sustainability approaches

Several important management and organizational theories support the concept of sustainability in supply chain operations. The conceptual tools to comprehend why and how businesses implement green supply chain practices are provided by these theories. The Triple Bottom Line, Stakeholder Theory, Institutional Theory, and the Resource-Based View (RBV) are the four main theoretical pillars that underpin the incorporation of sustainability into supply chain management.

Triple Bottom Line (TBL) approach

The concept of the Triple Bottom Line (TBL), developed by John Elkington in the 1990s, transformed the way businesses perceive success. Historically, companies assessed their performance exclusively based on financial gain. The triple bottom line consists of three components: profit, people, and the planet. Businesses can utilize these elements to understand their environmental obligations and identify any adverse social effects they may be causing.

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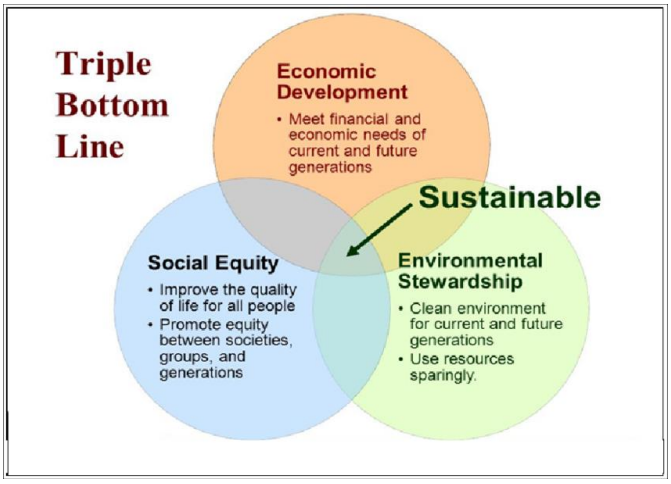

Figure No 3.2 Triple Bottom Line

Profit

In a capitalist system, the success of a company largely hinges on its financial results, specifically the profits it provides to its shareholders. Strategic initiatives and crucial business decisions are typically crafted to enhance profits while lowering expenses and managing risks.

Historically, many companies have primarily aimed for economic growth and impact. Today, purpose driven leaders are realizing that they can utilize their businesses to create positive changes in the world without compromising financial success. In numerous instances, embracing sustainability initiatives has been shown to foster business achievement.

People

The second element of the triple bottom line emphasizes a company's influence on society or its dedication to people. It's essential to differentiate between a company's shareholders and stakeholders. Historically, businesses have prioritized shareholder value as a measure of success, aiming to create value for individuals who own shares in the company. As companies have progressively adopted sustainability principles, they've begun to focus on generating value for all stakeholders affected by their business activities, which include customers, employees, and community members. Some straightforward methods for companies to positively influence people and benefit future generations include implementing fair hiring practices and promoting volunteerism among employees. They can also seek to create broader change by forming strategic partnerships with nonprofit organizations that align with their mission-driven objectives.

Planet

The last aspect of the triple bottom line focuses on creating a beneficial impact on the environment. Since the onset of the Industrial Revolution, major corporations have significantly contributed to environmental pollution, a primary factor driving climate change and raising environmental issues. A report from the International Energy Agency indicated that the global energy sector emitted 135 million tonnes of methane into the atmosphere in 2022. Although businesses have traditionally been the largest contributors to climate change, they also possess the potential to foster positive transformations. (Source-Harvard Business School. (2021) *What is the Triple Bottom Line?*

Available at: https://online.hbs.edu/blog/post/what-is-the-triple-bottom-line? DOI: 1 May 2025).

Stakeholder Theory

The Stakeholder Theory, created by R. Edward Freeman, posits that a company's obligations go beyond shareholders to encompass a wider group of stakeholders. These stakeholders consist of employees, customers, suppliers, regulators, local communities, and even future generations. The theory underscores that thriving organizations are those that generate value for all their stakeholders, not only those with a direct financial stake.

The stakeholder theory is a concept in organizational management and business ethics that considers various groups affected by business activities, including employees, suppliers, local communities, creditors, and others. The stakeholder perspective on strategy combines a resource-based approach with a market-oriented approach while also incorporating a socio-political dimension. One prevalent interpretation of stakeholder theory aims to identify a company's key stakeholders (the normative theory of stakeholder identification) and then explores the circumstances under which managers regard these groups as stakeholders (the descriptive theory of stakeholder salience).

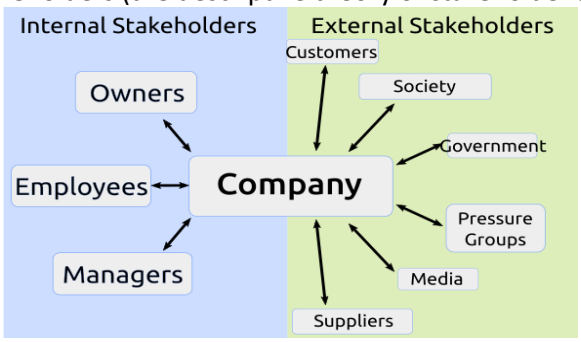

Figure No 3.2 Stakeholder Theory

(Source-Wikipedia.(2024)'*Stakeholder theory*. Available at: https://en.wikipedia.org/wiki/Stakeholder_theory . DOI: 1 May 2025).

Institutional Theory

Institutional Theory offers understanding into how external influences shape organizational actions, particularly regarding environmental practices. This theory asserts that organizations typically adhere to the rules, norms, and expectations set by the institutional context in which they function. These pressures can arise from governmental regulations, industry associations, global standards, and even community values.

In the field of green supply chain management, institutional theory clarifies the reasons why companies implement environmental management systems and pursue certifications such as ISO 14001 or LEED. Adherence to environmental regulations and the quest for institutional legitimacy are significant motivators for adopting sustainable practices. Within the aviation sector, airports and associated organizations are frequently driven to comply with international environmental standards to uphold reputational credibility, obtain funding, or qualify for government incentives. For instance, the Airport Carbon Accreditation program, which acknowledges airports' initiatives to manage and lessen carbon emissions, acts as both a regulatory and reputational motivation for airports to adopt

green supply chain strategies. (Source- Wikipedia. (2024) *Institutional theory*. Available at: https://en.wikipedia.org/wiki/Institutional_theory. DOI: 1 May 2025).

Resource-Based View (RBV)

The Resource-Based View (RBV) of the organization highlights the strategic significance of internal resources and capabilities in attaining competitive advantage. According to RBV, resources that are valuable, rare, inimitable, and non-substitutable (VRIN) constitute the foundation of long-term organizational achievement. This perspective redirects the emphasis from external pressures to internal strengths.

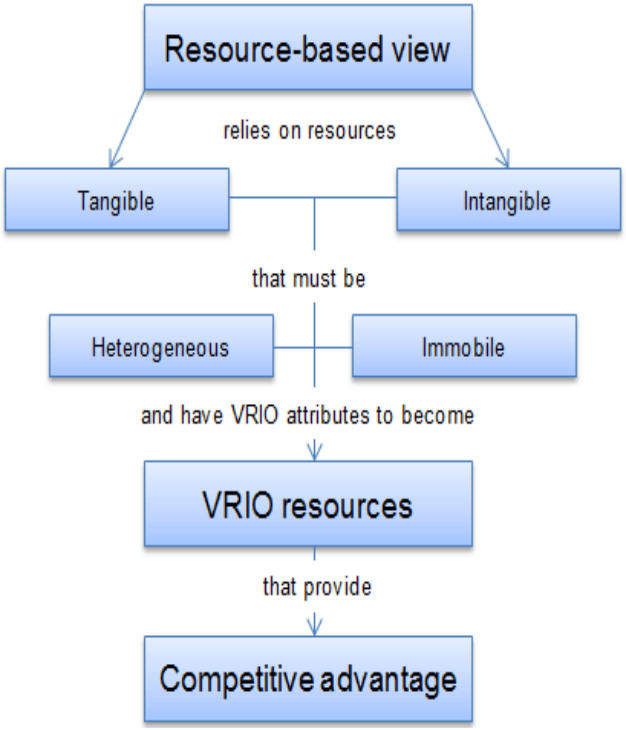

Figure No 3.2 Resource Based View

In relation to green supply chain management, RBV indicates that sustainability can serve as a source of competitive differentiation when organizations cultivate distinctive capabilities such as proficiency in renewable energy integration, sophisticated waste management systems, or green logistics infrastructure. For example, an airport that invests in a large-scale solar power facility not only diminishes its carbon footprint but also achieves energy independence and operational cost benefits. These internal competencies are often challenging for competitors to emulate and can enhance brand value, stakeholder trust, and regulatory goodwill. Therefore, RBV endorses the notion that sustainability is not merely a moral obligation but an astute business strategy.

The Green Framework for Resource Management

The Green Framework for Resource Management provides a practical structure for assessing sustainability performance across seven key operational domains. These domains are energy, water, waste, emissions, land use, community engagement, and regulatory compliance are interconnected and together form the backbone of a sustainable supply chain, especially in complex environments like airports.

Category	**Sub-categories**
Energy Management	Renewable Energy Use, Energy Efficiency
Water Management	Water Conservation, Wastewater Management
Waste Management	Solid Waste Handling, Hazardous Waste Management
Gaseous Waste Management	Carbon Emissions Reduction, Noise Pollution Control
Biodiversity and Land Use	Preservation of Natural Habitats, Green Spaces
Community and Stakeholder Engagement	Communication with Local Communities, Public Involvement in Planning
Policy and Regulation Compliance	Adherence to Environmental Laws, Certifications (e.g., ACA, LEED)

Table No 3.3 The Green Framework for Resource Management

Energy Management

Energy management serves a crucial function in fostering sustainability in airports, due to the substantial energy requirements linked to terminal operations, runway lighting, security systems, and ground support equipment. Historically, airports depended on fossil fuels, but the transition towards sustainability highlights the need to minimize this reliance by adopting renewable sources such as solar, wind, and biomass. Numerous airports are now implementing extensive solar farms and rooftop panels to satisfy part or all their energy requirements, significantly reducing their carbon emissions. Additionally, enhancing consumption through energy-efficient technologies like LED lighting, smart grids, motion-sensor-based lighting, and automated HVAC system improves operational efficiency while minimizing energy waste. Intelligent building management systems also enable real-time

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monitoring, facilitating the swift detection of inefficiencies and ensuring that energy consumption matches demand.

Regular energy audits are a vital component of effective energy management. These audits assist in identifying areas of high consumption and inform decision-making for forthcoming upgrades or retrofits. Besides lowering operational expenses, robust energy management systems can create new revenue possibilities, such as selling surplus renewable energy back to the grid. Airports that excel in energy efficiency frequently obtain esteemed environmental certifications and attract environmentally conscious travelers and investors, further solidifying their market position. Ultimately, implementing advanced energy management strategies promotes not just environmental responsibility but also long-term durability and a competitive edge in an increasingly sustainability-focused world.

Source - Uysal, O. and Sogut, M.Z., 2017. *Integrated research for architecture-based energy management in sustainable airports*. Energy, 140(2), pp.1382–1393. doi: 10.1016/j.energy.2017.09.011.

Water Management

Water management is a crucial component of enhancing sustainability within airport operations. Airports utilize substantial amounts of water every day for activities like landscaping, sanitation, HVAC cooling systems, aircraft maintenance, and emergency services such as firefighting. Sustainable water management strategies seek to diminish this consumption by implementing water-efficient technologies. The installation of low-flow plumbing fixtures, sensor-activated faucets, and waterless urinals can greatly reduce unnecessary water usage. Furthermore, rainwater harvesting systems are increasingly being used to collect and store rainwater, which can subsequently be used for non-potable purposes like irrigation, toilet flushing, and cleaning tasks. By harnessing naturally available resources, airports can decrease their reliance on municipal water supplies and aid in the preservation of freshwater ecosystems.

Another essential aspect of sustainable water management is the treatment and reuse of wastewater. Airports that invest in on-site advanced wastewater treatment facilities can treat greywater to a level appropriate for reuse in non-drinking applications, thus creating a closed-loop water system that significantly lowers overall consumption. These systems not only reduce the demand for freshwater resources but also prevent the release of untreated wastewater into nearby lakes, rivers, and groundwater sources, safeguarding local biodiversity and water quality. Sustainable drainage systems (SuDS) such as permeable pavements, bioswales, and retention ponds further assist in managing stormwater runoff, avoiding flooding, and protecting surrounding habitats. Through comprehensive water conservation initiatives, airports can establish themselves as environmental stewards while also realizing operational cost savings.

The article titled "Green Supply Chain Management in the Indian Automobile Industry: A Review" offers a detailed examination of how sustainable practices are being incorporated into the supply chains of the Indian automobile industry. The authors conduct a critical analysis of literature from both global and Indian perspectives to underscore the growing significance of sustainability in supply chain operations. The review discusses the application of Green Supply Chain Management (GSCM) practices, including green design, eco-friendly procurement, sustainable manufacturing, and logistics. It highlights the main drivers for adopting GSCM, such as regulatory policies, rising consumer awareness, and competitive pressures, alongside obstacles like high expenses, insufficient expertise,

and poor infrastructure. Source - Singh, A., Jain, N. and Sharma, A., 2018. *Green supply chain management in Indian automobile industry: A review*. International Journal of Research in Engineering, IT and Social Sciences, 8(5), pp.98–108.

Waste Management

Waste management is a crucial aspect of the green supply chain framework, concentrating on reducing waste generation and encouraging responsible handling and disposal techniques. Airports produce various types of waste, from general solid waste created by passengers and staff to hazardous waste substances like chemicals, oils, de-icing fluids, and electronic components. Effective waste segregation methods are vital for enhancing recycling and composting results. Setting up distinct waste bins for plastics, metals, paper, organics, and hazardous materials at source locations throughout terminals can significantly improve material recovery rates. Organic waste produced by airport restaurants, lounges, and catering services can either be composted on-site or sent to external composting facilities, transforming waste into valuable soil enhancers instead of adding to landfill volumes.

Hazardous wastes need special attention and must be managed according to strict environmental protocols to prevent soil, water, and air contamination. Safe storage, labeling, collection, and disposal procedures must adhere to international and local environmental regulations. Airports can also enhance their waste management strategies by incorporating circular economy principles, which emphasize designing products for reuse, repair, and recyclability. This involves refurbishing old equipment, repurposing construction debris, and motivating suppliers to use eco-friendly packaging. With comprehensive waste management systems that focus on reduction, reuse, recycling, and responsible disposal, airports not only reduce their environmental impact but also showcase leadership in sustainable development and resource conservation. By embracing an integrated waste management approach, the document promotes a cleaner, healthier environment and advocates for circular economy principles where waste is perceived as a resource instead of a liability. (Source - Sarbassov, Y., Venetis, C., Aiymbetov, B., Abylkhani, B., Yagofarova, A., Tokmurzin, D. and Inglezakis, V.J., 2020. Municipal solid waste management and greenhouse gas emissions at international airports: A case study of Astana International Airport. *Journal of Air Transport Management*, 85, p.101789. https://doi.org/10.1016/j.jairtraman.2020.101789)

Emissions and Pollution Control

Controlling emissions and pollution is an essential aspect of sustainable airport operations, considering the aviation industry's significant role in greenhouse gas emissions and local air quality decline. Carbon dioxide (CO_2), nitrogen oxides (NO_x), and particulate matter are typically emitted during aircraft operations, fuelling ground service vehicles, and utilizing conventional energy sources at the airport. One of the most effective methods for decreasing these emissions is the electrification of ground support equipment and shuttle buses, substituting fossil-fuel-powered vehicles with electric or hybrid options. Airports are also implementing optimized taxiing and aircraft movement procedures that reduce idle times and fuel use. Furthermore, introducing low emission building systems and transitioning to renewable energy sources also aids in achieving emission reduction targets.

Noise pollution is an additional major issue, particularly for communities situated near airports. Extended exposure to aircraft noise can impact both physical and mental health. Strategies to alleviate noise pollution include modifying flight paths to avoid heavily populated regions, enforcing nighttime flight restrictions, and investing in noise-mitigating infrastructure such as sound barriers and insulated

terminal buildings. The creation of green belts and buffer zones around airport property not only dampens sound but also enhances air quality. Ongoing air quality and noise monitoring systems assist in ensuring that emissions stay within regulatory limits and that the airport remains compliant with environmental standards. These efforts not only serve the nearby community but also strengthen the airport's dedication to sustainable and responsible operations. Source - Nikoleris, T., Gupta, G. & Kistler, M., 2011. Reducing Air Pollutant Emissions at Airports by Controlling Aircraft Ground Operations. Washington, DC: Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER).

Land Use and Biodiversity Conservation

Land use and biodiversity preservation are vital aspects of sustainable airport development, seeking to harmonize infrastructure expansion with environmental protection. Expanding airports frequently results in the removal of natural flora, disturbance of local ecosystems, and the division of habitats. To reduce these ecological impacts, sustainable land management practices must be incorporated during the planning and building stages. This encompasses performing comprehensive environmental impact evaluations, safeguarding current green areas, and steering clear of construction in ecologically delicate regions. Airports can also adopt green infrastructure features such as green roofs, permeable pavements, and storm water management systems that bolster ecosystem functions while promoting sustainability.

Beyond lessening harm, airports can adopt proactive measures to restore and improve biodiversity. Planting indigenous and drought-tolerant species aids in maintaining local ecological equilibrium while minimizing reliance on artificial irrigation and chemical fertilizers. Establishing wildlife pathways and buffer zones can facilitate species movement and mitigate conflicts between airport activities and wildlife. Reforestation initiatives on and near airport grounds not only capture carbon emissions but also enhance air quality and provide natural sound barriers. Sustainable landscaping aids in regulating microclimates, boosts visual attractiveness, supports pollinators, birds, and other regional species. By adopting biodiversity-supporting practices, airports showcase environmental stewardship and meet their social obligation to protect natural resources for future generations. (Source - Alibeygi, A., Sabbagh, F., Delavar, M.R. and Askar, A., 2022. *Analyzing, modeling, and assessing the performances of land use by airports*. [pdf] Available at: https://doi.org/10.1007/s12145-021-00701-1 [Accessed 2 May 2025].

Community and Stakeholder Engagement

Community and stakeholder involvement is vital in the social aspect of sustainability, as it cultivates a favorable and inclusive connection with all entities impacted by airport activities. Interacting with local community members, employees, authorities, and various stakeholders is imperative for the effective execution of eco-friendly initiatives. Clear communication concerning operational modifications, environmental ramifications, and any corrective actions aids in establishing trust and mitigates possible disputes. Airports can actively engage communities in the decision-making process by organizing public consultations, conducting workshops, and implementing grievance systems to handle issues.

Policy and Regulatory Compliance

Policy and regulatory adherence are the foundation of any sustainable initiative in airport operations. Following national and international environmental regulations guarantees that airports function within legal boundaries, reducing risks and preserving trust with stakeholders. Abiding by standards such as the Paris Agreement or local governmental requirements averts possible fines and penalties, aligning airport operations with worldwide environmental objectives. Moreover, rigorous compliance with regulations indicates to the public and investors that the airport is devoted to ethical and responsible practices.

Acquiring certifications such as ISO 14001 (Environmental Management Systems), LEED (Leadership in Energy and Environmental Design), and Airport Carbon Accreditation aids in benchmarking and highlighting an airport's environmental performance. These certifications not only reflect regulatory compliance but also act as markers of the airport's dedication to ongoing improvement. Frequent environmental audits, clear sustainability reporting, and the creation of continuous improvement processes based on feedback guarantee that high environmental standards are regularly achieved. This proactive stance towards policy compliance promotes long-term sustainability, strengthens stakeholder confidence, and improves the airport's image as a responsible and progressive organization.

Source - Hardaway, R.M., 1991. Airport Regulation, Law, and Public Policy: The Management anaad Growth of Infrastructure. University of Denver: Digital Commons @ DU. Available at: https://digitalcommons.du.edu/law_facpub/293 [Accessed 3 May 2025].

Framework Integration into Case Study

This theory was used as the analytical perspective for investigating the implementation of green supply chain practices at a particular airport, such as Cochin International Airport (CIAL). The case study will offer a thorough analysis of how the seven essential sustainability domains energy management, water management, waste management, emissions control, land use and biodiversity, community engagement, and regulatory compliance have been tackled at CIAL. Each domain was evaluated through interview inputs by various respondents – officials and operations staff of CIAL- to ascertain the degree of its incorporation into operational processes, emphasizing the obstacles encountered and the successes reached in embracing sustainable practices. Qualitative data analysis using triangulation for complementary evidence support was carried out by examining the archives of popular media, newspapers, write ups and reviews and the extent of correctness of inputs from the interviews was evaluated through this triangulation.

The primary data obtained through structured interviews was examined for looking at the key themes that emerged from discussions with experts. The need for ethical standards necessitated the permission of the interviewees before using their original names, this has not been done as this study is a work in progress. A summary of key concepts, opinions, recollections and events pertaining to each element of the framework is presented. Due to lack of time and the need to use the short article format, only interview excerpts derived are shown below:

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Energy Management- on the ground experiences and opinions of employees and workers

The following statements were derived from the interview excerpts:

-ambitious idea of becoming first solar generated airport

-Concern with environmental impact of operations

-Not just reducing cost but a real, tangible difference

-Recognizing that airport had a responsibility to lead by example

-Large scale operations, like aviation sector can embrace renewable energy.

-Aligning CIAL with global push towards carbon emissions

-Transforming into a model of sustainability

--Airport operations driven by consistent, non expensive sources than conventional sources

-Volatility reduced, better forward planning and predictable cost structure

-Enabling better financial planning, les unpredictability, better long-term project planning and profits

-Grains and perishable storage clean and renewable energy used

-Cooling and ventilator systems smoothly running

Strengthened relationships with green supply chain partners

-A shared sense of purpose for stronger more collaborative relationships between partners of GSC

-Tracking and optimizing energy usage through data

--Real time data on energy generation and consumption- enabling decisions on how and when energy should be used, analysing patterns and adjusting operations to make most of the solar energy generated in peak hours

-Importance of energy storage systems for different time of day use

-Work independent of the grid

Waste Management: on the ground experiences and opinions of employees and workers

*-**Development of a specialized infrastructure and team for overseeing solid and hazardous waste produced***

-Collection, segregation storage and final disposal in systematic and environmentally conscious way

-Recyclable sent to approved recycling facilities, solid waste processed onsite with eco friendly techniques

--Hazardous waste dealt with KSPCB and other governing bodies. Stored in designated area before transportation to authorized treatment, storage and disposal facilities (TSDFs)

-Efficient management of these systems is key to reputation as environmentally friendly airport

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-Waste management process at CIAL even before materials are delivered to the airport

-Adherence to environmental and safety regulations

-Collaboration with external agencies for recycling and disposal of hazardous waste

-Smooth operational process for waste produced in various locations. Sorting for composting, recycling or safe removal.

-Adherence to stringent protocols for hazardous waste and categories like medical supplies, paint and solvent waste, electronic waste and parts

-Incinerated or sent to authorized disposal without disrupting airport operations, ensuring the preservation of the environment and ensuring a good passenger experience.

-Employees pride in being part of an organization that makes a meaningful contribution to environmental protection through responsible and systematic practices.

Water Management: on the ground experiences and opinions of employees and workers

Excerpts from the Interviews:

-Energy and water integrated through innovation

-Agri voltaic activities- land beneath solar panels used for agricultural purposes

-Optimization of land

-Environmental stewardship

-Irrigation through collected rainwater and treated waste water

-Significant water savings

-Long term vision of CIAL is to balance ecological responsibility with operational efficiency

-Water conservation was an interconnected sustainability strategy

-Rainwater harvesting systems installed across airport premises to collect and channel water to storage tanks

-Used for irrigation. Waste water also used in agriculture after being treated

-Vegetables cultivated under solar panels used in airport's food services

-Made available for sale externally

-Closed loop system to promote local sustainability and reduce food miles

-Solar panel design not just for energy generation but to support sustainable agriculture

-Fall of sunlight and flow of rainwater and tilted to allow sunlight for panels and crops while also guiding rainwater naturally down the ground.

-Balance maintained by smart irrigation tools and moisture sensors in the soil would detect when plans needed water and automatically adjust supply

-Sustainability in action where land water and sunlight all worked together efficiently

-Responsible environmental management

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-Crops chosen based on climate, ability to grow in shade, water requirement etc

-Monitoring health of soil, water and crop cycles became important

-Connection with local community for planting, harvesting and training in eco friendly farming techniques

-A shared effort that people genuinely proud to be a part of.

-Utilized in house and within airport limits

-Closed loop approach to be as self sufficient as possible, to cut down cost and keep sustainable operations

-This kind of integration to make system more resilient and future ready

-Working model for airports and large facilities towards sustainability

-Emissions and pollution control

-Decision to transition to electric and hybrid vehicles

-Considerable reduction in fuel consumption

-Airports logistic operations aligned with broader sustainability agenda

-Fewer delays and fast grain delivery

-Optimizing of transportation routes using fuel efficient paths to minimize consumption of fuel, and emissions

-Eliminating detours and idle times, carbon footprint of transport decreased

-Increasing predictability of transportation making operations efficient

-Redefining logistics

-Airport shifted from plastic to biodegradable and reusable packaging led to marked reduction in waste.

-Rethinking supply chain in ways that was environmentally responsible.

-Suppliers also adopted the practice, and more of a closed loop system, and by adopting and sharing best practices the airport was helping to foster a culture of environmental responsibility

Biodiversity and Land Use: experiences and opinions of employees and workers

Excerpts from interviews:

-One of the most innovative and commendable aspects of CIAL was multifunctional land use contributing not only to biodiversity but also to food sustainability and water conservation

-Airport environment felt different from conventional infrastructure zones.

-Lush green space, and haven for local biodiversity

-Reducing noise, improved air and a more pleasant microclimate.

-Maintaining green zones reduced urban heat island effect, helped with groundwater recharge and prevented soil erosion

-Holistic vision of sustainability- people, land and nature

-A living classroom or climate conscious development

-Harmony between infrastructure and ecology

Community and Stakeholder Engagement: experiences and opinions of employees and workers

Excerpts from interviews:

-Maintained strong communication and engagement with local communities

-Inclusive environmental practice that prioritizes hiring from nearby areas

-Strengthening community ties

-Benefits of development shared locally

-Local stakeholders have been involved in various stages of the airports expansion and sustainability initiatives

-Broader social impact, inspiring neighboring communities to adopt similar sustainability practices, especially in areas like organic agriculture and water conservation.

-Spreading awareness and encouraging environmentally responsible behavior in the region.

-Through its Corporate Social Responsibility (CSR) activities, CIAL has supported education and infrastructure development in nearby areas,

-Strengthening its relationship with the local population and building trust in its long-term vision

-Even without formal public consultations, CIAL's approach to planning and development clearly reflects an awareness of local needs and aspirations.

-By staying transparent, setting visible examples, and sharing the benefits of growth, the airport has built trust and support within the community.

-It's this kind of quiet collaboration grounded in respect and mutual benefit that makes CIAL's story one of not just growth, but shared progress.

-Standout example of how an infrastructure project can grow with support and participation of local community

-Engaging community with empathy and understanding

-Settlement packages consisting of compensation, jobs for displaced families and freehold plots. One member from each house got a job

-Taxi operations through cochin airport taxi operators' society that distributes profits among members weekly

-Rare example of rehabilitation beyond material compensation.

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Policy And Regulatory Compliance: reported experiences and opinions of employees and workers

Excerpts from statements/ interviews:

-The airport prioritizes exceeding the necessary environmental regulations to ensure its activities are consistent with national policies regarding land use, pollution management, and energy efficiency.

-CIAL has achieved the Airport Carbon Accreditation (ACA) Level 3+ (Neutrality), which is a certification that acknowledges its initiatives to lower carbon emissions and offset any remaining emissions through verified carbon credits, thereby achieving carbon neutrality.

-While it does not possess formal LEED certification, the airport's eco-friendly practices such as solar energy systems, green landscaping, and energy-efficient construction align closely with LEED principles.

-The airport has established a variety of systems to remain fully compliant with environmental regulations, underscoring its dedication to sustainability and environmental accountability.

Emergent Themes from Qualitative Data

From a peripheral analysis of the qualitative data obtained from the interviews and observations, as well as the archives from newspapers, published reports, case studies and institutional study material, a few emergent themes are suggested. As with all qualitative approaches, this has been a reflexive account of the evidence and researchers' insights are drawn from the interpretivist and reflexivity as a philosophical orientation

CIAL as ***environmental steward***

CIAL as a ***transformational agent*** for similar industries

Evolving and continuously improving technology as a key agent for tangible benefits through process, adoption, implementation and results

People at the center of the progress of the system, **community as the beacon** for sustainable adoption, implementation and outcomes

Holistic adoption of sustainable principles **across, within and between stakeholders**

Findings and Conclusion

In the run up to this study, a small attempt was made to understand Cochin international airport Ltd in terms of the green supply chain management principles and using the green framework for resource management as a tool to analyse individual facets of the entire operations that encompass an airport, in full realization of the depth, the variety and the multiple perspectives of the stakeholders involved. Using qualitative data derived from interviews with organizational representatives and secondary data from archival records that dealt with the particular events and processes that made the organization occupy a center stage in sustainability driven initiatives, an attempt was made to identify the broad themes that evolved from the literature, and the evidence presented through interviews. An

attempt of 'constant comparison' or content analysis approach that is central to qualitative data analysis was used for the same, in a small way. Limitations have been many, the paucity of time and the need for presenting some sources of evidence in the short article format, but an outcome, albeit tentative has been made to suggest a possible approach for the role that CIAL has taken in the larger picture of the society, environment and governance angles. It is one of environmental stewardship (Bennet, Whitty, Finkbeiner et al, 2018) – a less explored term in the literature, but with enormous potential. It has been used to refer to such diverse actions as creating protected areas, replanting, reducing harmful activities, restoring degraded areas, environmental conservation actions, active restoration activities and the sustainable use of management resources. It can be taken at diverse scales, from global to local efforts, and from rural and urban contexts, as also with small, large and multinational entities as organisations and this study may be considered as a precursor for the stewardship perspectives that CIAL can highlight in further research scope.

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