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From Environmental Management Systems to Airport Environmental Performance: A Model Assessment

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Abstract

In the last decades, aviation industry has expressed an increasing interest in the application of environmental management systems (EMSs). Many scholars have examined the environmental impact of the airports' operations, but few have studied the management practices used to develop airport environmental policies. This study aims to contribute to academic and managerial knowledge by exploring and evaluating the application of EMS in the largest Greek airport, namely Athens International Airport (AIA). To achieve this goal, a qualitative case study was conducted in every dimension and aspect of AIA's Environmental Management System. Subsequently, a new Airport Environmental Performance Model (AEP) was built combining the case study results with the most common benchmarking models proposed in the literature. This research enhances the understanding about the airport environmental management and offers best-practice insights to scholars and aviation professionals altogether, proposing the new AEP.

Keywords: airports; environmental management systems; airport environmental performance; AEP model; air transport; environment.

JEL Classification: Q50; Q56.

Introduction

As early as the 1920s, commercial air transport gained international support because of its ability to interconnect people, places, and products (Marinakos and Poulaki 2019). After the end of World War II, air transport has grown significantly enabling the rapid and comfortable mass transportation of people and freight, thus contributing to the growth of tourism in global level. However, the negative environmental costs associated with this growth, which often translate into social and economic ones, are also significant (Daley 2016). The environmental impacts of air transport are both local at airports, while others are global. In any case, their effects can no longer be ignored. Although there have been technological and operational improvements in the industry, that have hampered pollution of the natural environment, the absolute environmental effect of air transport continues to grow, with the result that environmental regulations are becoming increasingly stringent (Brasseur & Gupta 2010).

To mitigate the negative externalities produced by the aviation activities both government and industry bodies have taken action, *i.e.* the International Civil Aviation Organization (ICAO), the International Air Transportation Association (IATA), the Air Transport Action Group (ATAG), the Airport Council International (ACI), the European Union Aviation Safety Agency (EASA), the European Environment Agency (EEA) and the European Organization for the Safety of Air Navigation (Eurocontrol) have developed detailed white papers, recommendations, manuals and green agendas (ICAO, 2019a,b; IATA, 2019; ATAG, 2020; ACI, 2020; EASA; EEA; Eurocontrol, 2019). Considerable initiatives have been also taken by national regulatory bodies, such as the US Federal Aviation Administration (FAA) and the UK Civil Aviation Authority (CAA) (FAA, 2006, 2015; CAA, 2014, 2017). In a corporate level, the two major aircraft manufacturers (Boeing and Airbus) as well as numerous airports and airlines apply and publish environmental protection measures as an integral part of their corporate social responsibility agenda (Airbus 2019 a,b; Boeing 2020). In fact, aviation industry's current environment is characterized by high competition, while Corporate Social Responsibility (CSR) is considered as a strategic business activity that may contribute to the sustainability of the sector, thus a competitive advantage mitigating its negative effects that concerns pollution, noise and carbon dioxide emissions (Serhan *et al.* 2018).

In a highly regulated industry such as aviation, environmental management remain voluntary in a great extent. Nevertheless, aviation firms are increasingly adopting green measures as part of their wider sustainability strategy, for a number of reasons that can be summarized in four groups (ICAO 2012): The market drivers include top management concerns, pressure imposed from the industry and the competitors, as well as other shareholders, investors, insurance companies, clients and suppliers (e.g companies that wish to operate within an airport are required to hold an ISO 14001 certificate) as reported in Guix *et al.* (2018). The social drivers refer to pressures from the local community and environmental organizations, media, public relations, customer expectations, corporate image and corporate citizenship (Stevenson & Marintseva 2019). The financial drivers include long-term cost savings and increased efficiency achieved through reduced energy consumption and waste production (Chen 2013). The regulatory drivers are connected to the conformation with the imposed environmental legislation and the wish to avoid or delay further regulatory action (CAA, 2017). Finally, Kılıç *et al.* (2019) added the institutional drivers, claiming that the political, legal, financial, cultural, and economic institutions have a significant impact on the tourism industry's levels of acceptance and CRS reporting.

Current research on environmental management in the aviation industry largely focuses on environmental impact (Timmis *et al.* 2015; Brasseur & Gupta 2016; Li *et al.* 2016; Paraschi & Poulaki, 2021; Grewe *et al.* 2021) and on the theoretical exploration of Environmental Management Systems (EMSs) formulation (Kılkış & Kılkış 2016; Maleviti & Stamoulis 2017; Lu *et al.* 2018; Santa *et al.* 2020; Kumar *et al.* 2020). Although theoretical contributions are valuable as a starting point, aviation business is a dynamic and highly practical-oriented sector, seeking for feasible solutions tested in practice. There is relatively little and fragmented work on the green practices engaged by airlines and airports, that could serve as best practices and benchmarking standpoints (Li *et al.* 2003; El-Mobaidh *et al.* 2006; Teoh & Khoo 2016; Zhdanko *et al.* 2016; Abrantes *et al.* 2021; Cabrera, E., & de Sousa 2022). Therefore, the aim of this study is to build a comprehensive Environmental Airport Performance (AEP) framework by combining the results of the in-depth case study with the most common EMSs described in the literature. The suggested AEP covers all the main environmental-related dimensions of airport operations, proposing specific measurement indicators for every dimension. This AEP framework can be used for a handy albeit thorough evaluation of an airport environmental performance. In this way, this study offers useful insights to aviation researchers seeking for integrated theoretical frameworks and to aviation practitioners seeking for applied solutions.

The rest of the paper is structured as follows. Section 2 reviews the literature on the environmental impact of airports and the benchmarking models proposed by the literature, while the research methodology is presented in section 3. Following, Section 4 summarizes the Environmental Management System (EMS) of Athens International Airport and discusses the managerial implications. Finally, section 5 deals with the limitations of the study and makes suggestions for future research.

1. Literature Review

1.1. The Environmental Impact of Airports

The main environmental concerns connected with airport operations are noise, emissions and climate change, land and water use, waste and pollution, energy consumption and loss of biodiversity (Paraschi & Poulaki 2021). The most detrimental environmental effect of aviation is produced by noise. Millions of people in Europe are exposed to aircraft noise at residential communities in the vicinity of airports. In addition to operation and engine testing, additional noise sources at airports are the auxiliary power units (APUs) used during ground operation, as well as other equipment such as ground power units (GPUs) and ramp vehicles. Noise can cause community annoyance and it is the first cause of complaints that airports receive from local residents. Moreover, the literature provides evidence for several adverse effects of aircraft noise on the public health, such as sleep disturbance or adverse cardiovascular and metabolic effects (Basner *et al.* 2011; Seidler *et al.* 2017; Van Kempen *et al.* 2018). Airports contribute to climate change due to aircraft emissions containing carbon dioxide (CO2) and other gases (Jardine 2005). An additional source of emissions is the ground-support equipment operating within airports as well as the vehicles (cars, taxis, buses, etc.) of the airport's surface access system (Sameh & Scavuzzi 2016).

Furthermore, as a result of the congestion problems that many airports already face, airport development with new and larger runways, taxiways, terminals, and roads seems inevitable. Besides, many airports have become small cities or ever metropolitan regions, the so called "aerotropolis" (Kasarda 2011), thus land use for cargo, industrial and commercial parks, hotels, and other passenger amenities will continue to affect and compete with adjacent communities (Sameh & Scavuzzi 2016). The environmental issues connected to airport size and placement include land use, soil erosion, surface and subsurface water drainage, and the adverse impact on flora and fauna (Freestone & Baker 2010). One of the earliest restrictions were concerned with height control of possible hazards or obstacles in the land use near airports. Other, potentially conflicting actions include activities that could cause electrical interference with radio communications and navigation aids, lights that might confuse pilots, smoke that reduces visibility and the presence of accumulated solid waste because they can cause bird concentration (ICAO, 2002). Soil erosion may result from vegetation clearing, and, to a lesser extent, by aircraft jet blast. Surface and subsurface water is affected due to changes to the natural drainage patterns of an area during the construction or the expansion projects of an airport, something that can overload certain streams causing flooding, while the diversion of flow may cause other streams to dry up. Moreover, the positioning of some airports may constrain the shorelines of rivers, lakes and the sea, thus causing disturbances to the local flora and fauna (Freestone & Baker 2010). Further, heritage considerations may rise since many airports are located within or close to natural or cultural environments with aesthetic, historic, scientific, social, or national significance (ICAO, 2018d).

In addition to air pollution, air operations can cause water and soil pollution through in-flight waste, sewage, green waste, solid waste and hazardous waste (Mehta 2015). Airport waste can be produced by passengers, aerodrome operations and maintenance, construction, and demolition work. A variety of chemicals is used in their day-to-day operations such as aircraft and airfield de-icing and anti-icing activities, fuel storage and refueling, aircraft and vehicle cleaning and maintenance, fire suppressant chemicals and foams dispersed in firefighting exercises, dust, dirt and hydrocarbons from paved surfaces and herbicides and pesticides, all of which may release pollutants to adjacent water bodies (ACI, 2008; Sameh & Scavuzzi 2016). In addition, fuel and chemical spills that often happen on the apron, as well as accidents and incidents involving dangerous goods or hazardous materials may affect the environment (ACI, 2008; Mehta 2015).

In order to perform the multiple activities that are carried out in airports, large amounts of energy are necessary. The most important energy sources are electricity and fuel (natural gas, petrol, diesel, propane, etc.), with the former being the major energy source for airports and the latter for the airlines (Ortega & Manana 2016). The majority of energy used at an airport is associated with the provision of heating, ventilation and air conditioning (HVAC, 24.5%), terminal and other buildings' lighting (19.8%), Information and Communication Technologies (ICT, 18.3%), external companies (11.8 %), airfield lighting (7%) radio navigation systems (4.8%), electromechanical facilities (2.4%), meteorological systems, vehicles and others (11.5%) (Ortega & Manana 2016; Baxter, *et al.* 2018). The largest part (76%) of energy is consumed at the landside (Ortega & Manana 2016). It is estimated that energy costs account for about 5 per cent of the total operating costs of a modern airport and that the use of the best available conservation techniques can reduce this cost by 5 to 20 per cent (ICAO, 2002).

Airports can impact biodiversity in several ways, including loss or degradation of habitats especially in airports' expansion, frightening or controlling wildlife for operational reasons, and causing light and noise pollution which is detrimental on some species (Altuntas 2019). Airports are built in open countryside near large urban centres, therefore, many are surrounded by ecosystems that can be of particular value in terms of their biodiversity. Within the boundaries of the airport, operational and safety issues create an environment that is hostile to the flora and fauna of the area. Problems may also arise to species or habitats sensitive to aircraft noise. Noise is also known to have negative impacts on wildlife causing panic fleeing alert and escape behaviour, changes in vocal behaviour and threatened reproductive success (Alquezar & Macedo 2019). Considering that airports occupy large land areas, there is a high probability that isolated populations of sensitive species of flora and fauna may be affected. In such cases almost any development of aviation activity may affect the biodiversity of the region, which requires extensive coordination between airport environmental services and the relevant organizations and bodies (Culberson 2011, ICAO 2018c).

1.2. Environmental Management in Airports

According to Bohdanowicz, Zientara and Novotna (2011), the tourism industry has fertile ground for promoting environmental sustainability. Measures in this direction concern the development of environmental management/sustainability systems, which monitor and contribute to the reduction of water and waste generation and energy consumption, the installation of devices that are characterized as resource efficient and based on the latest technologies (such as lighting with LEDs or low flow valves) which help to reduce energy and water consumption and the transition to the use of renewable energy sources. In this context, different solutions and mechanisms are employed by the airports to mitigate the negative environmental externalities. These strategies are usually integrated into the airport Environmental Management System (EMS).

Since noise is the most apparent negative externality of aviation, ICAO has adopted a three-tiered noise mitigation approach: noise reduction at the source, noise reduction by adjusting take-off and landing procedures and passive sound insulation of the buildings at the vicinity of airports (ICAO, 2019c). In line with ICAO guidance, the European Commission issued the EU Environmental Noise Directive (EC/2002/49) and the associated Balanced Approach Regulation (EU 598/2014) aiming at promoting the sustainable development of air transport through the reduction of aircraft noise pollution at airports. Controls may be imposed on the noise generated by aircraft engine and auxiliary power units (APU) ground running, ground movement of aircraft and certain airport construction activities (ICAO, 2002). Additionally, curfews during night might seem to be some of the most practical measures often imposed by local or national authorities to protect local communities in the vicinity of airports (ICAO, 2019c). Nevertheless, restrictions on night flights and curfews lead to under-utilization of infrastructure, which is not favorable with respect to growth and economic viability of airports (Sameh & Scavuzzi 2016). Land-use planning is also engaged to alleviate noise annoyance to exposed residents. Airports can redistribute noise by managing runways and routes use when possible. Acoustical barriers and sound-screening methods can also be used. Finally, when urban planning is used for noise abatement, the authorities designate district noise zones around noise sources, where the noise level exceeds the recommended noise limit (ICAO, 2002). Additional measures, such as passive sound insulation of dwellings can be effective in reducing sleep disturbance but may not reduce annoyance levels when it is associated with poor indoor air quality (Baxter *et al.* 2018).

Several steps can be taken at the airport level to improve air quality and mitigate climate change, such as the construction of energy saving buildings, the installation of renewable energy power systems, or utilization of green power, the provision and promotion of fixed electrical ground power (FEGP), the optimization of the efficient flow of air traffic to prevent unnecessary aircraft idling and taxiing and the investment in transport links to encourage more use of public transport (CAA, 2017). To increase the fuel efficiency and decrease emissions from airport ground support vehicles, actions recommended by ICAO involve frequent maintenance; shutting off engines when applicable; driving at optimum speeds; accelerating smoothly; reducing driving distances by planning routes; using alternative bio-diesel and low-sulphur diesel fuels or natural gas or electric power or hybrid-fuelled vehicles; using oxidation catalysts and particulate trap which can reduce hydrocarbon and particulate mass emissions up to 95 per cent; replacing the power/air conditioning requirement on the ground with more energy/fuel-efficient equipment in order to cut the amount of operation time of APUs; and improving public transport access to airports so as to reduce emissions from private vehicles (ICAO, 2002; 2018a). At an institutional level, the Airport Council International (ACI) introduced in 2009 the Airport Carbon Accreditation, a global carbon management certification program which independently assesses and recognizes the efforts of airports to manage and reduce their carbon emissions through six levels of certification: 'Mapping' (*i.e.* carbon footprint measurement), 'Reduction' (*i.e.* reduction of the airport operator's carbon footprint), 'Optimization' (*i.e.* engaging others at the airport to reduce their CO2), 'Neutrality' (*i.e.* offsetting any residual CO2 emissions from the airport operator), 'Transformation' (*i.e.* transforming airport operations to achieve CO2 in line with global climate goals) and 'Transition' (i.e offsetting residual CO2 emissions from an extended list of sources at the airport site). Up to date, more than 340 airports worldwide participate in the Airport Carbon Accreditation program (ACI, 2020).

Land-use planning within and around airports is used to maintain efficient airport operations and ensure the safety of people in the air and on the ground. Therefore, ICAO as early as 1967 developed in Doc 9184 Airport Planning Manual Part 1 (APM Part 1) which regulates height control of possible hazards or obstacles at the vicinity of airports controls other potentially conflicting activities, such as electrical interference with radio communications and navigation aids; lights that might confuse pilots; smoke that reduces visibility; and accumulated solid waste on which birds may feed and thus could cause accidents to approaching or departing. More recently (1985), environmental concerns connected with airport operations led to Airport Planning Manual Part 2 which contains information on possible land uses that should be appreciated in terms of their compatibility or incompatibility to airport operations such as natural land use (forests, open land, rivers, etc); agricultural land use; highways and railways built near airports; recreational land use (golf courses, swimming pools, tennis courts, etc.); municipal facilities (water, sewage disposal and power utilities); commercial and industrial land use; residential and institutional (schools, hospitals and churches) land use; and heritage considerations (ICAO, 1985). Overall, the airports land use planning should follow a "balanced" philosophy based on the cooperation between, national and local government as well as the multiple other stakeholders involved in airport operation, with clear consultation and decision-making processes (Freestone & Baker 2010).

Airport waste management concerns the reduction of both hazardous and non-hazardous wastes. The ACI Policy Handbook provides a decision hierarchy of descending waste management choices: avoiding; reducing; reusing; recycling; and finally, disposing with the ultimate goal of eliminating waste going to landfills (ACI, 2008). It is obvious that the best choice is to minimize the generation of waste at the source. Further, waste reduction efforts may include minimum packaging and the use of alternative, online processes to go paperless (e.g., e-boarding pass). Recycling is a well-established policy among airports. It is estimated that approximately 75 % of the airports' waste is recyclable or compostable. With recycling, residual waste is reduced and energy and materials are recaptured with paper being the largest single category of MSW generated by the airline industry (Mehta 2015). Lately, aviation industry is working towards the 'waste to energy' process which turn waste into energy in the form of heat, electricity, or fuel through several processes such as incineration, anaerobic digestion, gasification, and landfill gas recovery (ICAO, 2018b).

To mitigate the environmental impact from energy consumption, aviation organizations follow a strategy with two main elements: (a) effective utilization and management of energy, and (b) choice of energy source (ICAO, 2002). The first option includes a wide range of energy saving measures applied both in the design and the operation of infrastructure. For example, the appropriate location and configuration of the airport buildings can achieve optimal utilization of natural lighting, thus significantly reducing the needs of artificial lighting (ICAO, 2002). Moreover, airports cooperate closely with tenants, concessionaires, and service partners to reduce energy consumption through the introduction of low-energy equipment (Baxter *et al.* 2018a). Except for energy saving, airports are exploring new and alternative energy sources, other than the conventional fossil fuels. There are several energy technologies currently being developed as energy sources for airports, such as photovoltaics, concentrating photovoltaics, wind, oil and gas exploration, steam generation and transmission (Baxter *et al.* 2018a). Among them, solar photovoltaics (PV) have become a widely applied means of renewable energy source at airports. Airport open landscape and buildings can provide suitable sites for solar facilities. In addition, airports can also achieve potential returns from selling surplus energy back into the power grid (Baxter *et al.* 2018b).

Biodiversity impacts are usually addressed in the context of airport planning and land management. ICAO recommends that airport strategic plans for biodiversity shall start with environmental assessments in order to identify sensitive habitats, any risks, and appropriate mitigation and shall include increased biodiversity awareness and integration of biodiversity values into all processes (ICAO, 2018c). Safeguarding measures for ecosystems, species, and genetic diversity may include re-creation of habitats elsewhere to provide a home for flora and fauna, or the diversion of watercourses. Any measures should be based in joint planning, knowledge management, and capacity building in cooperation with internal and external stakeholders, like government agencies, business structures, nongovernmental organizations, and the local population (Altuntas 2019).

1.3. Assessment of Airport Environmental Performance

Despite the increasing interest of airport industry on green and sustainable practices, the literature offers only limited examples of comprehensive environmental assessment frameworks that could serve as industry benchmarks. Airport managers have to combine several individual approaches into their Environmental Management Systems and even then, they cannot be sure that they have created a compete EMS that would sufficiently serve airport sustainability. The first attempt to synthesize the most common and effective airport sustainability practices was made by the Airport Cooperative Research Program (ACRP, 2008). This report covers the environmental, economic and social dimensions of airport sustainability. The environmental sustainability performance assessment uses twelve criteria: measuring and monitoring; water conservation and quality; air quality; climate change; land use; biodiversity; construction and hazardous materials; waste; noise and aesthetics; energy and green buildings and several sub-criteria, as shown in Appendix 1.

Kılkış & Kılkış (2016) developed a Sustainability Ranking of Airports (SRA) Index with five dimensions: airport services and quality; energy consumption and generation; carbon dioxide emissions and mitigation planning;

environmental management and biodiversity; and atmosphere and low emission transport. The five dimensions are evaluated with twenty-five indicators (Appendix 1). Lu *et al.* (2018) adopted a sustainability-balanced scorecard (SBSC) for the evaluation of the sustainable performance of airports. The SBSC has five dimensions: financial perspective; internal business process; learning and growth; environmental perspective and social perspective, further analyzed into fifteen criteria (Appendix 1).

Santa *et al.* (2020) proposes a green airport model based on social and environmental management systems. Their model consists of ten indicators: noise reduction; emission reduction and air quality; energy management; water management; waste management; biodiversity conservation and land use; cost and economy; quality of the internal environment; transport and vehicle control; social and cultural aspects. The above indicators are evaluated using fifty-eight sub-indicators (Appendix 1). Kumar *et al.* (2020) employed a hybrid of Best Worst Method (BWM) and VIKOR methodologies to calculate the weight of different green performance criteria. Their model consists of forty-three indicators grouped into seven green performance categories: air and noise control; green building and infrastructure; waste management and recycling; environmental monitoring and control; green operation and transportation; employee green training and green policies and regulations (Appendix 1).

2. Methodology

2.1. Research Approach

Since the main purpose of this research is to investigate how to adopt and implement EMS in the context of the airport, a case study-based qualitative research approach was chosen. The case study approach is based on analytical generalizations rather than statistical generalizations. Stuart *et al.* (2002) claims that case studies are non-representative, but rather aimed at being exemplary. The focus of the research is to gain insight in order to understand and map the main environmental measures adopted in practice. Case study methodology is often engaged to capture the sustainable practices of airports (Kilkis and Kilkis 2016; Li and Loo 2016; Chao *et al.* 2017). However, Greer *et al.* (2020) suggest that more case study airports are necessary to capture local and regional impacts, claiming that results can be generalized by modeling the environmental impact of the average airport (that is, sustainability indicators can be applied to a wider range of airports). In this line, the Grounded Theory approach (Strauss & Corbin 1997) was used to develop a new theoretical model, drawing from the case study results.

This study followed a selective or purposeful sampling methodology. Purposeful sampling is a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources (Palinkas *et al.* 2015). This includes identifying and selecting individuals or groups of individuals with specific knowledge or experience about the phenomenon of interest. (Patton 2002). Based on the above criteria, Athens International Airport (AIA) was selected as the subject of the case study. AIA is the busiest Greek airport and belongs to large airports according to ACI's classification, therefore it has a broad range of environmental-related activities that need properly handling. Additional criteria that were used to choose the study subject included its organizational culture (AIA has a strong sustainability and environmental-friendly culture); its established reporting system and data availability (AIA keeps detailed records and publish annual sustainability and environmental reports) and its openness and willingness to participate in the study. The case study used secondary qualitative and quantitative longitudinal data obtained from a range of corporate documents, including AIA's annual, environmental and sustainability reports for the years 2015, 2016, 2017, 2018, 2019 and 2020.

2.2. Athens International Airport

Athens International Airport Eleftherios Venizelos (AIA) is the first major transportation infrastructure in Greece (Vogiatzis *et al.* 2021). It was established in 1996 as a Public-Private Partnership with a 50-year concession agreement and started operation in 2001. AIA is a privately managed company, with the Greek State holding 55% of shares, while the private shareholders collectively hold 45%. AIA serves the capital of Greece, Athens and is the main gate of entrance to the country. More specifically, AIA operates as a hub to other Greek destinations not only by air with connecting flights but also by land and by sea. It is worth mentioning that Aegean Sea Islands having airports with short runways are served by AIA in terms of international traffic since there are no direct international connections due to insufficient infrastructure (Ballis *et al.* 2018). AIA is currently the busiest airport in Greece and the 19th-busiest airport in Europe, with more than 25 million passengers in 2019 (AIAa, 2021; HCAA, 2019), a number that corresponds to the 42% of the total flights that country receives in annual basis. According to Airports Council International (ACI) European airports' division, AIA belongs to the second largest (25-40 million passengers) out of five categories. In fact, in 2021 AIA was awarded as the best airport of this category (ACI Europe, 2021).

The airport extends in an area of approximately 16,000 km2 and has two runways in compliance with ICAO Aerodrome Reference Code "4E", (03L/21R: 3,800x60m and 03R/21L: 4,000x60m). The Airport features a 168,000m2 Main Terminal Building and a 34,000m2 Satellite Terminal Building with a total of 24 Contact Bridges and 75 active remote aircraft parking positions. The AIA airport community includes 316 companies and 14.816 employees (AIA, 2019). AIA is the main base of Aegean Airines, as well as other smaller Greek airlines.

Considering the abovementioned, AIA is an exceptional case to study in terms of environmental management system due to its size and its importance for one of the top tourism destinations in the Mediterranean Sea. The results and the implications of the study may be reflected to other airports of similar characteristics towards a sustainable air transport and tourism future.

3. Case Study Findings and Discussion

3.1. Environmental Management

Athens International Airport has historically placed a very high focus on sustainable environmental management. AIA aims to monitor all environmental aspects responsibly and effectively; and to minimize or prevent, where possible, the Airport's environmental impact through initiatives that exceed regulatory requirements in accordance with the corporate Environmental Policy (AIA, 2020). The airport has an Environmental Management System (EMS), certified in accordance with the international standard ISO 14001 since 2000. In addition, AIA remains the only Greek airport with an Energy Management System (EnMS) certified in accordance with the ISO 50001 standard. Additionally, by the end of 2019, 74 companies within the airport community had a Certified Environmental Management System (AIA, 2020). To promote the environmental cooperation among the airport's stakeholders, AIA holds an annual Environmental Workshop and has established Environmental Excellence Awards for third parties.

3.2. Energy Management

AIA is committed to reducing its contribution to climate change by reducing emissions. The measures include energy-efficient design of airport buildings and infrastructure, widespread use of natural gas, and good public transport access to the airport. As seen in Table 1 the airport constantly reduces the total airport electricity consumption per passenger since 2016 and has also reduced the total airport natural gas consumption per passenger by in 2019 22,5% compared to 2015. Energy consumption (both electricity and natural gas) was also reduced in 2020 due to covid-19 travel restrictions that caused a decline of 68.4% compared to 2019 passenger volumes (AIA 2021b,c).

Table 1. Athens International Airport energy consumption and production

	2015	var	2016	var	2017	var	2018	var	2019	var	2020
Electricity Consumption											
Total Airport * (MWh)	100,396.7	3.64%	104,058.60	0.60%	104,715.80	4.90%	109,796.50	3.2%	113,336.6	-18.2%	92,762.2
AIA only** (MWh)	50,665.00	3.80%	52,582.70	3.50%	54,407.20	7.10%	58,276.60	5.1%	61,263.8	-16.7%	51,020
Total Airport consumption per passenger (kWh/pax)	2.8	85.70%	5.2	-7.30%	4.82	-5.60%	4.55	-2.64%	4.43	159%	11.48
Natural Gas Consumption											
Total Airport * (Nm^3 x 1000)	2,199	-2.52%	2,143.50	6.60%	2,285.50	-13.70%	1,972.90	20.20%	2,371.40	-3.40%	2,291.8
AIA only ** (Nm^3 x 1000)	1,147	-3.30%	1,109.10	-2.50%	1,068.30	-13.30%	925.8	28.38%	1,188.50	-5.10%	1,248.6
Total Airport consumption per passenger (Nm^3/pax)	0.12	-8.30%	0.11	-4.50%	0.105	-21.90%	0.082	13.41%	0.093	5.10%	0.28
PV Plant Operation											
Total Energy Production (MWh)	n/a	-	13,280.6	2.70%	13,641.8	-5.08%	12,948.4	2.20%	13,234.5	0.90%	13,358.5
Total PVP CO_2 emissions savings equivalent (tons)	n/a	-	9,097.5	-12.70%	7,939.5	-0.68%	7,885.6	6.60%	8,443.6	-4.60%	8,055.2

Source: Authors' elaboration based on Athens International Airport data (2015-2020)

*Notes: * Refers to the entire airport community.*

*** Refers to the Airport company only.*

However, the reduced traffic (8.08 million passengers in 2020 in comparison to 25.6m in 2019) is also the reason for the significantly (159%) increase in the total airport consumption per passenger for 2020 (Table 1). Besides, the Airport's environmental profile is further bolstered by the production of clean electricity by its 8.05 MWp Photovoltaic Plant (PVP) established in 2011. The PVP produces about 13,000MWh annually which leads to equivalent savings of 8,500 tons of CO2 on average (Table 1).

3.3. Greenhouse Gas Emissions and Management of Climate Change

AIA participates in the Airport Carbon Accreditation initiative led by the Airports Council International and it successfully renewed its certification at level 3+ (Neutrality) for 2020. AIA maintained its carbon neutral status by purchasing Guarantees of Origin (from its local electricity supplier through the Greenpass program) ensuring that all electricity consumed by AIA was produced by renewable energy sources and by purchasing verified carbon offsets for AIA's other remaining emissions (*e.g.* its vehicle fleet) (AIA, 2021b,c). Together with the other members of ACI Europe AIA is not only committed to Net Zero Carbon by 2050, but, recognizing the need for more urgent action, AIA announced its official commitment to achieve net zero carbon emissions by 2025 (ROUTE 2025). The airport took further actions in 2019 towards the end of net zero carbon emissions by 2025, including a study for the replacement of two air-cooled chillers with highly efficient water-cooled ones, a tender for the purchase of ten more environmentally friendly vehicles and two buses, a study for the remodeling of the airport's potable water network, the continued conversion of paper-based corporate forms and procedures to electronic format, the conversion of several applications to cloud-based versions, the replacement of twelve physical servers with virtual ones and the launching of AIA's first-ever Climate Change Adaptation study (AIA, 2020). By heavily investing in energy-efficient technology over the past six years, AIA has managed to reduce its carbon footprint per passenger by approximately 18% except for 2020 when the collapsed passenger volumes artificially increased the portion of CO2 emissions per passenger, although the total CO2 emissions are significantly lessened (Table 2).

Table 2. Athens International Airport CO2 emissions

	2015	2016	2017	2018	2019	2020
Grid Electricity	34,707	36,019	31,665	35,490	39,086	30,765
Natural Gas (Nm^3)	2,415	2,31	2,254	1,945	2,504	2,602
Vehicle fleet						
Petrol (lt)	329	214	121	209	185	130
Diesel(lt)	1,029	1,068	1,066	1,21	1,243	939
Other sources						
Diesel (lt)	69	33	36	76	124	62
Heating oil (lt)	7	60	29	21	4	31
Total	**38,556**	**37,394**	**35,171**	**37,741**	**43,146**	**34,529**
Annual passengers	18,743,026	19,973,704	21,669,421	24,049,905	25,486,624	8,078,394
CO2 emissions (Kg) per passenger	**2.06**	**1.87**	**1.62**	**1.57**	**1.69**	**4.27**
variation		**-9.0%**	**-13.3%**	**-3.3%**	**7.9%**	**152.5%**

Source: Authors' elaboration based on Athens International Airport data (2015-2020)

Athens International Airport is one of the best-equipped airports in the world, in respect to air quality and meteorological monitoring. Emissions of air pollutants from all airport sources are monitored in a constant basis and measures are taken to reduce them where possible. AIA's monitoring equipment includes an Air Quality Monitoring Network (AQMN), a Differential Optical Absorption Spectroscopy system (DOAS), a SOnic Detection and Ranging system (SODAR), a Radio Acoustic Sounding System (RASS) and a meteorological Station (AIA, 2020b,c). The AQMN consists of five permanent monitoring stations installed in the areas of Glyka Nera, Koropi, Markopoulo, Pallini and Spata and measuring the concentrations of the major air pollutants: nitrogen oxides (NOx), ozone (O3), particulate matter (PM10 and PM2.5), sulphur dioxide (SO2) and carbon monoxide (CO) as well as basic meteorological parameters (such as wind speed and direction, temperature, relative humidity, atmospheric pressure, solar radiation and rain) (AIA, 2020). The concentrations of monitored pollutants at the AQMN are given in Table 3. According to the World Health Organization (WHO, 2006) the accepted rates for these pollutants are the following: 40 μg/m3 for NOx, 120 μg/m3 for O3, 30 μg/m3 for PM10, 20 μg/m3 for PM2.5,50 μg/m3 for SO2 and 10 μg/m3 for CO. All measured concentrations that exceed these maximum rates are marked with an asterisk (*). As seen in Table 3, all pollutant concentrations lay well below the international limits except for PM2.5 at the Koropi station and PM10 at the Markopoulo station. However, the rate of both pollutants reduced significantly in 2019 to meet the required standards and reduced further in 2020 when the traffic declined sharply due to the covid-19 pandemic.

Table 3. Concentrations of monitored pollutants at the Air Quality Monitoring Network Stations (in µg/m3)

Station	Pollutant	2015	2016	2017	2018	2019	2020
Glyka Nera	NO_x	17.3	15.2	13.1	12.2	13.2	13.6
	O_3	87	83.1	84.8	84.4	81.1	77.2
	PM10	27.2	28.1	23.1	26.8	19.9	18.9
	PM2.5	n/m	n/m	n/m	n/m	12.6	11.3
	SO_2	6.7	7.1	5.1	6.1	6.4	5.4
	CO	0.3	0.3	0.3	0.3	0.3	0.3
Koropi	NO_x	13.4	11.4	10.5	9.6	10.4	n/a
	O_3	79.2	79.8	81.9	78.3	78.2	74.7
	PM10	n/m	n/m	n/m	n/m	23.6	21.9
	PM2.5	22*	21.7*	21.8*	23.3*	13.1	11.3
	SO_2	n/m	n/m	n/m	n/m	n/m	n/m
	CO	n/m	n/m	n/m	n/m	n/m	n/m
Markopoulo	NO_x	14	15.6	14.5	10.6	10.9	10.7
	O_3	79.9	78.5	81.7	n/a	83.3	77.6
	PM10	39.8*	35.2*	27.4	32.4*	24	21.4
	PM2.5	n/m	n/m	n/m	n/m	15.6	13.6
	SO_2	n/m	n/m	n/m	n/m	n/m	n/m
	CO	0.3	0.3	0.4	0.4	0.3	0.3
Pallini	NO_x	11.6	10.4	7.7	5.8	7.5	6.6
	O_3	85.5	87.6	87.8	83.7	91	86.9
	PM10	n/m	n/m	n/m	n/m	83.7	20.1
	PM2.5	14.3	13.1	14	16	14.8	13.1
	SO_2	5.4	5.7	5.8	5.1	6.2	4.3
	CO	0.3	0.2	0.2	0.3	0.3	0.3
Spata	NO_x	17.2	16.1	14.2	13	13.7	12.9
	O_3	79.3	75.1	78	73.4	73.5	81.00
	PM10	28.7	30.9	31.2	n/a	73.4	21.00
	PM2.5	n/m	n/m	n/m	n/m	14.6	12.4
	SO_2	4.3	4.6	4	3.7	3.5	3.2
	CO	0.3	0.3	0.3	0.3	0.3	0.2

Source: Authors' elaboration based on Athens International Airport data (2015-2020)

*Notes: *: the concertation exceeds the WHO acceptable limits*

n/a: data non available

n/m: pollutant not measured in the specific station

3.4. Noise

AIA acknowledges the fact that noise is one of the main environmental challenges associated with any airport's operation. Noise is produced from various sources, primarily the aircraft's engines but also from airflow around aircraft. The Airport Company addresses noise issues responsibly by taking measures that aim to reduce annoyance to its neighbours. As such, Noise Abatement Procedures such as the preferential runway use system (Table 4) have been in place since the Airport opened, implemented in collaboration with the Hellenic Civil Aviation Authority (HCAA) and airlines, to reduce noise in the residential areas around the Airport. In addition, AIA has established a dedicated telephone line called "We Listen" that concerned citizens may call to register their complaints or request clarifications on noise-related issues. A relevant form is also available on its corporate website (AIA, 2020). The airport handles about 32 noise complaints annually which corresponds to one complaint per 12,000 aircraft movements. Although in 2020 all noise levels in the ten NMTs were reduced (Table 5), a total of 72 noise complaints were received, a significantly high number compared to previous years when AIA was three-times busier in air traffic. This rise can be explained by the need to accommodate a large number of aircraft grounded due to covid-19, as well as other operational needs that necessitated periodic changes in runway use. Additionally, the long period with very few flights in the first half of 2020 triggered noise complaints when traffic was partially restored during the summer (AIA 2021b,c).

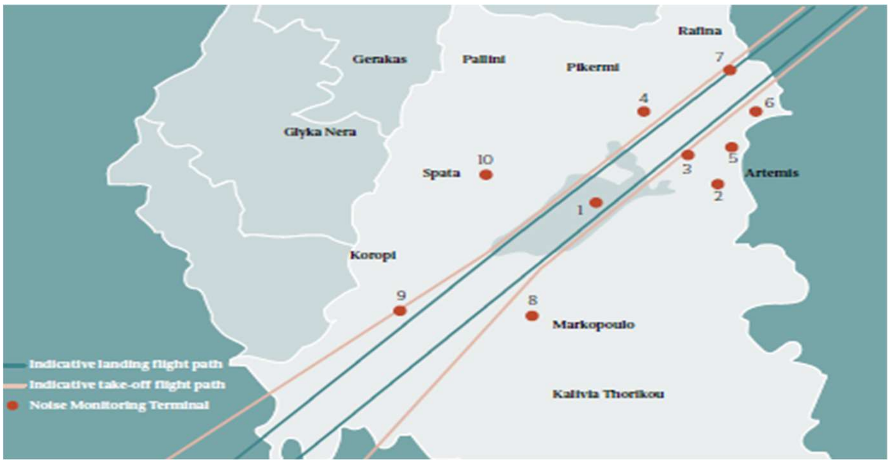
Table 4. Athens International Airport Noise Abatement Procedures

Use of runways: • Runway 21L not used for landings during 11pm –7am. • Runway 03R not used for departures during 11pm – 7am. • Chapter 2 aircraft licensed to use the airport not allowed to use runway 03R for take-offs or runway 21L for landings on a 24-hr basis. Also marginally accepted Chapter 3 aircraft are also excluded from runway 03R for take-offs or runway 21L for landings on a 24-hr basis. • Use of runway 03R is not allowed for all military aircraft for departures and runway 21L for landings on a 24-hr basis • Deviations of the above may be allowed for flight safety reasons, i.e during extreme meteorological conditions or when airport's capacity and operational procedures made those deviation necessary.
Use of reverse thrust
Thrust Reduction and Acceleration for runways 03L and 03R during take-off
AIA's NOise MOnitoring System (NOMOS) with 10 permanent stations
24-hr Public Complaint Management System
Environmental Noise Reporting

Sources: AIA (2020, 2021b,c), Vogiatzis *et al.* (2020)

Moreover, AIA has conducted a study of Strategic Noise Map (SNM) and the Noise Action Plan (NAP) for the Aircraft Noise, in accordance with the European Directive 2002/49/EC (AIA, 2020). AIA has installed a NOise MOnitoring System (NOMOS) consisting of one mobile and ten permanent Noise Monitoring Terminals (NMTs), which creates detailed profile of aircraft noise in the residential areas near flight paths (Figure 2).

Figure 2. Map of Athens International Airport Flight Paths and NMTs



Source: AIA (2021b)

Table 5. Average Noise Level per Noise Monitoring Terminal

	2015		2016		2017		2018		2019		2020	
NMT	L_{den}	L_{night}	L_{den}	L_{night}	L_{den}	L_{night}	L_{den}	L_{night}	L_{den}	L_{night}	L_{den}	L_{night}
2	38.4	18.5	39.9	26.6	39.5	25.8	43.6	22.6	46.2	26.6	41.9	22.5
3	59.6	43.1	60.4	44.5	61.2	45	60.1	45.5	60.7	44.9	55.8	41.5
4	60.9	52.3	60.1	51.5	57.6	49.9	54.4	46.7	58.7	50	53.2	43.5
5	53.8	36.7	54.3	38.2	54.9	40.5	53.7	38.5	51.1	34.6	46.4	31.9
6	51.4	39.7	51.2	37.5	50.3	39.1	49.4	35.9	49.1	36	45.9	35.2
7	52.5	45	53.3	45.7	53.2	45.7	53.3	45.8	53.9	46.4	47.9	39.7
8	50.4	37.2	47.8	37.1	46.8	35.7	46.6	6.1	45.8	34.6	42.4	28.8
9	55.3	41.6	54.9	41.3	55.6	42.1	54.7	41.2	54.8	41.7	52.1	41.4
10	32.3	15.7	33.1	19.7	31.7	21.2	32.7	24.2	31.4	18.9	31.8	20.0

Source: Authors' elaboration based on Athens International Airport data (2015-2020)

The system is connected with HCAA's radar, so that correlations between measured noise levels and aircraft movements can be established based on the actual flight track information. AIA has implemented the recent maximum permissible limits as per the Greek legislation (JMD 211773/2012) and according to the European Directive 2002/49/EC for both road, rail and airport environmental noise indexes, Lden (24 h) and Lnight (8 h), defined as follows: a) Noise index Lden (24 h): 70 dB(A). b) Noise index Lnight (8 h): 60 dB(A) (Vogiatzis *et al.* 2020). It is worth mentioning that despite the increase of aircraft movements, there are no significant negative effects on airborne noise, and all measurements from the ten NMTs are under the legally permissible limits of environmental noise indicators (Table 5).

3.5. Water Management

AIA systematically monitors potable and irrigation water consumption (Table 6), as well as surface and ground water quality. AIA has applied several water-saving measures, such as the use of treated wastewater from its own Sewage Treatment Plant (STP) for irrigation of the airport's non-public green areas. The on-site Industrial Wastewater Treatment Facility (IWTF) receives wastewater primarily from aircraft maintenance activities but also from other sources (wastewater from runway degumming, oil-water separators, etc.). AIA regularly monitors the quality of surface water through ad hoc sampling and analyses following rain events, and constantly by an Online Water Monitoring System (OWMS) before being discharged offsite. An approved Spillage Response Plan is implemented each time a spillage occurs, which calls for the use of bioremediating substances and appropriate sweeper vehicles. Due to the local climate, aircraft/helicopter and runway anti/de-icing operations are not often. Nevertheless, relevant procedures have been established for the ground handling companies which provide de-icing services following ICAO and IATA standards, the Local Ground Handling Regulation and the respective concession agreements. In 2020, the airport water consumption was significantly reduced because of the collapsed passenger volumes during the covid-19 pandemic.

Table 6. Athens International Airport's water consumption

	2015	var	2016	var	2017	var	2018	var	2019	var	2020
Total Airport* (m^3/1000)	603	-0.2%	602	2.2%	615	4.4%	642	0.8%	647	-38.9%	395
AIA only (m^3/1000)**	n/a	---	398	2.5%	408	7.4%	438	-1.4%	432	-37.7%	271
Total Airport consumption per passenger (m^3/pax)	0.003	9.1%	0.03	-5.7%	0.0283	-6.0%	0.0266	-4.9%	0.0253	93.3%	0.049

Source: Authors' elaboration based on Athens International Airport data (2015-2020)

*Notes: * Refers to the entire airport community.*

*** Refers to the Airport company only.*

3.6. Waste Management

AIA has the responsibility for managing all waste produced on the Airport premises. AIA has developed a comprehensive system grounded on the principle "The polluter pays", promoting waste separation at the source and recycling. AIA provides financial incentives (reimbursements) to Third Parties for all recyclable materials separated from their municipal waste streams.

Table 7. Athens International Airport's non-hazardous recycled waste (in tons)

	2015	var	2016	var	2017	var	2018	var	2019	var	2020
Paper	2,082	16.60%	2.427	-4.70%	2.313	-1.30%	2,283	6.8%	2,438	-51.0%	1,194
Metal	227	69.20%	384	10.70%	425	-23.30%	326	26.7%	413	-43.6%	233
Glass	172	54.70%	266	12.00%	298	10.40%	329	7.9%	355	-65.9%	121
Plastic	999	7.20%	1,071	24.80%	1,337	19.40%	1,596	-20.0%	1,277	-37.7%	796
Wood	301	-4.70%	287	-3.10%	278	15.80%	322	15.2%	371	-29.4%	262
Tetra pak	37	83.80%	68	48.50%	101	39.60%	141	5.7%	149	-61.7%	57
Aluminium	36	-19.40%	29	-31.00%	20	-15.00%	17	11.8%	19	73.7%	33
Tyres	8	-62.50%	3	-33.30%	2	350.00%	9	-55.6%	4	-25.0%	3
Edible oils	46	-8.70%	42	9.50%	46	-2.20%	45	-4.4%	43	-69.8%	13
Bio-waste	353	16.40%	411	3.20%	424	-3.30%	410	16.1%	476	-47.7%	249
Sludge STP	493	38.90%	685	36.90%	938	-27.40%	681	25.7%	856	-41.0%	505
Construction & Demolition waste	983	110.80%	2.072	66.70%	3,455	653.00%	26,016*	-77.6%	5,833	-70.5%	1,721
Total	**5,737**	**35.30%**	**7,761**	**24.20%**	**9,637**	**233.90%**	**32,175***	**-60.4%**	**12,734**	-43.4%	**7,207**

Source: Authors' elaboration based on Athens International Airport data (2015-2020)

*Note: *the increased mass of construction and demolition waste in 2018 was produced by the new terminal construction work.*

AIA has established a Recycling Center equipped with bins for paper, plastic, glass, aluminum, ferrous metal, electronic waste, batteries and edible oils where Airport employees can help protect the environment by bringing recyclables from home. The Recycling Rate exceeded 66% for Solid Non-Hazardous Waste (12,734 tons of the total 19,861 tons for 2019 and 5,264 tons of the total 7,925 tons in 2020) (Table 7).

Hazardous waste is disposed via Alternative Management Systems that include treatment, valorization, and/or recycling. 290 tons of hazardous waste were produced in 2019 and 221 in 2020 on the Airport site, of which about 30% was disposed via Alternative Management Systems, while the remaining 70% was transferred to licensed facilities for either treatment and valorization and/or recycling (Table 8).

Table 8. Athens International Airport 2019 & 2020 hazardous waste production (in tons)

	2019	2020
Used Oils and Lubricants	18.6	16
Packaging Containers from Oils & Lubricants	10.3	7
Used Batteries	15.7	1.9
Electronic waste	47	21.8

Sources: AIA (2020, 2021b,c)

During 2020, AIA also provided biohazardous waste management produced by covid-19 testing to employees and passengers (AIA, 2021b). Testing requirements resulted in significant (more than 5 tons) bio-hazardous waste volumes that needed to be handled appropriately. AIA engaged a licensed waste-management contractor to handle this waste under pertinent regulations, using dedicated containers that were then collected and transported to a licensed facility to be incinerated. Moreover, the Airport company also held a campaign to inform its employees on the proper disposal of masks and other personal protective equipment (AIA 2021b,c).

3.7. Biodiversity and Land Use

AIA implements a comprehensive program in the Airport's vicinity aimed at protecting the region's biodiversity at all levels: plant and animal species, ecosystems or habitats and the landscapes. The airport has a specific Wildlife Control Team (WCT) consisting of specialists with university degrees in Natural Sciences to monitor wildlife and flora, and to coordinate all the actions related to the biodiversity protection. Moreover, a Biomonitoring Program is in action with the aim of recording all the important ecosystems at the airport and in the surrounding area and their components, *i.e.*, the fauna the flora and the habitats, and to subsequently apply measures to protect biodiversity. The Airport constantly records the number of bird species spotted at the Airport, which has risen to 219 in 2020 and serves as an indicator of the overall health of the local ecosystem. In addition, the airport applies a Biodiversity-friendly Wildlife Hazard Control and Reduction Program, especially for birds, in order to reduce the risk of strikes with aircraft, both at the airport and in its immediate vicinity. Moreover, frequent surveys of the local flora are conducted and the number of the relevant taxa reached 662 in 2020.

The management of the airport's landscaping includes the creation of urban green areas in the adjacent Municipalities as well as the plantation of trees and shrubs at specific areas around the airport. The airport supports traditional land uses (*e.g.*, olive groves and vineyards) while providing recommendations to state authorities concerning changes in land use in the vicinity of the airport in order to promote sustainability and protect Biodiversity while continuing to ensure high levels of aviation safety. AIA has successfully partnered with the Hellenic Ornithological Society to protect and promote the Vravrona Wetland, a local area of unique ecological and archaeological value included in the Natura 2000 European network of protected areas as a Site of Community Importance (SCI). According to data collected so far, the biodiversity of the Vravrona Wetland includes 100 plant taxa, 224 bird taxa, 27 taxa of other terrestrial vertebrates, a scarce species of freshwater fish, and 15 habitat types as defined within the relevant EU legislation. Since 2015, the project has been extended to include initiatives at the Aliki Wetland in Artemis (one of the Priority A' wetlands in Attiki), where more than 140 bird species have been recorded. The Biodiversity-protecting actions of AIA are performed in cooperation with academic institutions, the Hellenic Ornithological Society (HOS) and other NGOs. Finally, these initiatives are welcomed by the local communities and are supported by the Municipalities, local associations, and residents (AIA, 2020).

Conclusions

Implications for Managerial Practice

Given the increasing interest for environmental-friendly operation, in the last decades, aviation companies are constantly seeking for applied and effective practices, able to mitigate the negative externalities produced by air transportation. To this end, the current study provides a real-world and in-depth case study about the specific EMS practices applied by the major Greek airport, Athens International Airport (AIA). Featuring AIA as a case study offers stakeholders (*e.g.* regulators, airport operators, ground handlers, the public) insight into best practices, or acceptable methods, for managing environmental impacts for major international airports. The time window of this study expands in six years which is considered an adequate period to draw a clear picture of the airport's EMS. Nevertheless, the last year of the study (2020) was marked by the covid-19 pandemic that had a devastating impact on aviation and this event allows for some additional insights to be drawn from the careful examination of the available data. The first is that, although the absolute volumes of pollutants produced by the airport AIA's were significantly reduced in 2020, the mean values per passenger seem to have increased, a result that may be biased by the smaller denominator (passenger volumes), rather than reflecting a real rise. This observation calls us to be more cautious when comparing data either in the same airport across years, or across different airports, because observed differences may be grounded in various causes, therefore, an examination of multiple instead of single indicators may be necessary to draw safe results.

Table 9. Summary of the Environmental Management practices applied in Athens International Airport

EMS area of interest	Athens airport practices
Environmental management	▪ Continuous monitoring ▪ Environmental Management System (EMS) ▪ ISO 14001 certification ▪ Environmental certification of 74 airport companies ▪ Annual Environmental workshop ▪ Environmental Excellence Awards for third parties
Energy	▪ Energy-efficient design of the airport infrastructure ▪ Reduction of electricity and extensive use of natural gas ▪ Production of clean energy by a PVP plant ▪ ISO 50001 certification
Greenhouse gas emissions and climate change	▪ Participation in the Airport Carbon Accreditation initiative led by ACI ▪ Replacement of vehicles and other equipment with new environmentally friendly ones ▪ Continuous and detailed air quality monitoring and recording ▪ Replacement of paper by electronic documents formats
Noise	▪ Noise abatement procedures implemented in collaboration with the Hellenic Civil Aviation Authority (HCAA) and airlines ▪ Complaint recording system via telephone and online form. ▪ Installation of a NOise MOnitoring System (NOMOS) operating in ten Noise Monitoring Terminals (NMTs) ▪ Strategic Noise Map study
Water and soil	▪ Monitoring water consumption and quality ▪ Online Water Monitoring System (OWMS) ▪ Use of treated wastewater from its own Sewage Treatment Plant (STP) for irrigation of non-public green areas ▪ Spillage Response Plan ▪ Operation of Industrial Wastewater Treatment Facility (IWTF)
Waste and pollution	▪ Establishment of a recycling centre ▪ Promoting recycling of employees' household waste ▪ Financial incentives to Third Parties for recyclable materials ▪ Application of "The polluter pays" principle ▪ Hazardous waste disposed via Alternative Management Systems ▪ Biohazardous waste handled by licensed contractor
Biodiversity and Land Use	▪ Partnerships with academic institutions, the Hellenic Ornithological Society (HOS) and other NGOs ▪ Biomonitoring Program to record the flora and fauna of the airport and surrounding ecosystems ▪ Wildlife Control Team consisting of Natural Scientists ▪ Application of a Biodiversity-friendly Wildlife Hazard Control and Reduction Program ▪ Creation of urban green areas in the adjacent municipalities ▪ Support of traditional land uses (*e.g.*, olive groves and vineyards)

Source: Own elaboration

This conclusion is further supported by the finding that noise complaints more than doubled in 2020 (72 complaints in 2020 compared to 32 in 2019), although the air traffic was subdivided. This rise can be explained by periodic changes in runway use. Additionally, the long period with very few flights in the first half of 2020 triggered noise complaints when traffic was partially restored during the summer. This finding implies that operational accommodations and personal perceptions play an important role in airport noise handling. Finally, one more interesting dimension drawn from the 2020 data was the treatment of the significant bio-hazardous waste volumes produced by the covid-19 testing of the airport employees and arriving passengers. AIA engaged a licensed waste-management contractor to handle this waste under pertinent regulations and held a campaign to inform its employees on the proper disposal of masks and other personal protective equipment. This result highlights the need to include in the airports' environmental management systems provisions for bio-hazardous waste management.

To summarize the findings in a comprehensive way, a selection of the applied EMS practices is provided in Table 9. Furthermore, the environmental practices applied in AIA are mapped with an asterisk (*) on the comparative summary of the most current environmental assessment frameworks presented in Appendix 1.

After spotting the applied solutions, the information 'grounded' in the data is conceptualized, using the Grounded Theory method. As a conclusion, an Airport Environmental Performance (AEP) model is proposed, which is a synthesis of the theoretical frameworks distilled through practice. As seen in Table 10, the AEP model consists of seven Key Performance Areas (KPAs) and thirty-nine Key Performance Indicators (KPIs). The seven KPAs refer to the airport's environmental management, emissions and climate change, noise control, water and soil, waste, energy and biodiversity management. The specific KPIs include both mandatory requirements according to government and regulatory rules (*e.g.* regular measuring and reporting, noise abatement procedures, wildlife hazard management, hazardous material management, etc.), and voluntary measures that are frequent in the theoretical frameworks presented in Appendix 1, featuring them as established trends among airports (*e.g.* airport EMS, ISO 14001 and 50001, green culture promotion, use of renewable energy sources).

Effort was made to produce a comprehensive albeit handy assessment framework that would be useful for scholars and airport professionals altogether. The proposed AEP framework can provide an environmental management benchmarking for the fourteen Greek airports privatized recently (2017) with a 40-year concession agreement with Fraport Greece. Moreover, any interested airport can use the proposed AEP as a template for its own environmental assessment framework, by removing unsuitable KPIs and adding new indicators from the theoretical pool summarized in Appendix 1. Furthermore, the proposed AEP may be of use by regulatory authorities wishing to build consensus about the environmental monitoring of the airports fallen under their jurisdiction.

Limitations and Future Research

This study has several limitations, one of them being the fact that the data were collected mainly through documentary evidence on a single sample and for a restricted 5-year period. These terms served the purpose of case study methodology used in this study; however, any generalization of the findings would be unsafe.

Table 10. The proposed Airport Environmental Performance (AEP) model

KPAs	Environmental Management	Emission & climate change	Noise control	Water & soil	Waste	Energy	Biodiversity
KPIs	▪ Regular measuring ▪ Detailed database ▪ Performance monitoring ▪ Airport EMS ▪ ISO 14001 certification ▪ Specific environmental department or team ▪ Cooperation with internal stakeholders ▪ Cooperation with external stakeholders ▪ Green culture promotion	▪ CO_2 emissions ▪ ACI accreditation ▪ Zero carbon commitment ▪ Other air pollutants monitoring and control	▪ Noise measurement and monitoring stations ▪ Noise zones ▪ Noise abatement procedures ▪ Noise reporting system ▪ Noise action plan	▪ Water saving methods ▪ Water recycling and reuse ▪ Polluted water storage and treatment ▪ Water quality analysis ▪ Prevention of soil pollution ▪ Soil pollution treatment ▪ Spillage management ▪ De-icing procedures	▪ Waste reduction ▪ Waste separation at the source ▪ Waste recycling ▪ Hazardous waste management ▪ Bio-hazardous waste management	▪ Energy saving practices ▪ Green building practices ▪ Energy audits ▪ Public transport network ▪ ISO 50001 certification ▪ Renewable energy sources	▪ Biodiversity-friendly wildlife hazard management ▪ Wildlife protection and preservation ▪ Natural habitats preservation

Source: Own elaboration

A more time-expanded longitudinal case study approach can evaluate the implementation process of an EMS and its outcomes over a longer time-period. Moreover, future research can utilize multiple data collection methods, such as interviews, observations, documents and surveys when needed. This type of study would provide a richer and more detailed description of the EMS' formation and implementation processes. Furthermore, to draw safe results about the general picture of environmental policies in the broad national or international airport industry, a larger sample is necessary to allow for meaningful comparisons. Drawing from the knowledge gained by the current study, future research can attempt a recording of environmental performance frameworks in a cross-border panel of airports, allowing for the best practices to emerge. Moreover, it must be considered that the airport presented in this study belongs to the private sector, has a large size and operates as an international hub. Therefore, any attempt to make comparisons or to transfer the environmental assessment methods described in this study to airports with different characteristics (*e.g.* public airports, small airports, domestic/general aviation airports) should take account their specific features. Future research can try a niche-specific mapping of the AEP application in practice suggesting specific, not only sector-oriented adjustments but also measures that will fit better to airports' size, location and governance.

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Appendix 1. Environmental Performance frameworks

*: practice used by the Athens International Airport (AIA)

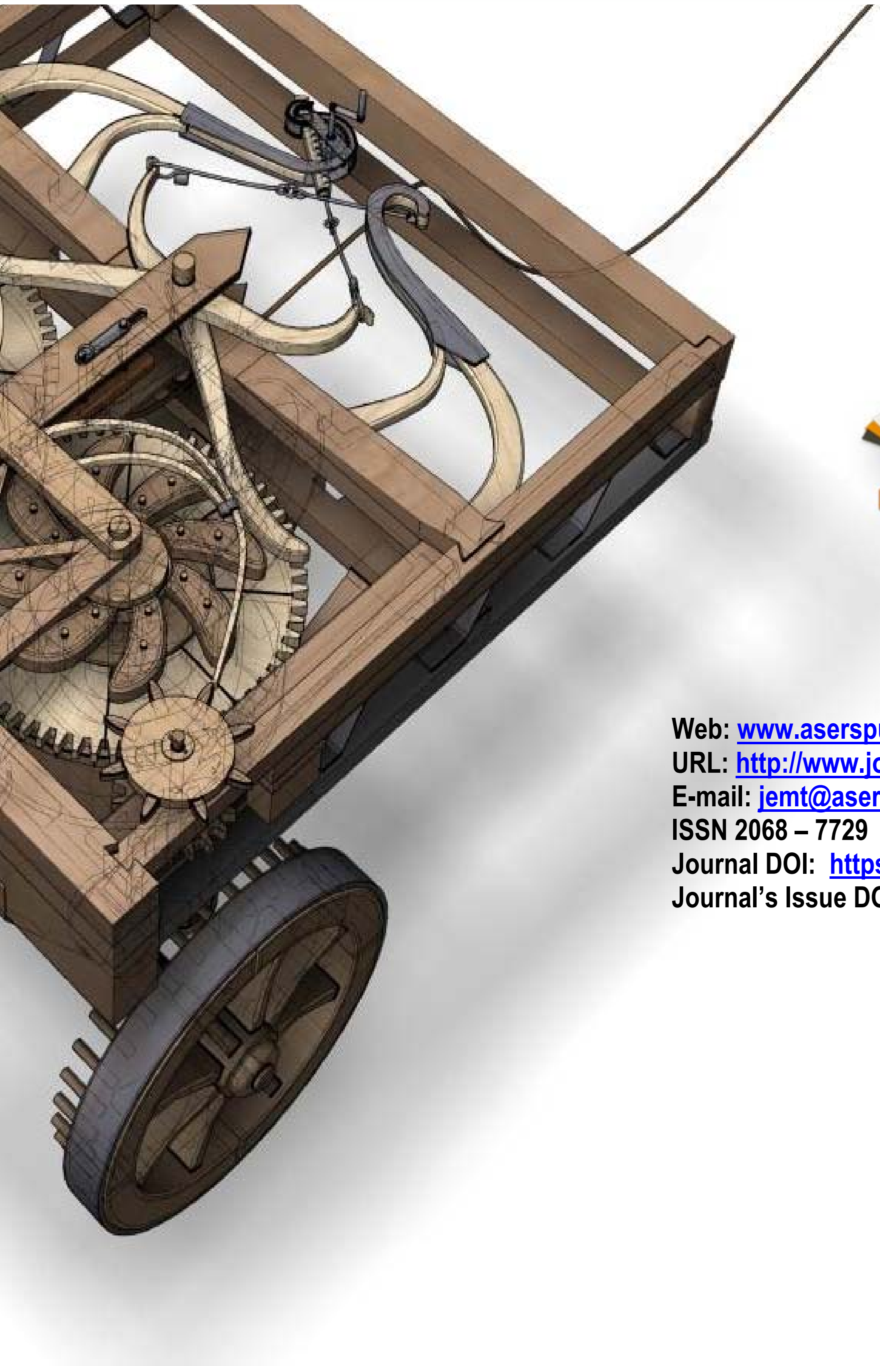
ACRP (2008)	Kılkış & Kılkış (2016)	Lu *et al.* (2018)	Santa *et al.* (2020)	Kumar *et al.* (2020)
Measuring and Monitoring* **Water Conservation*** **Water Quality*** **Climate Change** • *Ground Vehicles** • *Passenger Access** • *Aircraft on the Ground* • *Aircraft in the Air* • *Buildings** • *Monitor and Manage Emissions** • *Research and Partnerships** **Air Quality*** **Land Use** • *Contaminated Land* • *Land Use Planning** **Biodiversity** • *Nonlethal Bird Techniques** • *Habitat Protection or Enhancement** **Materials** • *Construction Materials** • *Hazardous or Toxic Products** **Waste**	**Environmental Management and Biodiversity** • *Water Withdrawal** • *Conserved Area (hectares)** • *Waste Generated (tonnes)** • *ISO 14001 Certification** • *Percentage of Recycled Waste** **CO2 Emissions and Mitigation Planning** • *CO_2 Emissions (tonnes)** • *CO_2 per Passenger* • *CO_2 Emissions per Unit Energy* • *ACA Level (1, 2, 3, 4)** • *CO_2 Neutrality Target** **Atmosphere and Low Emission Transport** • *Air Pollution at PM_{10}** • *Low-Emission Ground Vehicles** • *Share of Public Transport ** • *Biofuels in Aviation* • *Noise Abatement for dB (A) <= 60** **Energy Consumption and Generation** • *Energy Consumption**	**Environmental perspective** • *Carbon emission reduction and energy conservation** • *Preventing and monitoring noise** • *Green building practices** **Financial perspective** • *Return on investment* • *Transparency of finance* • *Non-aviation incomes* **Internal business process** • *Airport information* • *Electronic technologies* • *Public transport** **Learning and growth** • *Professional training* • *Health care management and safe work environment* • *Employee relationship management* **Social perspective** • *Customer service culture*	**Water management** • *reduction of consumption and make efficient use** • *water supply loss reduction systems; water drainage; flow meters; low flow faucets; and water saving toilets** • *non-potable rainwater collection system** • *rainwater harvesting program, polluted water storage and treatment, water recycling and reuse** • *aquifer contamination safety practices* **Emission reduction and air quality** • *reduction of car circulation* • *increase public transportation** • *building that minimizes greenhouse gas and carbon emissions** • *monitoring of carbon and greenhouse gas emissions** • *Invest and encourage partner companies to invest in low emission vehicles to develop track works** • *website that enables airport users and surrounding residents to view pollution levels in real time* • *surface temperature change control equipment* **Biodiversity conservation and land use** • *the least possible use of territorial space and green areas allowing soil permeability* • *priority to natural lighting of the airport buildings*	**Environmental monitoring and control** • *ISO certification for environment and energy management** • *Reduction of Greenhouse gas (GHG) emissions** • *Carbon footprint method for airport management** • *Greenhouse gas (GHG) inventory database system** • *Initiatives for clean development mechanism (CDM) projects* • *Green practices for thermal management and climate change** • *Geographical location of the airport* **Green operation and transportation** • *Low emission ground logistics vehicles* • *Green share of public transport** • *Use of lightweight aircraft* • *Use of alternative biofuels in aircraft* • *Green cargo hub for logistics activities* • *Alliance with green partners** **Air and Noise Control** • *Reduction of harmful pollutants** • *Emission and mitigation practices** • *Indoor Environmental Quality ** • *Monitoring and communication of noise level data** • *Noise abatement techniques** **Waste management and recycling practices**

• *Tenant/Airline Waste Management** • *Waste Disposal Logistics and Management** • *Recycling and Waste Management** • *Composting* **Noise and Aesthetics** • *Aircraft in the Air** • *Aircraft on the Ground** • *Surrounding Neighborhoods** • *Monitoring** • *Research and Partnerships** **Energy** • *Airport interiors** • *Energy audits and management** ***Green Buildings*** • *Certification and Policies* • *Green Building Practices**	• *Energy Consumed per Passenger* • *ISO 50001 Certification** • *Energy-Saving Measures** • *On-Site Production** **Airport Services and Quality** • *Annual Passenger Traffic (PAX)* • *Annual Growth in Passenger Traffic* • *Annual Cargo Load Handled* • *Annual Operating Revenue* • *Total On-Site Employment*	• *Airport image* • *Aviation education and human resource development*	• *provision of spaces for recreation and alternative means of transport such as walking and cycling** • *design to minimize the use of land and to reduce the prevalence of the Heat Island Effect* • *selection of location* • *potential conflicts in the airspace of tall buildings near the airport** • *protection against the invasion of animal species such as birds** • *natural habitats preservation** • *wildlife reporting and management plans** **Waste managemen*t*** • *waste management contracts with all service providers** • *operational manual for waste management** • *Solid waste collectors that allow the correct separation of waste** • *collecting and storing recyclable solid waste** • *reduce the generation of solid waste, such as packaging** • *materials, supplies and resources* • *disassembly, recycling and reuse of materials used during construction** • *priority to the purchase of recycled, bio-disposable and renewable materials* • *energy generation systems from waste incineration* **Noise reduction** • *use building materials that aid as noise protection barriers**	• *Wastewater harvesting** • *Use of cleaner technologies for recycling* • *In-house production of waste to energy* • *Reduction in community landfills due to solid waste ashes used for construction material* • *Ecological conservation** • *Safe disposal of hazardous waste** **Green building and infrastructure** • *Green building design and Retrofitted practices* • *Energy saving techniques** • *Eco-efficient airport parking area* • *Energy efficient materials for building construction** • *Infrastructural harmonization with the environment** • *Biodiverse seating lounge for travelers* • *Solar Energy storage capacity facilities** **Employee green training** • *Educational Seminars for Energy conservation* • *Reinforcing employee capabilities and attitude via professional training** • *Creating a friendly and safe work environment* • *Paperless work environment** • *Functional green teams** • *Knowledge transfer (KT) of environmental management experiences** **Green policies and regulations** • *Compliance with global environmental laws and regulation**

			• *have noise monitoring and prevention actions** • *accompany homes exposed to noise caused by aircraft operation* **Energy management** • *airport construction project should provide the reduction of energy consumption** • *regular audits of equipment** • *use intelligent energy control equipment and systems for lighting, heating, walkways and escalators* • *Prioritize low energy lighting such as LED lights.* • *prioritize alternative and renewable energy sources, such as solar energy** **Quality of the internal environment** • *intensity and quality of ventilation** • *thermal comfort* • *the internal lighting meets the requirements and standards of operating comfort and safety* • *the noise level is controlled in all environments** **Transport and vehicle control** • *prioritize airport construction where public and alternative means of transport are possible* • *bicycle racks, and parking with spaces and recharging stations* • *minimum number of cars on the runway* • *preference to companies using low environmental impact fuels to carry out runway transport* **Social and cultural aspects**	• *Airport carbon accreditation by the ACI** • *Enable financial regulatory framework for low carbon and climate change (LCR) infrastructure* • *Promote eco-tourism policies* • *Local community consultation for airport masterplan* • *Policies and regulations for green airport spaces to be structured in a supportive manner*

			• *Contribution to community with charitable and cultural activities** • *Transport accessibility* • *Health and well-being* • *Neighbourhood amenities** **Cost and economy** • *principles of administrative management* • *control over the costs of environmental impacts* • *financial results available to the public* • *encourage employees' qualification and training* • *ensure employees well-being and safety* • *encourage employees professional training* • *Customer service levels evaluation* • *promote economic growth and perpetuate the socio-environmental evolution of the region* • *Encourage tenants and concessionaires to operate in a sustainable manner* • *penalize companies and bodies that violate the sustainability policy*	

ASERS



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