CRANFIELD UNIVERSITY

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MODELLING FRAMEWORK FOR EVALUATING ENVIRONMENTAL STRATEGY AND WATER MANAGEMENT EFFICIENCY AT AIRPORTS

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Abstract

The growing concern about climate change and environmental protection represent significant barriers towards growth in the aviation sector. Currently, airport operators need to consider not only noise control and local air, soil and water pollution management, but also to control the consumption of non-renewable natural resources and to minimise their impact on climate change.

A detailed analysis of current applied practices pointed out that the main issues that airports need to manage, have to do principally with control of natural resources consumption, control of noise and management of emissions, water quality, waste and ecosystems. Although these issues in most of cases have been identified, airports' priorities regarding their management were not easily acknowledged.

The key findings of this research suggest that in the case of environmental management strategies, different patterns exist; thus, some airports seem to seek balance mostly between mitigating global and local environmental issues or resource consumption control and pollution management, while others obviously take measures aimed at managing one or the other impact. In the case of water management efficiency, while many airports seem to have applied measures to sustain water quality, only a few of them have applied sufficient consumption control measures.

Acknowledgments

This thesis is the result of an effort that actually began three years ago; an effort to improve my skills and my personality. I do not really know if I have managed to improve my personality but undoubtedly with this research I have really learned many things not only about the sustainability concept but also about the way a sustainable environmental growth in the next decade is encouraged. It is a pleasure to thank those who made this thesis possible.

First of all, I would like to thank my supervisor Dr. Dimitrios Dimitriou; without his help, guidance, motivation and support I could not have finished this thesis. During all these years unpleasant events made me lose my willingness and the courage to continue what I have started. Dr. Dimitriou was always there to encourage me; he always knew what to say to keep me on track and to enhance my efforts.

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Asimina Voskaki

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Abbreviations

ACI	Airports Council International
AEF	Aviation Environment Federation
ATAG	Air Transport Action Group
ATRS	Air Transport Research Society
CATE	Centre for Air Transport and the Environment
CO_2	Carbon Dioxide
EEA	European Environmental Agency
GHG	Green House Gas
GDP	Gross Domestic Product
GRI	Global Reporting Initiative
ICAO	International Civil Aviation Organization
ICTR	International Congress on Transportation Research
IPCC	Intergovernmental Panel on Climate Change report
MCA	Multi Criteria Analysis
NGO	Nongovernmental organisation
AEC	Airport Environmental Comprehensiveness

1. Introduction

Over the last decades airports have successfully supported local and regional economies, by creating economic growth and employment and by providing accessibility. Nowadays, the airport industry needs to face four major challenges in order to meet its customers' and communities' needs: capacity, environment, connectivity and security (Airports Council International (ACI) Europe, 2010).

Despite the fact that aviation forecasts have been projecting significantly lower rates of growth, aviation in Europe has managed to overcome the economic crisis. According to the new long-term forecast (Eurocontrol, 2010) the average annual growth in the next 20 years will be around 2.8%. Considering the anticipated growth in air traffic demand, there is a clear need for imporvements to airport capacity. It is estimated that 5-19% of air traffic demand will not be accommodated by the year 2030 because of limited airport capacity, affecting the flow of operations in the entire network (Eurocontrol, 2010). In addition, failure to provide increases in airport capacity could cost between 2.5-3% of national or regional Gross Domestic Product (GDP) respectively (ACI, 2004).

Whilst airports have become major issues of development in many regions, negative impacts on the environment and local communities constitute issues that relate directly to future airport growth (Thomas and Lever, 2003; Upham *et* al., 2003). Therefore, besides investing in extra infrastructure, airports need to balance the existing, as well as the extra capacity, with their environmental impacts. Consequently, environmental management has become an issue of considerable concern; the successful management of environmental issues is one of the greatest challenges to, and possible constraints upon, the future activities of airports (Graham, 2008).

Environmental management (Welford, 2002) is mainly focused on identification, assessment and control of various environmental risks associated with airport activities. The main environmental impacts concern noise, emissions, water pollution, water use, waste and energy management, wildlife, heritage and landscape; these environmental impacts have to be considered at a global and local level (Graham, 2008; Janic, 1999).

Even though many airport operators present their plans to manage or control airport's negative impacts, specific targets regarding environmental efficiency cannot easily be found. In most of the cases, the addressed targets concern the industry's commitments to reduce emissions (IATA, 2008) or local agreements regarding noise control and abatement procedures.

In addition, while many airports focus their efforts towards carbon neutrality, and take measures to reduce energy consumption, only a few of them have decided to take actions to control water consumption. This is surprising considering that various alterations in the hydrological cycle, as a result of climate change, will result in water shortages in many areas of the world (Intergovernmental Panel on Climate Change report (IPCC), 2008); the projected changes in water resources could have significant consequences for several economic sectors (European Environmental Agency (EEA), 2007), including the aviation industry.

The need to identify the various aspects that will lead to effective and efficient environmental management is generally regarded as essential; however, the absence of a common framework for environmental management with measurable objectives makes the evaluation of the various airport initiatives difficult (Dimitriou and Voskaki, 2010). The up to date analysis of the published airport environmental plans show that comparative measures cannot easily be found. This is partly due to the fact that the implementation of environmental performance evaluation procedures is still not mandatory (Dimitriou *et* al., 2010). In addition, nowadays, airport operators not only need to consider noise control, local air and water pollution management and biodiversity, but also climate change related to emissions and the control of non-renewable natural resources (water, oil, carbon etc.) consumption.

In this research, a systemic approach to evaluate the strategies used by airports in dealing with environmental issues is presented. In addition, a framework that could support decision making in regards to whether an airport is efficient or not, in terms of water management, is developed. The approach is based on the concept of sustainable development and the research background is based on Multi-Criteria Analysis (MCA) decision-making tool.

In addition to this introductory section, the thesis is organised in six sections. The second and third section analyse the methodology framework, providing the background reading, while in the following two sections the application is presented; these sections give the key issues of the analysis that has been carried out and the key messages for the selected airport sample. In the sixth section, the research conclusions and recommendations for further future research are presented. Finally, the references can be found at the end of the thesis.

2. Research methodology

This section introduces the methodological approach adopted for the current research; the research background is based on the concept of MCA, allowing the combination of data, detailed analysis and evaluation of individual airports environmental strategies, while taking into consideration the importance that stakeholders attach to different impacts. The key points of the methodological framework are given in the following chapters.

2.1 Research objectives & research questions

The need to identify all environmental issues that are linked with airport operations is generally regarded as essential; however, many airports still assess their performance by using simple traffic, operational and financial measures (Dimitriou and Voskaki, 2010). While environmental issues appear to be critical for airport development, not many airports present a specific environmental strategy that is focused on reducing the total environmental impact of their operations (Daley *et*. al, 2008; Upham, 2001).

In addition, as a result of growing environmental sensitivity, airport environmental management priorities seem to have changed over time. Environmental management strategies have evolved from pollution control to pollution prevention

(Brockhoff et al., 1999); from managing local environmental impact to tackling the global environmental impact of aviation (ACI Europe, 2010).

The main objective of the current research is to develop a framework to evaluate the strategies used by airport operators when dealing with environmental issues, taking into account the airports' environmental management priorities. The reviewed literature pointed out that even though airport sustainability reporting has increased significantly in recent years, there are a variety of sector specific themes that are not completely covered (Dimitriou *et*. al, 2010), like for instance, water management. In addition, applied conservation or management techniques cannot be evaluated because of the absence of a common framework; therefore, the developed framework is focused on evaluating airport water management efficiency. Accordingly, the main research objectives are:

- to review airport environmental plans and airport operators sustainability reports;
- to investigate applied techniques for reducing an airport's total environmental impact;
- to investigate applied water management techniques;
- to investigate differences and common practices in applied environmental strategies and systems, including water consumption control and waste water and pollution management;
- to define appropriate measures that could be used as evaluation criteria;
- to define appropriate measures that could be used to define an airports' environmental strategy;
- to provide a tool to evaluate airport environmental strategy;
- to define appropriate ratios for evaluating airport water management efficiency;
- to outline the directions for further research in the future.

Consequently, the key research questions could be summarised as follows:

- What are the key environmental issues that airports need to deal with?
- Which measures could be used as evaluation criteria?
- Which are the airports' environmental management priorities?
- How can we evaluate different airports regarding water management efficiency and which measures could be used as evaluation criteria?
- Which are the appropriate ratios to measure an airport's water efficiency?

2.2 Research contribution

The contribution of the current research is:

a) to support planners and managers in the airport industry,
    - to evaluate airport environmental management priorities;
    - to evaluate water management efficiency;

b) to develop a model which,
   - evaluates airport environmental strategies;
   - evaluates airport efforts to control water consumption;

Finally, the research could aid in the development of a program, similar to the Airports Carbon Accreditation (ACI, 2009) program, that could certify airports with different levels of accreditation regarding applied environmental strategies.

2.3 Research strategy & methodological framework

According to Saunders *et* al. (2009), the research strategy should enable the researcher to answer research questions and meet research objectives. In order to decide on the research strategy, the researcher identified the research objectives and research questions and reviewed the literature to come to a decision regarding which were the most appropriate research strategies, how they could be combined in this research and therefore, how the research would be conducted (Creswell, 2009). To meet the research's objectives, a combination of data techniques and analysis procedures was incorporated (mixed methods approach), allowing the researcher to combine qualitative and quantitative data (Saunders *et* al., 2009).

2.3.1 Data resources

The necessary data was obtained from primary and secondary sources. Primary sources included interviews (face to face or through e-mail contact) and discussions with airport industry's experts, academics, airport environment managers, researchers and conferences participants, as well as, questionnaires sent to airport departments for environmental and researcher observation notes. Secondary sources included books, journal papers, conference proceedings, official reports, airport operators' sustainability reports, airport environmental plans, airport operators' official web-sites and workshop presentations. Information regarding the key data sources is given below.

Literature review

A literature review (Creswell, 2009) was undertaken in order to examine the available data regarding airport environmental impacts, mitigating measures, sustainable operations, and water management techniques. The main literature that has been reviewed mainly involves book chapters, journal papers, official reports, conferences' material, interviews, web-sites and can be summarised as follows (Table 1). The key points of the reviewed literature are presented in the next chapter.

The necessary data for the application was collected from the airport operators' official web-sites, where environmental plans and sustainability reports were available. In addition, in order to obtain unpublished data, the researcher conducted interviews and sent e-mails requesting such information from the airports' departments for the environment.

Table 1: Reviewed Literature

Literature	Description
Journals Papers	Journal of Air Transport Management Environmental Pollution Journal of Environmental Science and Health Chemosphere Risk Analysis Atmospheric Environment Transportation Research European Journal of Transport and Infrastructure Research Resources Conservation and Recycling International Journal of Sustainable Development and Planning Bulletin of the Geological Society of Greece Research Technology Management Journal of Environmental Management
Official reports	ACI Europe, IPCC, ICAO, Eurocontrol, Omega, Department for Transport (UK), European Environment Agency, Air Transport Action Group, HM Treasury (UK), Global Reporting Initiative (GRI)
Books	Planning and design of airports Towards Sustainable Aviation Managing airports: an international perspective Management of the environmental impacts at airport operations Competitive and Corporate Strategy Research Design: Qualitative, quantitative and mixed methods approaches Exploring Corporate Strategy, Text and Cases Tools and Techniques for Strategic Management Research Methods for Business Students Corporate environmental management. Systems and strategies A User-Friendly Guide to Mastering Research
Conferences	14th Air Transport Research Society (ATRS) World Conference 5th International Congress on Transportation Research 'Air Transport of today and tomorrow' Hellenic Aviation Society Conference 1st International Seminar on Regional Airports 2009
Interviews	Thomas C. (CATE, MMU) Oh X. (ACI) Karamanos P. (Athens International Airport, Environment Department) Freeman A. (East Midlands Airport, Environment Department) Bold S. (Adelaide Airport, Environment Department) Johnson T. (AEF, UK)
Workshops	MSc Sustainable Aviation short course GRI Certified Workshop for Sustainability Reporting
Web-sites	Airport operators official web-sites & e-mails providing information on various environmental issues, Airport Carbon Accreditation.org, Department for Transport, Aviation Environment Federation, UNESCO, Omega, GRI

Conferences

During the research, the researcher participated in the following conferences, where papers were presented and useful information was collected from the proceedings, but also from various conversations with the participants.

- 5th International Congress on Transportation Research (ICTR), Hellenic Institute of Transportation Engineers and Hellenic Institute of Transport, Volos, Greece, 27-28 September, 2010.
  During the conference the researcher had the chance to attend many presentations regarding aviation and the environment and airport planning. In addition, the researcher presented the paper "Airports environmental management: Results from the evaluation of European airports environmental plans".

- 14th Air Transport Research Society (ATRS) World Conference, Porto, Portugal, 6-9 July, 2010.

During the conference the researcher had the chance to attend many presentations regarding aviation and the environment, airport planning, airport operations and airport performance. In addition, the researcher presented the paper "Airport sustainable development: what about managing the water needs?"

- Air Transport of today and tomorrow', Hellenic Aviation Society Conference, Athens, Greece, April 20-21 2010.
  During the conference the researcher had the chance to attend many presentations regarding aviation and the environment and airport performance. In addition, the researcher gave a presentation on "Airport's environmental impacts".

- 1st International Seminar on Regional Airports 2009, Wessex Institute of Technology (WIT), New Forest, UK, September 29 2009.
  During the conference the researcher had the chance to attend many presentations regarding regional airports planning and development, as well as regional airports' environmental management. In addition, the researcher presented the paper "Regional airports environmental management: key messages from ten European airports evaluation". This paper was published in a special issue of the 'International Journal of Sustainable Development and Planning', available from WIT Press.

Workshops and interviews

The researcher decided that attending the MSc Sustainable Aviation Short Course, at Manchester Metropolitan University (November 23-27, 2009) was preferable to additional interviews for a number of reasons. The short course concerned sustainability and the air transport industry and addressed issues regarding the impact of aviation on global climate change, airports' environmental capacity and airports' sustainable development. During the course, a number of experts, including academics involved in research into aviation and environmental issues, aviation industry professionals, airport managers and nongovernmental organisations (NGOs) staff concerned with environmental issues introduced the key issues of sustainable aviation.

Consequently, the researcher had the opportunity to discuss with various stakeholders the key issues of the research and identify the main research objectives. It should be noted that during the 5-day short course, the researcher conducted semi-structured and unstructured interviews (Dawson, 2002) with academics and managers and explored in depth the main environmental issues that airports need to deal with, as well as the water management applied techniques. The interviewees were:

- Callum Thomas, Professor of Sustainable Aviation in the Centre for Air Transport and the Environment (CATE), in Manchester Metropolitan University. Professor Thomas discussed the key issues that an airport is obligated to deal with in order to sustainably grow. In addition, he provided useful information regarding the importance of water management in the airport industry and gave examples of airports with modern water management systems.
- Tim Johnson, Director of the Aviation Environment Federation (AEF), the principal UK non-profit making environmental association concerned with the

environmental effects of aviation. He provided information regarding the environmental issues that airports need to deal with, from an NGO's point of view, but also provided helpful information about water management at Munich airport.

- Stephanie Bold, Environment manager in Adelaide airport, in Australia. She provided information regarding the issues that the department for the environment has to deal with and pointed out significant mitigating measures that have been applied.

In addition to the aforementioned interviews, the researcher conducted an unstructured interview with Dr. Panagiotis Karamanos, manager of the environmental department of the Athens International Airport, who provided information regarding environmental management in Athens International Airport, focusing on water management issues.

Finally, two more interviews were conducted using e-mail correspondence:

- Adam Freeman, East Midlands airport environment officer, who provided information regarding, amongst other issues, carbon management, runoffs management, energy and water consumption control, modes of transport and waste management.
- Xavier Oh, Senior Manager Environment and ICAO Liaison, ACI, who highlighted current environmental issues for airports and their importance in the future.

During the course of this research, the researcher attended the 'Global Reporting Initiative (GRI) Certified Workshop for Sustainability Reporting' (Athens, Greece, February 21-22 2011), in order to be able to understand and analyse the indicators that are commonly used in airport operators' sustainability reports.

2.3.2 Research limitations

The research is limited by the fact that only a sample of airports is going to be assessed. Therefore, the research results should be limited to the airports that possess the same characteristics, regarding geographic location (geomorphology, geology, hydrogeology, hydrology, meteorology) and environmental management techniques, including water management. It should be noted that the geographic location of the airport defines, amongst others, the current as well as the future availability of water resources, changes in the precipitation patterns and run-offs and probable extreme weather events.

In addition, the availability of the selected data is another limitation. The necessary data was obtained mainly from airport operators' web-sites, interviews and e-mails. Consequently, limited data was available. Besides that, the researcher could not easily use data that was not in English, or Italian; thus information that was written in other European languages was reluctantly used. Also, the data obtained from the questionnaire survey constitutes one more limitation; only 19 out of 55 airports took part in the research. Therefore, the research results are associated with the subjective views of the respondents.

Finally, the limited time frame constitutes another significant limitation. The data collection, the development of the methodological approach and the application had to follow the time schedule that had been developed. The researched had to deal with delays in data collection, but also in questionnaire survey and had to re-schedule more than twice.

Nevertheless, based on the available data, the researcher managed to meet research objectives. Consequently, the aforementioned limitations affect neither the analysis nor the application and therefore they cannot reduce the importance of this research.

2.3.3 Methodology framework

The current research aims to develop a modelling framework to evaluate applied environmental strategies and to support decision making in regards to whether an airport is water efficient or not. The research background is based on the concept of MCA.

The key advantage of MCA is that it provides a framework that allows impacts measured in different units to be taken into consideration and be treated equally in the analysis, through the use of scoring and weighting techniques (Department for Communities and Local Government, 2009). In addition, MCA allows decision makers to include a series of social, environmental, technical, economic and financial criteria. The weighting allows the decision makers to take into account the variations in importance that stakeholders attach to different impacts. The different levels at which weights can be obtained may refer to environmental, economic and social aspects (Defra, 2004; Center for International Forestry Research, 1999).

The methodological framework of the research is shown in the following figure.

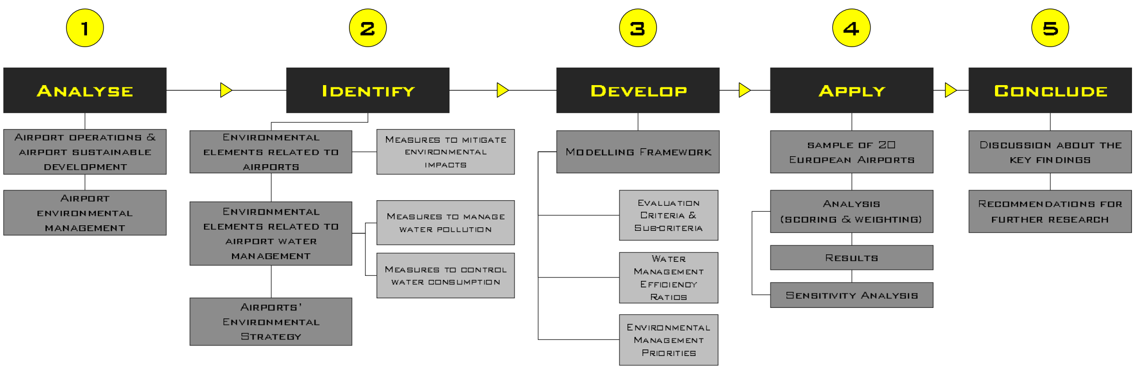

Figure 1: Research methodology framework
(Source: author)

In the following pages, the research methodological framework is going to be analysed, providing, at the same time, the background reading. The first two main steps (‘*analyse’* and ‘*identify’*) provide the literature review and the methodological approach to the research questions, while the next step (‘*develop’*) illustrates the modelling framework (detailed analysis is provided in the relevant chapter). The following step (‘*apply’*) refers to the application of the framework to a sample of 20 European airports; the key issues and the results of the analysis are going to be presented. The last step (‘*conclude’*) provides the conclusions of the research, discussion of the key findings and recommendations for further future research.

At this point, it should be noted that the thesis does not include a typical literature review chapter, as the researcher wishes to present the reviewed literature and the first steps of the methodological approach at the same time, providing an advanced overview of the whole research. Therefore, during the first two steps, the researcher reviewed the literature to identify airport environmental impacts and applied mitigating measures, using the comprehension on environmental impact assessment and environmental planning, as well as water management issues in airports from previous MSc. In addition, targets linked to airport sustainable development were identified; the main environmental issues related to airport operations and development, as well as airport water management systems were analysed. The key issues of the first two steps are presented in the next chapter.

2.3.4 Sampling

Considering that it is impossible for the researcher, to collect and analyse data from all the airports in the world, or even in Europe, mainly because of time restrictions and data availability in the given time frame, a sample of European airports was selected, not only for the questionnaire survey, but also for the application.

According to Saunders *et* al. (2009) the choice of sampling technique depends on the research questions and objectives; in addition, it depends upon the preference of the researcher (Dawson, 2002). Thus, the researcher decided to use mainly random sampling techniques (Saunders *et* al., 2009); details of which are given in the ‘Evaluation Framework’ and ‘Application’ chapters.

3. Airports environmental management

The significant role of airports on regional economy has been prominently recognised by many researches; airports bring significant social benefits and in many cases they are thought to be the single largest generator of economic activity in the regions they serve (Air Transport Action Group (ATAG), 2008; Caves, 2003). In addition, many reports highlight the fact that European regions with airports and significant air services have better social and economic development with lower unemployment, higher productivity and higher income per-capita, compared to regions without airports (ACI, 1998).

The airport industry has experienced strong growth over the past few years, and despite the recent economic crisis, the growth in popularity and importance of air transport is set to continue in the upcoming years (Eurocontrol, 2008; International Civil Aviation Organization (ICAO), 2007). According to Eurocontrol's new long-term forecast (2010) the average annual growth until 2030 will be around 2.8%; at that point airports will not be able to handle about 0.7-5 million flights per annum, as a result of limited capacity, representing 4-19% of the demand. Consequently, in order to satisfy the forecasted demand, airports have to invest in new infrastructure to increase their capacity; in any event, airport operators seem to be the first to seek the license to grow for the whole aviation industry (ACI, 2005).

However, major transport infrastructures such as airports (Horonjeff, 1975) have substantial effects on city's urban development because of their impact on local traffic, employment, economy and environment. Thus, along with the economic and social benefits, airports affect the surrounding urban planning and have negative impacts on the environment (Dimitriou and Voskaki, 2010).

Graham points out (2008) that the airport industry, like all other industries, is facing the effects of increasing environmental pressure; environmental concerns differ from one airport to another, depending on public scrutiny regarding aviation and other social issues. Additionally, every airport differs in terms of the environment in which it is set, the sensitivity of surrounding countryside and proximity to developed areas (Thomas *et* al., 2009).

Many reports show that the contribution of airports to environmental disturbance at a local and global scale is significant. Graham (2008) mentions that airports are large commercial sites with considerable environmental impacts that are associated with airport operations, and which concern noise, emissions, water pollution, waste, wildlife heritage and landscape, use of energy and water. The Parliament Office of Science and Technology's (POST) Report "Aviation and the Environment" (2003) points out that increases in air transport affect the environment at a local level through noise, effects on local air quality and ecosystems; at a larger scale, GHG emissions contribute to global warming.

Analytically, within the global context, airports have significant impact on the global environment in terms of climate change. Although aviation is currently responsible for only 2-3% of carbon dioxide (CO_2) emissions from anthropogenic sources, these emissions are increasing annually because the rate of growth of the industry is outstripping the rate of airframe and engine development (Lee *et* al., 2009; IPCC, 2007).

At a local level, even though noise seems to be the main concern over the last 20 years, air emissions, resources (energy and water) availability, waste and waste water management, ecosystems and land use planning constitute issues that are directly linked to local communities' tolerance. In addition, the adverse environmental and community impacts can lead to restrictions on existing airport operations and constraints upon future growth (Thomas *et* al., 2009).

Nevertheless, compared to previous decades, nowadays limitations imposed by authorities, organisations (e.g. Governments, ACI, Eurocontrol, ICAO etc), monitoring systems (e.g. noise or local quality monitoring systems) or various local agreements, have the potential to constrain the current operation, as well as the future capacity of an airport, especially if the cost of environmental mitigation is quite high. Therefore, the existing and extra capacity must be balanced against the airports' environmental impacts (Upham et al., 2004).

Thomas *et* al. (2009) highlights that the most sustainable strategy is one that manages airports' growth, while at the same time applies measures to mitigate impacts to local environment, as well as impacts to global environment. Failure to collaborate effectively to meet the key environmental challenges can result in, amongst other issues, increased operational costs, environmental related conflicts between stakeholders, non compliance with national legislation or local agreements, or even excessive mitigation costs (Eurocontrol, 2008).

Based on the reviewed literature, the main environmental impacts from airport operations (terminals, ground operations etc), airline operations, airport access or various construction projects in the airport landside are presented in Table 2.

Table 2: Environmental impacts

Environmental impacts	Airport operations	Airlines operations	Airport access	Construction projects
Climate change	✓	✓	✓	
Noise	✓	✓	✓	
Air pollution		✓	✓	✓
Water use	✓	✓		✓
Water pollution	✓		✓	✓
Biodiversity	✓	✓	✓	✓
Waste	✓	✓		✓

(Source: Airport Operators' Official Web-Sites)

While environmental issues have the potential to directly impact upon airport growth at a global and local level, current operations and the need for further infrastructure will determine their importance. Therefore, effective airport planning and management that deals with tools used to keep the balance between the benefits and the costs of the services provided in respect of the specific needs of global society, can help reduce the potential of environmental issues to emerge as capacity constraints and can therefore facilitate growth (Thomas *et* al., 2009).

Even as the need to identify the environmental issues that currently act as constraints on existing operations or would probably constraint future airport growth, the absence of a common framework with measurable objectives makes the evaluation of airports' applied measures difficult. This is partly due to the fact that the implementation of environmental performance evaluation procedures is still not obligatory. Even though Global Reporting Initiative (GRI) provides a credible framework and has published guidelines for airport sustainability reporting, a preliminary research regarding reporting trends in the airport sector showed that in the case of European airports, only four out of nine sustainability reports were based on GRI Guidelines (GRI, 2009).

Analysed environmental plans and airport operators' sustainability reports pointed out that airport environmental management is mainly focused on identification, assessment and control of the aforementioned environmental impacts that may act as operational or capacity constraints. The analysed data identified the following main issues:

- Carbon emissions management
- Energy consumption control
- Water consumption control
- Local water resources quality management
- Waste management
- Local air quality management
- Noise abatement and control
- Biodiversity management
- Promotion of environmental friendly access systems
- Land use planning

In addition, the analysis resulted in different ways of reporting the airports various actions for minimising environmental impacts; some issues were addressed differently and in most of the cases, quantitative information was not provided; therefore significant comparative measures could not be found.

The measures that airports apply to minimise their environmental impact, and the area of impact, are shown in Table 3.

Table 3: Applied measures to minimise the environmental impact

Measures	Area of impact
Climate change	Global environment
Resources use (energy and water)	Global and local environment
Noise	Local environment
Local air quality	Local environment
Water quality management	Local environment
Waste management	Global and local environment
Land use plan	Local environment
Surface access	Local environment
Biodiversity	Global and local environment

(Source: Airport Operators' Official Web-Sites)

Although waste is considered an impact to local environment, under the concept of sustainable development, recycling helps control the use of primary resources globally (e.g. the recycling of aluminum cans reduces the amount of bauxite mined and the recycling of paper saves trees) and therefore should be identified as an impact to both local and global environment. The same applies to biodiversity; the loss of species in a region affects the whole planet.

3.1 Managing global impacts

The Intergovernmental Panel on Climate Change report (IPCC, 2007) confirms that increases in GHG concentrations since the pre-industrial times have led to a positive radiative forcing of climate, tending to warm the surface of the Earth.

Lee *et* al. (2009) highlights the fact that the impact of aviation of the climate do not rise from its CO_2 emissions alone, but also from other associated emissions and effects. The total aviation radiative forcing in 2005, excluding cirrus, was 3.5% of total anthropogenic forcing, reaching 4.9% including estimates for induced cirrus. Taking into consideration future scenarios, by 2050 the aviation radiative forcing, excluding cirrus, will represent 4.0-4.7% of the total radiative forcing of climate.

Omega's final report "The rising Effect of Aviation on Climate" (Meinshausen and Raper, 2009) indicates that worldwide international aviation is one of the most rapidly growing sources of GHG emissions, producing a rise in global mean temperatures of 0.028°C; this represents 4.7% of the total anthropogenic change.

Airports, being the key aviation stakeholder, need to address their own non-aircraft emissions, and the emissions from other airport related activities (ACI, 2010). Non-aircraft airport emission sources mostly include power and heat generation, airport fleet vehicles, terminal use, support equipment, construction works and fire fighting procedures; these emissions are totally controlled by airport operators. On the other hand, emission sources that have to do with aircrafts (landing, take-off, taxiing etc), ground access vehicles and power generation plants off-site (purchased energy) are not controlled by airport operators (ATAG, 2010; ACI, 2010).

Emissions that are directly controlled by airport operators (non-aircraft) are ground-based and therefore included in Kyoto protocol national inventories and targets. Consequently, along with other aviation stakeholders, airports are trying to manage their own carbon emissions. In addition, some airports have set specific targets aiming at carbon neutral operations.

The most important measures that airports apply in order to reduce their carbon footprint or to manage emissions that are under their direct control include improvements in energy efficiency and conservation, ground fleet conversions, low emission power generation plants on site or renewable energy supplies (ACI, 2007). For example, many airports use geothermal energy to cover their cooling and heating needs; others generate renewable energy by wind turbines or photo-voltaic to cover lighting needs; others purchase hydroelectric energy or use biofuel to generate electricity on-site.

Over and above, many airport operators are becoming carbon accredited, to ensure efficient operations, to reduce costs, to raise airport's profile and credibility and to secure a license to grow. Airport Carbon Accreditation is the European carbon standard for airports, that assesses and recognises the efforts of airports to manage and reduce their carbon emissions with four levels of award: 'Mapping', 'Reduction', 'Optimisation' & 'Neutrality'. To achieve carbon neutral operations, airports need to offset the carbon emissions that they cannot eliminate (Airport Carbon Accreditation).

Accordingly, it can be said that at the moment, the airport industry mainly spends its efforts in looking for actions to reduce its carbon emissions. However, according to the recent literature (IPCC, 2007; European Environmental Agency (EEA), 2007) global warming results in alterations in the hydrological cycle that have the potential to change the precipitation patterns and run-offs and cause extreme weather events. These changes affect water availability and demand, as well as water resources quality. Many areas of Europe already have to manage both severe water stress and the delicate balance between water demand and water availability (EEA, 2009). The Stern Review on the Economics of Climate Change (2006) highlighted that a temperature rise of 2°C will have the potential effect of decreasing water availability in the Mediterranean region by 20-30%. Therefore, water availability may become another major barrier for growth, especially for the airports located in hot destinations (such as in Mediterranean region).

For this reason, in addition to carbon emissions management and energy consumption control, airports should also control water consumption. The key issues regarding applied water conservation strategies are presented in the following chapters.

3.2 Managing local impacts

Noise

Noise seems to be the most significant local impact affecting communities surrounding airports (Visser, 2009). Noise affects people's health and quality of life (World Health Organization, 2009), can make destinations less attractive and can generate opposition amongst local residents; this can lead to constraints to the operations and development of airports and therefore their capacity (Thomas and Lever, 2003).

Even though major technological improvements have taken place in regards to monitoring and management of aircraft noise, these have been offset by the rapid growth in air transport and reduced tolerance to aircraft noise; as a result, many airports are subject to operational constraints or capacity limits (Hooper, 2009). In Europe, approximately two thirds of European airports are already subject to noise restrictions, or have their operations indirectly constrained by noise related issues, and this figure could increase to 80% in 5-10 years (Upham *et* al., 2003).

According to the environmental noise directive 2202/49/EC, airports must implement specific measures to reduce environmental noise caused by their operations. Consequently, various mitigating or control measures have been adopted; the most common and often mentioned measures at the reviewed environmental plans (e.g. Frankfurt, Schiphol, Athens, Munich etc.) are listed below:

- noise monitoring systems and strategic noise mapping;
- air traffic management;
- operating restrictions and limits, especially at night;

- differential charging in order to encourage the use of quieter aircraft;
- anti-noise barriers or other relevant infrastructure, to protect local communities;
- registration of noise complaints

Air quality

Local air quality in the vicinity of an airport is determined by several factors, such as ground transport, aircraft emissions and apron activities. The most significant sources of air pollution related emissions include amongst other issues, aircrafts, airside and landside vehicles, ground support equipment, fuel storage, various point sources (electricity generation), engine testing, fire training and road vehicles (Theophanides and Anastassopoulou, 2009; Thomas, 2009).

Air quality pollutants of concern include oxides of nitrogen, carbon monoxide, hydrocarbons, particulate matter, sulphur oxide and carbon dioxide (Clark *et* al., 1983). Generally, the management of local air quality and the relevant emissions is basically targeted at achieving and maintaining compliance with local regulations regarding pollutant concentrations (ACI, 2010). The local air quality legislation has the potential to constraint airport growth either by restricting aircraft movements or road traffic (Dimitriou and Thomas, 2007).

Based on the airports' environmental plans, some of the measures that airports carry out to mitigate air pollution impacts include air quality monitoring systems, air traffic management, financial incentives to encourage the use of more environmental friendly aircrafts and the promotion of environmental friendly transport access nodes.

Water use

Water resources are of critical importance for airport operations and development, especially in regions under severe water stress, where strong competition for water exists. A number of airports already have to deal with water availability issues, especially those located in the Mediterranean region; nevertheless, even in the case of Heathrow airport, water availability was considered as a potential long term constraint (Eurocontrol, 2008).

A detailed analysis of the applied environmental strategies showed that, in most of the cases, the applied practices depend on the location of the airport (Dimitriou and Voskaki, 2010). The most important water efficiency measures that airports have applied, based on the reviewed environmental plans, are listed below:

- reduction of drinking water consumption;
- installation of water reduction devices;
- efficient irrigation;
- tracking water use;
- leak detection programme;
- water recycling and water re-use;
- desalination plants

Waste water

In addition to water conservation, airports also have to manage waste water efficiently without posing harm to employees, customers, local communities and the environment. The most important potential sources of surface and ground water pollution include the chemicals used for aircraft and airfield de-icing and anti-icing (Turnbull and Bevan, 1994; Switzenbaum et al., 2000), fuel spillages, fire fighting foam, chemicals and oils from aircraft and vehicle maintenance, detergents used in aircraft and vehicle cleaning and, sewage from terminals and aircraft (Manchester Airport Environmental Plan, 2008).

In order to control storm water discharges, airports implement practices that mostly prevent or minimise the discharge of pollutants into bodies of water (Luther, 2007) through the drainage system. Other measures, which were included in the reviewed environmental plans, include the following:

- monitoring water quality of surface and underground water;
- periodic sampling at discharge points;
- oil, hydrocarbon and grease separator systems;
- balancing ponds to control the quality and volume of water released;
- rainwater collection system;
- periodical analysis of output of wastewater treatment plant;
- use of biologically degraded de-icing and anti-icing agents;

Waste

Airport activities involve the production of significant amounts of waste (Pitt and Smith, 2003) that according to “the polluter pays” principle needs to be managed. The waste generation mainly includes solid urban waste, non-hazardous waste and special hazardous waste from terminal, airfield operations, maintenance activities, and aircraft catering. The amount of waste produced depends on the number of passengers and the number of employees.

The most significant measures that airports carry out in order to manage waste, include waste separation at source and recycling (Pitt and Smith, 2003); additionally, waste minimisation initiatives, such as implementation of financial incentives for recycled material or waste charging, re-use of equipments or materials and promotion of renewable products with the least environmental impacts are often applied in many airports (Dimitriou and Voskaki, 2010). In addition, collection and safe disposal of hazardous waste is taking place in accordace to the relevant national and European regulations.

Biodiversity

Airport development requires the replacement of large areas of land with runways, taxiways, aprons and terminal buildings, as well as additional infrastructure, including roads and railways (Dimitriou and Thomas, 2007; Daley *et* al., 2008); this affects the surrounding urban planning and the local ecosystems and can lead to degradation of their functions and biodiversity loss.

To protect the biodiversity, as well as areas and features of wildlife value, airports identify areas of ecological interest and monitor fauna or/and flora. In addition, they promote biodiversity in areas where it does not impact on the safe aviation environment.

3.3 Water management

As discussed in the previous chapter, water availability may become another major barrier for airport growth, as it is directly linked with its operations, but also with various environmental, economic, social and health issues. A number of airports, especially those located in the Mediterranean region, already have to deal with water availability problems; water availability has also already been considered by the UK Department for Transport as a potential long term constraint in the case of London/Heathrow airport (Eurocontrol, 2008).

To successfully manage the foreseen conditions, modern water management techniques and efficient use of water resources need to be incorporated. The purpose of water management is to reduce the quantity of fresh water used, while at the same time to efficiently manage the produced wastewater. Applied strategies involve, amongst other measures, water consumption monitoring and control, water recycling, water quality monitoring; in addition, measures to control drainage discharges in order to limit and manage the risk of soil and surface or ground water contamination are included (Dimitriou and Voskaki, 2010).

For the water supply of an airport, direct and indirect sources can be used. Direct sources refer to a local water distribution system or every other system that delivers water; indirect sources refer to alternative resources of non-potable water, such as rainwater, treated or grey water. The various operational or other consumption activities result in a significant amount of waste water being produced. The waste water, along with the run-off water must be collected and treated properly. As mentioned above, this waste water contains various pollutants that can degrade the water resources of the area, affect ecosystems and cause health problems. Most of the airports treat their waste water before it is driven to the nearest water receptor, or the local sewage treatment facilities. The treated water can then be re-used.

The importance of water re-use in the balance of water resources, especially in small Mediterranean districts, is described in a study of Manios and Tsanis (2006). The study suggests that areas with more than 1000 inhabitants could provide an adequate amount of wastewater that could change the balance of water resources of the area. According to Manchester Airport's Environmental Plan (2008) it is estimated that only around a third of the water used is potable water.

If the waste water reaches water receptors (rivers, lakes, ponds, streams etc) without treatment or without adequate treatment, the pollutants that it contains (e.g. chemicals, heavy metals, toxic, other hazardous substances, microbial load etc) (Chilakos and Kavouras, 2004) will affect the water quality and the ecosystems, as it will reduce the amount of dissolved oxygen and increase the amount of nutrient concentration. The overall degradation of the local water resources will probably depend on the local hydro-geological conditions of the area. At this point, it should be noted that in addition to the impact on the ecosystems of the area, the contaminated water can be linked with various water-borne diseases, depending on the pollutants. As one can imagine, the problem becomes even greater if this degradation takes place in areas that are already under water stress.

The detailed analysis of the applied measures showed that most of the airports control their discharges so as to avoid the contamination of surface and underground water, they monitor the surface water quality and they control the quantity and quality of wastewater; in addition, most of them apply specific measures to reduce the water consumption. Therefore, based on the analysed data, the most important issues and the area of their impact are presented in Table 4.

Table 4: Main categories of applied water management measures

Measures	Area of impact
Water consumption control	Global and local environment
Use of recycled water (treated water, rainwater, greywater etc)	Global and local environment*
Sewage and wastewater management	Local environment
Runoff management	Local environment
Water quality (surface and underground water) management	Local environment

(Source: airport operators' official web-sites)

* the use of recycled water suggests that the airport will use less potable water and therefore less water will be abstracted

The water supply, consumption and waste water management in airports, in simple terms, is given in Figure 2 schematically.

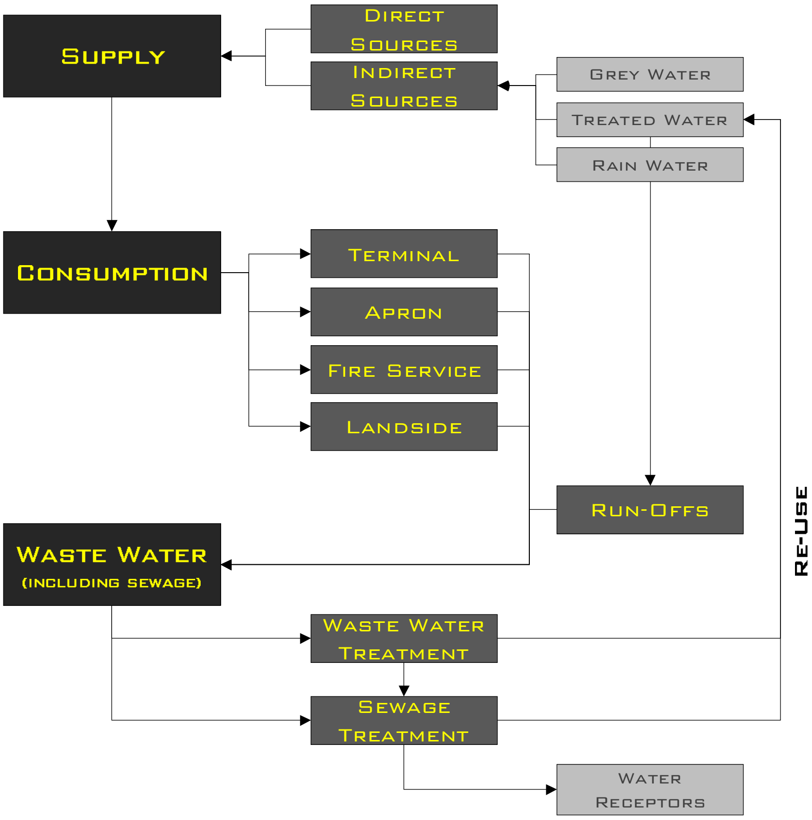

Figure 2: Water supply and consumption sources at airports
(Source: author)

4. Evaluation framework

Many reports show that the airports' contribution to environmental disturbance in local and global scale is significant. Literature points out that environmental management has become an issue of considerable concern; the successful management of environmental issues is one of the greatest challenges to, and possible constraints upon, the future activities of airports (Graham, 2008).

According to a research conducted by CATE for Eurocontrol (2002), to gain environmental capacity airports must invest in environmental management, mitigation programmes, or in compensating local communities to tolerate nuisance from their operations. According to Janic (2010) the key principle underlying sustainable development is recognition that there are limits to growth or the environmental implications of growth. Airport sustainable development implies mitigating impacts or constraining growth; therefore, the most commonsense strategy for most airports is to manage growth sustainably.

The POST Report (2003) suggests two possible approaches for sustainable aviation. The first one involves the consumption of fewer resources for each unit of productivity; the second one requires the reduction of the resources flowing into, and wastes flowing out of the system. Consequently, if we consider the airport as a system, sustainable development, amongst others, implies (Figure 3):

- Resources consumption control (energy, water and materials)
- Recycling (energy, water and materials)
- Emissions management (carbon and air quality related emissions)
- Waste water management
- Solid waste management

Figure 3: The airport system
(Source: author)

While airport operators present sustainability reports giving details about implementation measures to minimise the negative impact on the environment, this data could not be used in a straightforward manner for an evaluation model. In most of the cases, the researcher had to deal not only with different measuring units and variable information, but also with reporting within different timeframe. Even in the case of airports that use a common reporting framework (GRI), the researcher had to deal with airports that do not report on the same indicators.

Therefore, the challenge for the researcher was not only to conceive of an evaluation process, but also to choose the appropriate environmental management evaluation criteria. In addition, the researcher thought that the whole process to combine all this information to assess airports' environmental strategy was considerably interesting.

4.1 MODELLING FRAMEWORK DEVELOPMENT

Taking into consideration the analysis of the environmental issues associated with airport operations, in order to obtain a comprehensive overview of airports' strategic environmental objectives and water management issues the modelling framework incorporates a combination of analysis techniques (Figure 4). Regarding environmental strategy evaluation, the modelling framework is based on MCA, which allows combination of data, detailed analysis and evaluation of strategies, taking into consideration the importance that airport operators give to different environmental impacts. In the case of water management efficiency, a ratio analysis is incorporated.

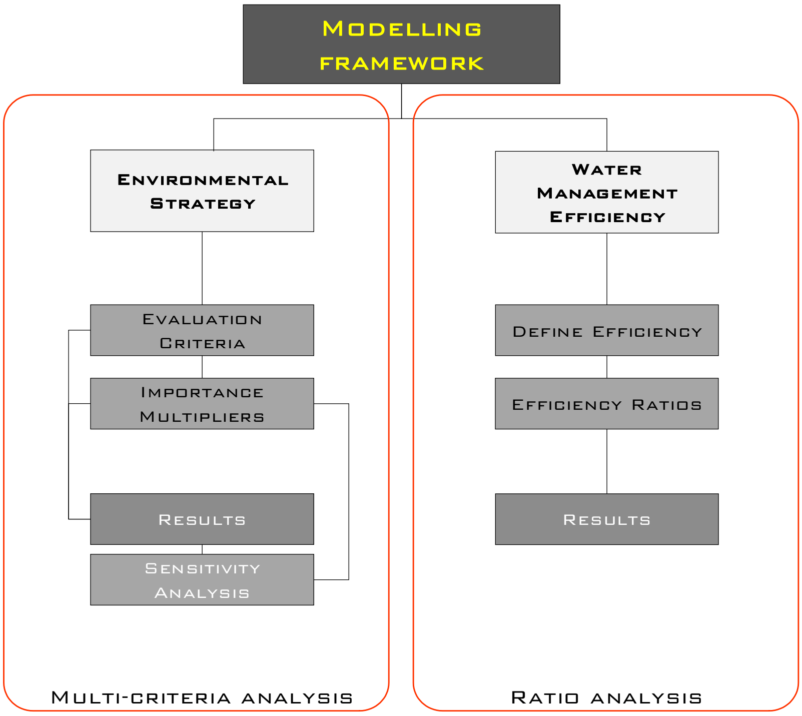

Figure 4: Modelling framework
(Source: author)

In the next paragraphs the key components of the modelling framework are analysed, giving details about the choice of evaluation criteria, the importance multipliers used and the developed ratios to evaluate water management efficiency.

4.1.1 Evaluation Criteria

Based on the analysis of the environmental issues associated with airport operations and development projects the main issues that in most of the cases are identified have to do principally with the control of natural resources consumption, the control of noise and the management of emissions, water quality, waste and ecosystems (Figure 5).

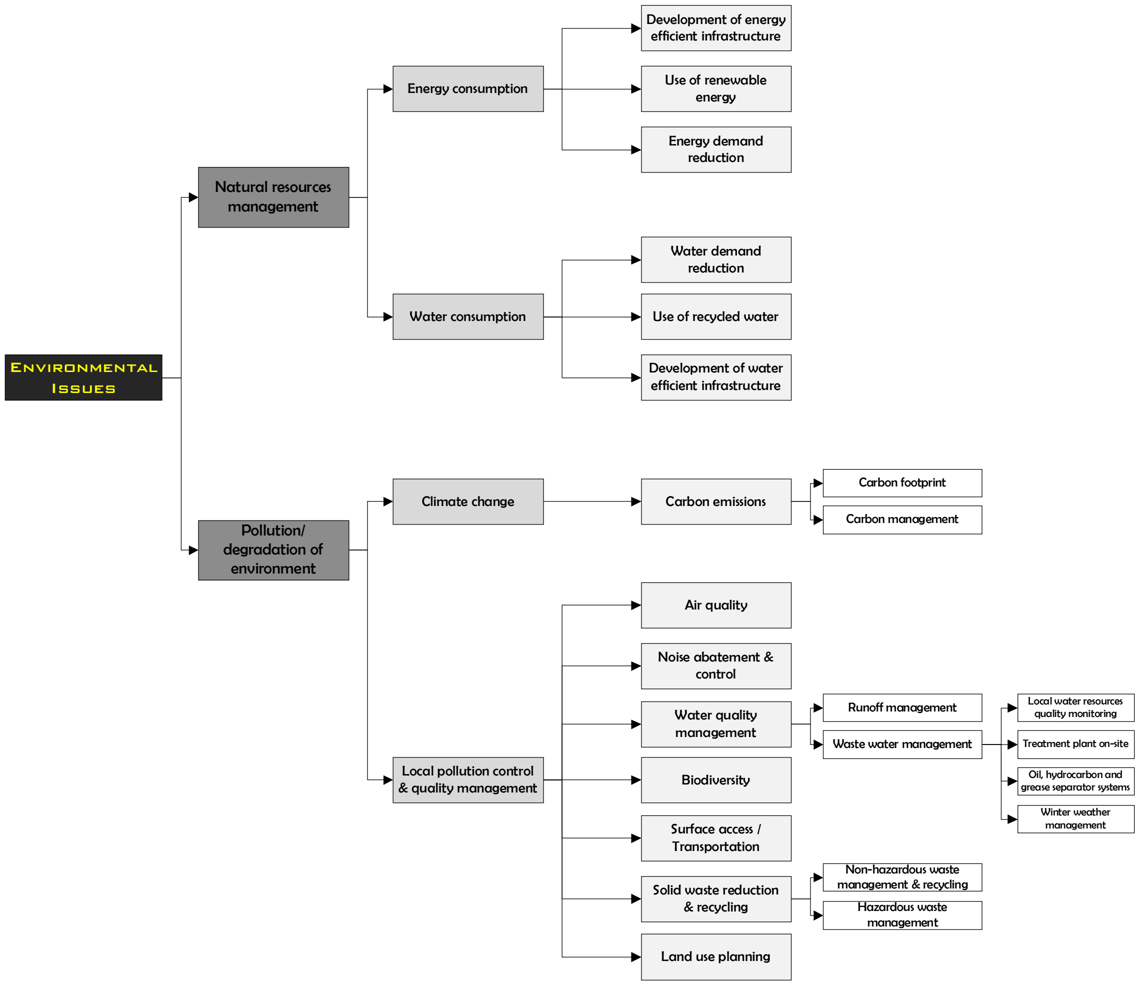

Figure 5: Environmental issues associated with airports operations and development projects
(Source: author)

The major environmental disturbance of airports operation and development projects could be considered in two levels. The first level regards the assessment of airports' environmental strategy, taking into consideration the importance that airports give in the main environmental categories. Analytically, issues like carbon emissions, energy and water efficiency, liquid and solid waste management and air quality management are considered important to airport industry and stakeholders, but also to policy and decision makers at national and international level. The second level has to do with environmental issues, directly linked to local communities. Air quality, noise, access systems, ecosystems, land use, water consumption, and liquid and solid waste management are considered important at local or, in some cases, regional scale. Finally, in addition to these two assessments, to obtain a comprehensive overview on water management issues a third assessment is included. Like the previous category, water management is considered important at local or, in some cases, regional scale. Details regarding this assessment are presented in the water management efficiency paragraphs.

The evaluation framework incorporates detailed analysis of measures to mitigate environmental impacts, management actions to reduce emissions or to deal with wastes and various long and short term targets. Therefore, for each one of the environmental categories (e.g. carbon emissions, energy consumption, air quality) the following are identified:

Policy issues	(P)	airports environmental policy statement shows whether or not the management endorses the importance of the environment in the sustainable development of the airport. In addition, it shows whether or not specific long and short term targets, with regard to specific environmental areas, have been set (e.g. target towards carbon neutral operations)
Management actions	(M)	includes specific actions to address and manage environmental topics related to airport operations and further development (e.g. actions towards emissions reduction, resources consumption reduction)
Control issues	(C)	refers to specific measures that have been applied in order to improve airport's environmental performance (e.g. resources consumption, emissions, waste generation)

4.1.1.1 CRITERIA CATEGORIES AND SUB-CRITERIA FOR THE MAIN ENVIRONMENTAL ISSUES

Regarding the main environmental issues, the following criteria categories are acknowledged:

1. Carbon emissions:

Airports, being the key aviation stakeholder, need to address non-aircraft GHG emissions from sources that are owned or controlled by the airport operator (ACI, 2010). Generally, the most common mitigating measures include plant equipment, fleet vehicle modernization, and energy efficiency; in addition, airports are encouraged to set goals to become carbon neutral. According to ACI (Airport Carbon Accreditation, 2010), carbon neutrality is when the net carbon dioxide emissions over an entire year is zero (i.e. the airport absorbs the same amount of carbon dioxide as it produces). In most of the cases to achieve carbon neutral operation airports carbon offset the carbon emissions they cannot reduce.

For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets towards carbon neutral operations, b) present a comprehensive carbon management plan and c) have applied specific measures to control GHG emissions are taken into consideration. Analytically, the sub-criteria for this category are:

1.1 (P) Target to reach carbon neutrality by the year 2020
1.2 (P) Short-term target to reduce carbon emissions
1.3 (M) Use of low carbon fuels (airport vehicles and ground support equipment)
1.4 (M) Green operational procedures and/or relevant technological innovations (e.g. power charging or biofuel stations etc)
1.5 (M) Airport collaborative decision making
1.6 (C) Carbon accreditation
1.7 (C) Carbon footprint reduction over the past year

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

2. Energy consumption:

Airports need large quantities of electricity for the operation of their infrastructure. Energy consumption is mostly associated with heating, ventilation, air conditioning and lighting (Graham, 2008). The most common applied measures to reduce energy demand include improvements in energy efficiency and renewable energy supplies. Energy efficiency improvements may include improvements in lighting systems, establishment of low-energy heating and cooling solutions, modification in architecture design and use of energy efficient systems. Renewable energy may refer either to electricity generated on-site (e.g. geothermal, wind turbines, photo-voltaic), or to electricity supplied by others (e.g. hydroelectric, biofuels, wind turbines).

For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets towards conventional energy demand reduction, b) present a comprehensive energy efficiency plan and c) have applied specific measures to reduce energy consumption levels or to increase the proportion of green energy used are taken into consideration. Analytically, the sub-criteria for this category are:

2.1 (P) Short-term target to reduce energy consumption levels more than 5%
2.2 (P) Short-term target to increase green energy consumption levels
2.3 (M) Energy efficient lighting
2.4 (M) Energy efficient cooling/heating systems
2.5 (M) Low-energy equipment (i.e. escalators, baggage belts, IT systems)
2.6 (M) Green energy generation on-site
2.7 (M) Use of co-generation systems
2.8 (C) Green energy covers more than 10% of the total demand
2.9 (C) Energy demand reduction over the past year

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

3. Water management (consumption control & waste water management):

Water availability is already considered another major barrier for airport growth (Eurocontrol, 2008), especially in areas with limited water resources. Generally, the most common applied measures to control water consumption include efficiency improvements in water infrastructure, reduction of drinking water consumption, efficient irrigation and leak detection systems. Water recycling is reusing water, rainwater, grey water or other treated water; it enables the conservation of natural resources, offering, at the same time, water and economic savings. Many airports, especially those that have to deal with water availability problems, have already reviewed opportunities for water recycling within the airport; they have separate supply network and use rainwater or treated water to sanitary areas or fire-fighting equipment or even for irrigation to maintain airport green areas.

For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets towards water demand reduction, b) present comprehensive water efficiency and waste water management plan and c) have applied specific measures to reduce drinking water consumption levels or to increase the proportion of recycled water are taken into consideration. Analytically, the sub-criteria for this category are:

- 3.1 (P) Target to reduce water consumption levels
- 3.2 (P) Target to increase water recycling levels
- 3.3 (M) Use of low-water devices and efficient distribution network
- 3.4 (M) Water leak detection devices
- 3.5 (M) Smart irrigation systems
- 3.6 (M) Rainwater harvesting system
- 3.7 (M) Spill traps and oil separators or other relevant systems
- 3.8 (M) Surface and ground water monitoring system
- 3.9 (C) Increase in water recycling usage over the past year
- 3.10 (C) Drinking water consumption reduction over the past year

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

4. Waste management:

Airports' activities involve the production of significant amount of waste, which according to 'the polluter pays' principle needs to be managed. Even though most of the waste is generated by airlines, it is generally managed by airport operators (Graham, 2008). Waste generation at airports includes solid urban waste, non-hazardous waste and special hazardous waste from terminals, airfield operations, maintenance activities and aircraft catering; thus recyclable and non-recyclable materials. Waste recycling is a process that in the end prevents the loss of potentially useful materials and reduces the consumption of raw materials; in addition, it indirectly contributes to the reduction of energy use and GHG emissions.

For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets to increase waste recycling rate or to reduce waste sent to landfill, b) present comprehensive waste and hazardous waste management plan and c) have implemented measures to minimise the generated waste are taken into consideration. Analytically, the sub-criteria for this category are:

- 4.1 (P) Target to increase waste recycling rate
- 4.2 (P) Target to reduce the amount of waste sent to landfill
- 4.3 (M) Sorting recycle bins at terminals
- 4.4 (M) Use of recycled/recyclable materials/substances
- 4.5 (M) Organic waste separation
- 4.6 (M) Hazardous waste management system
- 4.7 (C) Waste generation pricing or relevant financial incentives
- 4.8 (C) Increase in waste recycling rate over the past year

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

5. Air quality management:

Air quality is generally a significant threat to human health and the environment; in areas surrounding airports, air quality is determined by several factors, such as ground transport, aircraft emissions and apron activities.

For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets to sustain good air quality, b) present comprehensive local air quality action plan and c) have implemented measures to control emissions (air quality and noise) are taken into consideration. Analytically, the sub-criteria for this category are:

- 5.1 (P) Target to reduce noise complaints
- 5.2 (P) Target to sustain air quality related pollutants concentration below national norms
- 5.3 (P) Target to achieve a more than 40% transport model split
- 5.4 (M) Night flight restrictions
- 5.5 (M) Preferential runways
- 5.6 (M) Continuous descent approach
- 5.7 (M) Newer technology (e.g. Euro 5 engines) vehicle fleet (fossil fuels)
- 5.8 (M) Fixed electrical ground power systems
- 5.9 (C) Emissions landing charge
- 5.10 (C) Noise landing charge

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

4.1.1.2 CRITERIA CATEGORIES AND SUB-CRITERIA FOR THE LOCAL ENVIRONMENTAL ISSUES

Regarding the local environmental issues, the following criteria categories are acknowledged:

1. Air quality:

Generally, the management of air quality is targeted at achieving and maintaining compliance with local regulations regarding pollutant concentrations. For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets to sustain good air quality, b) present comprehensive local air quality action plan and c) have implemented measures to control air quality related emissions are taken into consideration. Analytically, the sub-criteria for this category are:

- 1.1 (P) Target to sustain air quality related pollutants concentration below national norms
- 1.2 (M) Newer technology (e.g. Euro 5 engines) vehicle fleet (fossil fuels)
- 1.3 (M) Fixed electrical ground power systems
- 1.4 (C) Emissions landing charge

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

2. Noise:

Besides air quality related pollutants noise seems to be the key impact affecting communities around airports. For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets to minimise the annoyance of local communities, b) present comprehensive noise action plan and c) have implemented measures to control noise are taken into consideration. Analytically, the sub-criteria for this category are:

- 2.1 (P) Target to reduce noise complaints
- 2.2 (M) Night flight restrictions
- 2.3 (M) Preferential runways
- 2.4 (M) Continuous descent approach
- 2.5 (C) Noise landing charge

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

3. Water management (consumption control & waste water management):

Water management involves water consumption control as well as waste water management. For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets towards water demand reduction, b) present comprehensive water efficiency and waste water management plan and c) have applied specific measures to reduce drinking water consumption levels or to increase the proportion of recycled water are taken into consideration. Analytically, the sub-criteria for this category are:

3.1 (P) Target to improve the quality of water leaving the airport site
3.2 (M) Spill traps and oil separators
3.3 (M) Use of low-water devices and efficient distribution network
3.4 (M) Rainwater harvesting system
3.5 (C) Reduction in the total water demand over the past year

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

4. Waste management:

Waste management involves waste generation control, hazardous waste management and recycling systems. For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets to increase waste recycling rate or to reduce waste sent to landfill, b) present comprehensive waste and hazardous waste management plan and c) have implemented measures to minimise the generated waste are taken into consideration. Analytically, the sub-criteria for this category are:

4.1 (P) Target to increase waste recycling rate
4.2 (P) Target to reduce the amount of waste sent to landfill
4.3 (M) Hazardous waste management system
4.4 (C) Waste generation pricing or relevant financial incentives
4.5 (C) Increase in waste recycling rate over the past year

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

5. Land use, ecosystems and new development:

This criteria category generally involves planning in the airport area and impacts on biodiversity from the consumption of resources and airport operations. In addition, it involves ecosystems management to achieve safe flights. For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets to redevelop areas in order to minimise impact on the environment, b) present comprehensive management plan to protect and manage the local ecosystems and c) have implemented measures to control development in the airport vicinity are taken into consideration. Analytically, the sub-criteria for this category are:

5.1 (P) Target to redevelop areas to minimise environmental impact (i.e. terminal improvement works, energy facilities, waste treatment facilities (solid or/and liquid)
5.2 (M) Fauna/flora monitoring system
5.3 (M) System to manage bird activity to ensure safe operations
5.4 (C) Control of development in the vicinity to maintain safety and efficient operations

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

6. Access systems:

This criteria category regards the proportion of passengers and employees using public transport or other environmental friendly accessibility systems for their journey to and from the airport. For the purposes of this research, actions to illustrate whether or not a) airports have set specific targets to increase transport modal split, b) present comprehensive management plan to encourage the use of environmental friendly accessibility systems and c) have implemented measures to increase the employees using public transport are taken into consideration. Analytically, the sub-criteria for this category are:

6.1 (P) Short-term target to achieve a more than 40% transport modal split
6.2 (M) Cycling network
6.3 (M) Information systems and technological innovations to promote environmental friendly accessibility systems
6.4 (M) Attractive pricing or other promotion measures (i.e. fast access, travel options)
6.5 (C) Car share scheme or discounted travel for airport employees

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

4.1.2 Importance Multipliers

Even though literature provides some information on the various categories of airport environmental impacts, focused research on the importance of each environmental topic is quite limited. Based on the conducted interviews, airports focus their interest mostly on noise and local pollution, as well as in measuring and controlling climate change emissions. For considering airport industry's priorities on the management of different environmental impacts, instead of using data from literature, a questionnaire survey was conducted.

The questionnaire survey was used as it can provide data using numeric rating questions (Saunders *et* al., 2009; Dawson, 2002; Fanning, 2005). Based on the conducted interviews with academics and environmental managers the questionnaire takes into consideration the main issues that airport industry needs to deal with. In addition, it distinguishes environmental topics based on their area of impact.

Analytically, respondents were asked to assign a value, ranging from 1 to 5 based on the importance of each environmental topic in their airport's management priorities. Thus, if a topic is of low importance, it scores 1; if it is of high importance it scores 5. In addition, they were asked to characterise airport's environmental concerns during the past five years compared to other considerations.

To be able to incorporate the survey results into the evaluation framework, the questionnaire takes into consideration the choice of the evaluation criteria. Thus, three different levels are identified. The first level regards the importance that airports give in the main environmental topics (i.e. carbon emissions, energy, water, waste, air quality). The second level deals with environmental issues directly linked with local communities and the third level is focused on water management issues. Moreover, qualitative data regarding applied key measures, applications and procedures to manage environmental impact, as well as details regarding applied water management systems, is collected using free-response questions. The questionnaire can be found in the Appendix A.

The researcher thought that the questionnaire survey should be focused on European airports, as they present comparable characteristics and they operate under common regulations (cluster sampling) (Saunders *et* al., 2009). Therefore, the questionnaire was sent by e-mail to European airports with annual passenger traffic of more than 10 million, based on ACI statistics for the year 2007 (ACI Europe). To obtain a comprehensive overview, the researcher decided to include airports with annual passenger traffic of less than 10 million; as a result the questionnaire was sent to some additional airports.

The survey resulted in answers from 19 European airports out of 55, which were contacted, providing a response rate (Dawson, 2002) 34.5% (Table 5). The survey results are given in the relevant chapter.

Table 5: Response rate to questionnaire survey

Description	Rate
Airports sample	55
Airports responded	19
Response sample	34.5%

(Source: author)

4.1.3 Airports Environmental Comprehensiveness

For many airports dealing with environment is still primarily about compliance; environmental strategy deals with the airports operator obligation to meet national or regional legislations. However, for some airports environmental concerns are basic components of every aspect of their strategy; thus, the incorporated strategy besides legislative or regulatory framework takes into consideration issues towards airport business sustainable development. The environmental strategy for these airports not only encompasses efforts to improve environmental performance but also addresses the responsibility of management to maintain business sustainable growth (Dimitriou and Voskaki, 2011).

'*Airports Environmental Comprehensiveness*' (AEC) term is introduced in order to linkage airports environmental strategy with management performance on sustainability (Dimitriou and Voskaki, 2011). AEC is defined as the ability of airport management to comprehend that they follow a strategy towards sustainability of airport business. In other words, comparisons of AEC between airports provide useful information regarding environmental strategy efficiency (Dimitriou and Voskaki, 2011).

To measure AEC the following issues are taken into consideration:

- measures to mitigate environmental impacts, management actions to reduce emissions or to deal with wastes and various long and short term targets, as all these are expressed through the chosen evaluation criteria;
- airports' priorities regarding the management of different environmental impacts

Accordingly, AEC can be measured using the following equation:

$$AEC_{(i,j)} = A_{(i,j)} \bullet I_{(i,j)} \qquad [1]$$

where:

i = category (i=1,2,…n)
j = criterion (j=1,2,…n)
$A_{(i,j)}$ = score for each criterion
$I_{(i,j)}$ = importance multiplier

4.1.4 Water Management Efficiency

Water management efficiency evaluation process incorporates two different approaches. First of all encompasses analysis of measures, management actions and targets regarding water consumption, waste water and water resources quality issues. Besides that, it includes a ratio analysis to evaluate airport efficiency in terms of water consumption control.

4.1.4.1 CRITERIA CATEGORIES AND SUB-CRITERIA FOR THE WATER MANAGEMENT ISSUES

Regarding the water management issues, the following criteria categories are acknowledged:

1. Water consumption:

Actions to illustrate whether or not a) airports have set specific targets towards water demand reduction, b) present comprehensive water efficiency plan and c) have applied specific measures to reduce drinking water consumption levels are taken into consideration. Analytically, the sub-criteria for this category are:

1.1 (P) Target to reduce water consumption levels
1.2 (M) Use of low-water devices and efficient water distribution network
1.3 (M) Water leak detection devices
1.4 (M) Smart irrigation systems
1.5 (C) Drinking water consumption reduction over the past year

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

2. Water recycle:

Actions to illustrate whether or not a) airports have set specific targets towards water recycling, b) present comprehensive water recycle plan and c) have applied specific measures to increase water recycling rate are taken into consideration. Analytically, the sub-criteria for this category are:

2.1 (P) Target to increase water recycling levels
2.2 (M) Separate water network
2.3 (M) Rainwater harvesting system
2.4 (C) Increase in water recycling usage over the past year

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

3. Water quality management:

Actions to illustrate whether or not a) airports have set specific targets towards water resources quality standards, b) present comprehensive waste water and run-off management plan and c) have applied specific measures to control the quality of local surface and underground water resources are taken into consideration. Analytically, the sub-criteria for this category are:

3.1 (P) Target to improve the quality of water leaving the airport

3.2 (M) Spill traps and oil separators or other relevant systems
3.3 (M) Surface water quality monitoring system
3.4 (M) Underground water quality monitoring system
3.5 (C) Absence of incidents of non-compliance to discharge consents

For the measurement of this action a scale from 0 to 10 is used; thus if an airport covers all the sub-criteria it scores 10.

4.1.4.2 WATER MANAGEMENT EFFICIENCY RATIOS

In addition to the aforementioned water management evaluation criteria, in order to be able to analyse how well an airport uses water resources the researcher looked into airports environmental plans and sent questionnaires to airports departments for the environment, requesting information, amongst other issues, regarding annual water consumption, proportion of potable water and whether the airport recycles water or not.

To measure how efficient the airport uses and controls water resources the researcher used the following three (3) key water management efficiency ratios. An improvement in the ratios may imply respective improvement in airport's water management efficiency. To be able to compare airport's efforts to improve efficiency, besides W_1, W_2, W_3 their average score for the past three years is taken into consideration; a comparison between years 2009 and 2007 provides information on the overall water management efficiency. Analytically:

1. Water demand ratio (W_1):

The W_1 ratio measures the total annual water demand per passenger (in lt). When this ratio is high, it may indicate that the airport does not efficiently control water consumption. The ratio is calculated using the following formula:

$$W_1 = \frac{\text{Total annual water consumption}}{\text{Annual passenger traffic}} \quad [2]$$

2. Drinking water consumption ratio (W_2):

The W_2 ratio measures the percentage of the annual drinking water consumption per passenger, compared to the total annual water consumption. It should be noted that the drinking water consumption indicates the quantity of water demand that cannot be replaced by other sources, such as recycled water, mostly due to health reasons. When this ratio is high, it may indicate that the airport does not efficiently control water consumption; additionally, the airport has not yet applied measures to recycle water. If the ratio is too low, it may imply a water management efficient airport, where low quality water is used to the maximum possible extent. The ratio is calculated using the following formula:

$$W_2 = \frac{\text{Annual potable water consumption}}{\text{Total annual water consumption}} \quad [3]$$

3. Water recycle ratio (W_3):

The W_3 ratio measures airport's water recycling rate and therefore represents the airport's efforts to recycle resources rather than directly or indirectly abstract fresh ones. Even though this may imply water shortage, the conservation of natural water resources typically suggests a sustainable strategy. Consequently, if this ratio is high, it may imply that airports' efforts are focused on natural resources conservation. This ratio is calculated using the following formula:

$$W_3 = \frac{\text{Annual water recycle}}{\text{Total annual water consumption}} \quad [4]$$

4. Water demand change ratio (W_4):

The W_4 ratio measures the change (decrease or increase) in the annual water demand (in lt per passenger). For the measurement of this ratio, the water demand for years 2009 and 2007 is taken into consideration. If this ratio is high, it may indicate that effective water consumption control measures have been applied. This ratio is calculated using the following formula:

$$W_4 = \frac{\text{Water demand 2009}}{\text{Water demand 2007}} \quad [5]$$

5. Drinking water change ratio (W_5):

The W_5 ratio measures the change (decrease or increase) in the annual consumption of drinking water (in lt per passenger). For the measurement of this ratio, the drinking water consumption for years 2009 and 2007 is taken into consideration. If this ratio is high, it may indicate that the airport does not make efforts to efficiently control drinking water consumption and therefore does not make efforts towards natural resources conservation; in addition, this implies that the airport has not yet planned to use non potable water. If this ratio is low, it implies substitution of drinking water with industrial or other recycled water. This ratio is calculated using the following formula:

$$W_5 = \frac{\text{Drinking water consumption 2009}}{\text{Drinking water consumption 2007}} \quad [6]$$

6. Water recycle change ratio (W_5):

The W_6 ratio measures the change (decrease or increase) in the annual water recycling rate. For the measurement of this ratio, the rate for years 2009 and 2007 is taken into consideration. When this ratio is high, it may imply that the airport has applied measures to expand the use of recycled water and therefore suggests a water management efficient airport. This ratio is calculated using the following formula:

$$W_5 = \frac{\text{Recycling rate 2009}}{\text{Recycling rate 2007}} \qquad [6]$$

4.2 ENVIRONMENTAL STRATEGY

The process of analysing AEC resulted in that airport environmental strategies not always focus on actions to minimise the whole environmental impact. In some cases the applied actions show a balance aiming to mitigate global or local environmental impact. In other cases, the applied measures or management actions focus on controlling resources consumption rather than ensuring high quality levels for air, water and soil. Finally, there are cases where all actions aim at improving energy rather than water efficiency. To assess the applied environmental strategies the AEC score for environmental actions associated with these parameters is taken into account. These actions represent the evaluation sub-criteria for the main environmental issues, as analysed in the previous paragraphs.

Analytically, for the following three assessments, Table 6 illustrates the evaluation sub-criteria classification:

a) GLOBAL (G) vs. LOCAL (L) environmental impacts
b) CONSUMPTION (C) control vs. POLLUTION (P) management actions (global & local)
c) ENERGY (E) vs. WATER (W) consumption

Table 6: Sub-criteria classification for environmental strategy assessment

Sub-criteria	G	L	C	P	E	W
Target to reach carbon neutrality by the year 2020	X			X		
Short-term target to reduce carbon emissions	X			X		
Use of low carbon fuels (airport vehicles and ground support equipment)	X			X		
Green operational procedures and/or relevant technological innovations	X			X		
Airport collaborative decision making	X			X		
Carbon accreditation	X			X		
Carbon footprint reduction over the past year	X			X		
Short-term target to reduce energy consumption levels more than 5%	X		X		X	
Short-term target to increase green energy consumption levels	X		X		X	
Energy efficient lighting	X		X		X	
Energy efficient cooling/heating systems	X		X		X	
Low-energy equipment (i.e. escalators, baggage belts, IT systems)	X		X		X	
Green energy generation on-site	X		X		X	
Use of co-generation systems	X		X		X	
Green energy covers more than 10% of the total demand	X		X		X	
Energy demand reduction over the past year	X		X		X	
Target to reduce water consumption levels		X	X			X
Target to increase water recycling levels	X		X			X
Use of low-water devices and efficient distribution network		X	X			X
Water leak detection devices		X	X			X
Smart irrigation systems		X	X			X
Rainwater harvesting system	X		X			X
Spill traps and oil separators or other relevant systems		X		X		
Surface and underground water monitoring system		X		X		
Increase in water recycling usage over the past year	X		X			X
Drinking water consumption reduction over the past year		X	X			X
Target to increase waste recycling rate	X		X			
Target to reduce the amount of waste sent to landfill		X		X		
Sorting recycle bins at terminals	X		X			
Use of recycled/recyclable materials/substances	X		X			
Organic waste separation		X		X		
Hazardous waste management system		X		X		
Waste generation pricing or relevant financial incentives		X		X		
Increase in waste recycling rate over the past year	X		X			
Target to reduce noise complaints		X		X		
Target to sustain air quality related pollutants concentration below national norms		X		X		
Target to achieve a more than 40% transport model split		X		X		
Night flight restrictions		X		X		
Preferential runways		X		X		
Continuous descent approach		X		X		
Newer technology (e.g. Euro 5 engines) vehicle fleet (fossil fuels)		X		X		
Fixed electrical ground power systems		X		X		
Emissions landing charge		X		X		
Noise landing charge		X		X		

(Source: author)

4.2.1 Water Management Strategy

As already mentioned, the process of analysing AEC resulted in that airport environmental strategies not always focus on actions to minimise the whole environmental impact. In order to assess the balance between water management and other environmental topics linked with local environment the AEC score for the following actions is taken into consideration: a) local air quality, b) noise, c) water, d) waste, e) land use and ecosystems and f) transportation mode.

Analytically, for the following assessment, Table 7 illustrates the evaluation sub-criteria classification:

a) WATER (W) vs. LOCAL (L) environmental impacts

Table 7: Sub-criteria classification for water management strategy assessment

Sub-criteria	W	L
Target to reduce water consumption levels	X	
Target to increase water recycling levels	X	
Target to improve the quality of water leaving the airport	X	
Use of low-water devices and efficient distribution network	X	
Water leak detection devices	X	
Smart irrigation systems	X	
Separate water network	X	
Rainwater harvesting system	X	
Spill traps & oil separators or other relevant systems	X	
Surface water quality monitoring system	X	
Underground water quality monitoring system	X	
Drinking water consumption reduction over the past year	X	
Increase in water recycling usage over the past year	X	
Absence of incidents of non-compliance to discharge consents	X	
Target to sustain air quality related pollutants concentration below national norms		X
Newer technology (e.g. Euro 5 engines) vehicle fleet (fossil fuels)		X
Fixed electrical ground power systems		X
Emissions landing charge		X
Target to reduce noise complaints		X
Night flight restrictions		X
Preferential runways		X
Continuous descent approach		X
Noise landing charge		X
Target to increase waste recycling rate		X
Target to reduce the amount of waste sent to landfill		X
Hazardous waste management system		X
Waste generation pricing or relevant financial incentives		X
Increase in waste recycling rate over the past year		X
Target to redevelop areas to minimise environmental impact		X
Fauna/flora monitoring system		X
System to manage bird activity to ensure safe operations		X
Control of development in the vicinity to maintain safety and efficient operations		X
Short-term target to achieve a more than 40% transport modal split		X
Cycling network		X
Information systems and technological innovations		X
Attractive pricing or other promotion measures (i.e. fast access, travel options)		X
Car share scheme or discounted travel for airport employees		X

(Source: author)

4.3 Environmental Strategy Assessment Depiction

For assessing incorporated environmental strategies the AEC for the above environmental actions are taken into consideration. While energy has already incorporated recognisable sustainable ratings, no such coverage exists in transportation issues (Samberg *et* al., 2011). Therefore, to assess environmental strategy a rating system is defined, based on the AEC score. In addition, for depicting the assessment results a multi-coloured square is chosen (Figure 6).

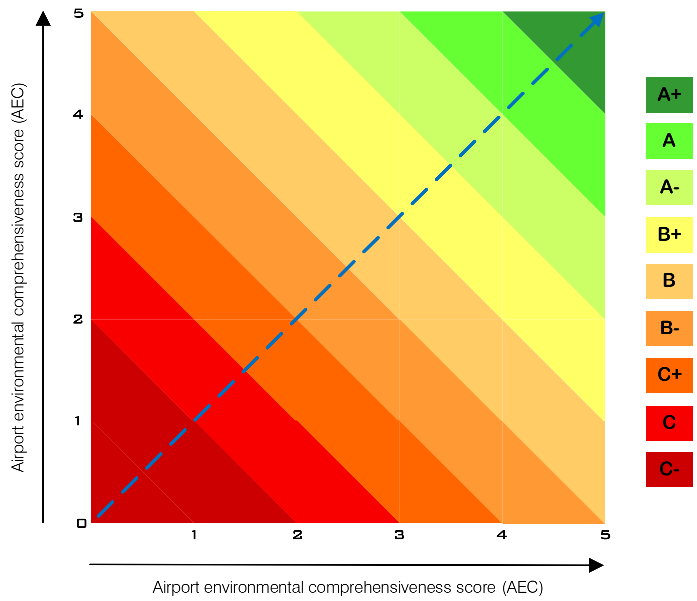

Figure 6: Environmental strategy assessment depiction (ESAD)
(Source: author)

As Figure 6 shows, the square is divided into nine colour zones. Each zone is associated with a different set of combinations of AEC. The symbols in each zone represent different groups of environmental strategies, ranging from sustainable to unsustainable ones. In general, airports depicted in section 'A+' present the highest environmental comprehensiveness and sense of responsibility of their environmental impact. The blue diagonal line implies a balanced environmental strategy between the two axes. This may imply that applied actions are considered as part of a comprehensive action plan.

At this point it should be noted that the researcher, in order to define the nine zones, took into consideration the importance that airports give in managing the key environmental issues in year 2011 and 2020.

Analytically:

A+	Sustainable AEC is above 4.5 Environmental plans and relevant reports include specific targets and measures to reduce impacts on the environment Management recognises sustainability as an essential tool for further development Very high perception on sustainability
A	Sustainable AEC ranges from 4.0 to 4.5 Although environmental plans and relevant reports include targets and measures to reduce environmental impacts there are issues that need special care Management recognises sustainability as a very significant tool for further development High perception on sustainability
A-	Sustainable AEC ranges from 3.5 to 4.0 Although the environmental plan includes targets and measures to reduce impacts on the environment there are issues that need improvement Environmental management recognises sustainability as a significant tool for further development Significant perception on sustainability
B+	Above the average in comprehensiveness scale AEC ranges from 3.0 to 3.5 According to the environmental plans and relevant reports additional measures should be applied and additional targets should be set to improve environmental performance Environmental management is recognised as a tool to provide advantages towards competition and business development Narrow perception on sustainability
B	Average in comprehensiveness scale AEC ranges from 2.5 to 3.0 According to the environmental plans and relevant reports some new measures should be applied and new targets should be set to improve environmental performance Environmental management is recognised as a necessary tool to cover the need of the existing market to overlap business restrictions Very narrow perception on sustainability
B-	Below the average in comprehensiveness scale AEC ranges from 2.0 to 2.5 According to the environmental plans and relevant reports a wide range of measures in many areas should be applied Environmental management is not significant for airports' further development Limited perception on sustainability

C+	Unsustainable AEC ranges from 1.5 to 2.0 According to the environmental plans and relevant reports a few measures have been applied to reduce environmental impacts Environmental management is recognised as a tool of low importance for airports' development Poor perception on sustainability
C	Unsustainable AEC ranges from 1.0 to 1.5 According to the environmental plans and relevant reports very few measures have been applied to reduce environmental impacts Environmental management is recognised as a tool of very low importance for airports' development Very poor perception on sustainability
C-	Unsustainable AEC is below 1.0 No measures have been applied to reduce airports' environmental impacts Environmental management is not recognised as a tool for airports' development No perception on sustainability

Table 8 presents the key points of the AEC rating scale

Table 8: Environmental comprehensiveness assessment rating scale

	AEC	Perception on sustainability	Description
A+	AEC ≥ 4.5	Very high	Environmental plans and relevant reports include specific targets and measures to minimise environmental impact.
A	4.0 ≤ AEC < 4.5	High	Although environmental plans and relevant reports include targets and measures to reduce environmental impacts there are issues that need special care
A-	3.5 ≤ AEC < 4.0	Significant	Although the environmental plan includes targets and measures to reduce impacts on the environment there are issues that need improvement
B+	3.0 ≤ AEC < 3.5	Narrow	According to the environmental plans and relevant reports additional measures should be applied and additional targets should be set to improve environmental performance
B	2.5 ≤ AEC < 3.0	Very narrow	According to the environmental plans and relevant reports some new measures should be applied and new targets should be set to improve environmental performance
B-	2.0 ≤ AEC < 2.5	Limited	According to the environmental plans and relevant reports a wide range of measures in many environmental topics should be applied to improve environmental performance
C+	1.5 ≤ AEC < 2.0	Poor	According to the environmental plans and relevant reports a few measures have been applied to minimise environmental impact
C	1.0 ≤ AEC < 1.5	Very poor	According to the environmental plans and relevant reports very few measures have been applied to minimise environmental impact
C-	AEC < 1.0	No perception	According to the environmental plans and relevant reports no significant measures have been applied to control environmental impact

(Source: author)

5. Application

This chapter will present the application of the methodological framework, which was developed previously, to a sample of 20 European airports.

5.1 Airport Sample

Similar to the questionnaire survey, the researcher thought that the airport sample should be focused on European airports, as they present comparable characteristics and they operate under common regulations (cluster sampling) (Saunders *et* al., 2009).

Amongst the European airports, a random selection (Saunders *et* al., 2009) was combined with airports' size and location, in order to have a more evenly dispersed distribution amongst Europe. Table 9 presents the key facts about the airport sample.

Table 9: Data for the sample of European airports

	Airports (IATA code)	City/Location served	Operator	Passengers (million)
1	Frankfurt Airport (FRA)	Frankfurt, Germany	Fraport	50.9
2	Schiphol Airport (AMS)	Amsterdam, Netherlands	Schiphol Group	46.3
3	Munich Franz Josef Strauss Airport (MUC)	Munich, Germany	Flughafen München GmbH	32.7
4	London Gatwick Airport (LGW)	London, UK	Gatwick Airport Limited	32.4
5	Barcelona Airport (BCN)	Barcelona, Spain	Aena	30.3
6	Paris-Orly Airport (ORY)	Paris, France	Aéroports de Paris	25.1
7	Zurich Airport (ZRH)	Zurich, Switzerland	Flughafen Zürich AG	21.9
8	London Stansted Airport (STN)	London, UK	BAA	20.0
9	Copenhagen Airport (CPH)	Copenhagen, Denmark	Københavns Lufthavne	19.7
10	Brussels Airport (BRU)	Brussels, Belgium	Brussels Airport Company SA	17.0
11	Athens International Airport (ATH)	Athens, Greece	Athens International Airport SA	16.2
12	Stockholm-Arlanda Airport (ARN)	Stockholm, Sweden	Swedavia	16.1
13	Hamburg Airport (HAM)	Hamburg, Germany	FHG Flughafen Hamburg GmbH	12.2
14	Geneva International Airport (GVA)	Geneva, Swotzerland	Geneva International Airport (AIG)	10.9
15	Birmingham International Airport (BHX)	Birmingham, UK	Birmingham International Airport Ltd	9.1
16	Edinburgh Airport (EDI)	Turnhouse, Edinburgh	BAA Limited	9.0
17	East Midlands Airport (EMA)	East Midlands, UK	Manchester Airports Group (MAG)	5.7
18	Ibiza Airport (IBZ)	Ibiza island, Spain	Aena	4.8
19	Francisco Sá Carneiro Airport (Porto) (OPO)	Porto, Portugal	ANA Aeroportos de Portugal	4.5
20	Bologna Guglielmo Marconi Airport (BLQ)	Bologna, Italy	Bologna Airport SpA	4.2

(Source: Airport operators' official web-sites)

5.2 Environmental Management Priorities

The researcher conducted a questionnaire survey in order to take into consideration the airport industry's environmental management priorities. The survey resulted in answers from the following 19 European airports (Table 10), providing a response rate 34.5%.

Table 10: Airport sample for the questionnaire survey

Airports (IATA code)		Location
1	Frankfurt Airport (FRA)	Germany
2	Amsterdam Schiphol Airport (AMS)	Netherlands
3	Munich Airport (MUC)	Germany
4	London Gatwick Airport (LWG)	United Kingdom
5	Barcelona Airport (BCN)	Spain
6	Istanbul Airport (IST)	Turkey
7	Zurich Airport (ZRH)	Switzerland
8	Brussels Airport (BRU)	Belgium
9	Athens International Airport (ATH)	Greece
10	Hamburg Airport (HAM)	Germany
11	Geneva International Airport (GVA)	Switzerland
12	Prague Airport (PRG)	Czech Republic
13	Nice Airport (NCE)	France
14	Warsaw Airport (WAW)	Poland
15	Birmingham Airport (BHX)	United Kingdom
16	Edinburgh Airport (EDI)	United Kingdom
17	Budapest Airport (BUD)	Hungary
18	Newcastle Airport (NCL)	United Kingdom
19	Francisco Sá Carneiro Airport (Porto) (OPO)	Portugal

(Source: Questionnaire survey that was conducted by the author)

The results are presented in the following tables (Table 11-14).

Table 11: Results on environmental management priorities for the key environmental issues (year 2011)

Environmental Management Priorities		Rating range	Standard Deviation	Average Score (I)
E_1	Carbon Emissions	from 2 to 5	0.9	3.6
E_2	Energy Consumption	from 2 to 5	0.9	3.8
E_3	Water Management	from 1 to 5	1.3	3.4
E_4	Waste Management	from 1 to 5	1.1	3.3
E_5	Air Management	from 2 to 5	1.1	3.8

(Source: Questionnaire survey that was conducted by the author)

Table 12: Results on environmental management priorities for the key environmental issues (year 2020)

Environmental Management Priorities		Rating range	Standard Deviation	Average Score (I)
E_1	Carbon Emissions	from 3 to 5	0.6	4.5
E_2	Energy Consumption	from 2 to 5	0.8	4.5
E_3	Water Management	from 1 to 5	1.0	3.9
E_4	Waste Management	from 1 to 5	1.1	3.8
E_5	Air Management	from 3 to 5	0.8	4.1

(Source: Questionnaire survey that was conducted by the author)

Table 13: Results on environmental management priorities for the local environmental issues

	Environmental Management Priorities	Rating range	Standard Deviation	Average Score (I)
L_1	Air Quality	from 2 to 5	0.8	3.6
L_2	Noise	from 3 to 5	0.7	4.6
L_3	Water	from 1 to 5	1.0	3.7
L_4	Waste	from 1 to 4	0.8	3.1
L_5	Land Use Planning	from 2 to 5	1.0	3.5
L_6	Access Systems	from 1 to 5	1.2	2.8
L_7	Biodiversity	from 1 to 5	1.2	2.7

(Source: Questionnaire survey that was conducted by the author)

Table 14: Results on environmental management priorities for the water management issues

	Environmental Management Priorities	Rating range	Standard Deviation	Average Score (I)
W_1	Water Consumption Control	from 2 to 5	0.9	3.0
W_2	Water Recycle	from 1 to 5	1.3	2.3
W_3	Waste Water Management	from 1 to 5	1.1	3.8
W_4	Runoff Management	from 1 to 5	1.1	3.5
W_5	Water Quality	from 1 to 5	1.2	3.7

(Source: Questionnaire survey that was conducted by the author)

Based on the survey results, standard deviation, in most of the cases is near 1.0, implying that the respondents more or less agreed on the average importance of each environmental topic. Even though this does not necessarily imply that airports have applied measures to mitigate environmental impacts it depicts the recognised importance of certain environmental issues by airport management. Therefore, the average scores from this questionnaire survey are used as importance multipliers in the evaluation framework.

Even though this survey is not amongst research's objectives, some comments on the results are given in the following paragraphs.

At the moment, airports seem to consider energy consumption, noise and local air quality the most important issues that they need to manage. However, as far as the next decade is concerned, airports environmental management priorities are quite different; airports consider that managing their impact on the global environment is of greater importance when compared to air quality management, as well as noise and local air pollution control. As a result their first priority will be to manage their carbon emissions, followed by their energy consumption control; air management comes as a third in their priority list. This may imply that climate change is considered the main constraint directly linked with airports long-term development.

Water and waste management appear to be of medium importance in current airports' environmental priorities; nevertheless, their management in the next decade is considered more significant.

Figure 7 illustrates airports environmental management priorities regarding the key environmental issues.

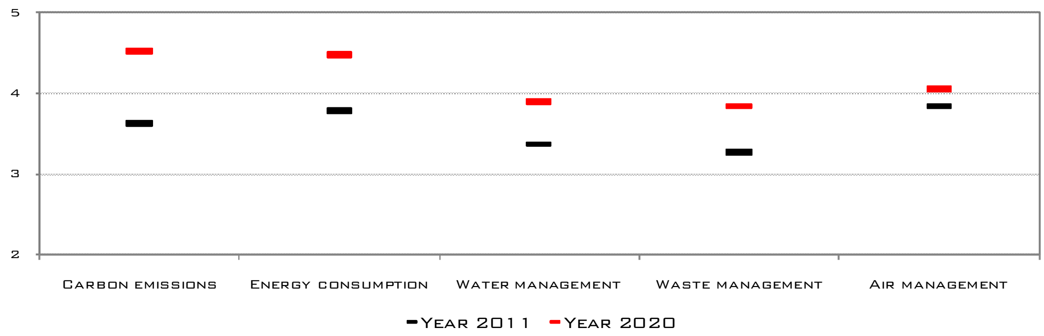

Figure 7: Environmental management priorities for the key environmental issues
(Source: author)

In regards to the local environmental issues, noise seems to be the most important local environmental impact that airports must manage. This is not surprising considering that many airports are subject to noise restrictions; in addition, this implies that the airport industry considers noise the most important issue regarding medium and short term development.

The researcher needs to highlight the fact that even though water management was not considered by ACI amongst the top environmental management priorities, as it is mostly linked with regional water availability problems, based on this survey it seems to be the airports second priority. Land use planning and air quality management constitute important issues that the airports need to deal with; waste management and access systems appear to be issues of medium importance. Unexpectedly, biodiversity management is as also considered of medium importance.

The survey results are graphically shown in Figure 8.

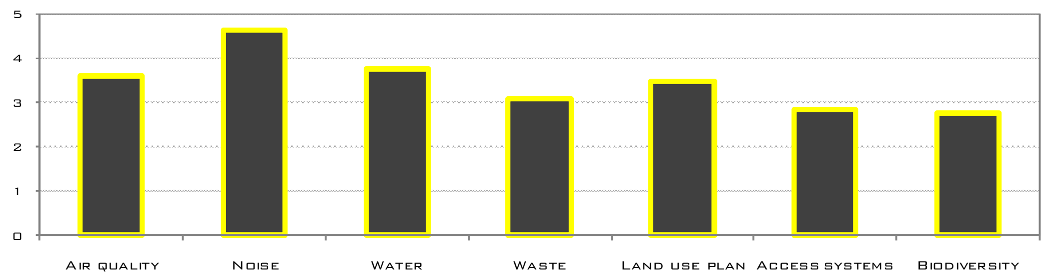

Figure 8: Environmental management priorities for the local environmental issues
(Source: author)

As already discussed, water management appears to be one of the main issues that the industry needs to deal with. Even though water availability in many regions constitutes an additional constraint to airport operations, based on the survey results waste water management and water quality are the most important issues that they need to manage, followed by water runoffs. Water consumption control and water recycle appears to be of medium importance; only 28% of the airports consider consumption control of great importance; this percent fell to 17% in the case of water recycle. This is not surprising taking into account that not all European regions currently face water availability problems; yet potential cost savings and natural resources conservation should be taken into consideration. The survey results are graphically shown in Figure 9.

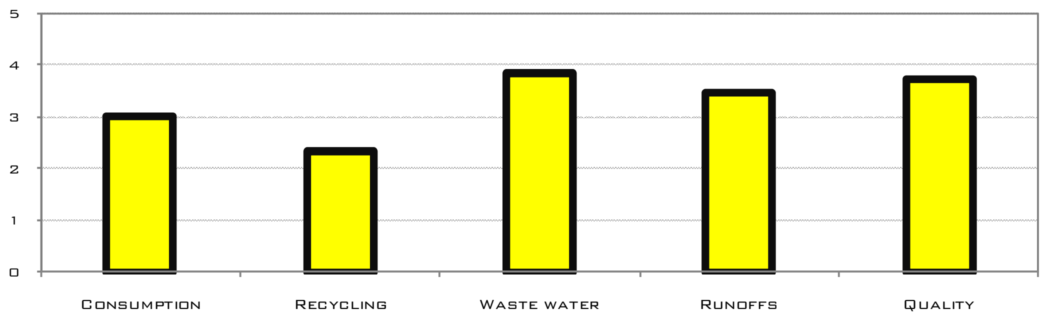

Figure 9: Environmental management priorities for the water management issues
(Source: author)

Finally, it is noteworthy that based on airports' strategic consideration of environmental issues, during the past five years, 32% of the airport sample consider environment less important than other considerations; only 16% considered environment more important than other considerations. Analytically:

- FRA, OPO and WAW considered environment more important than other considerations;
- MUC, BCN, BUD, ATH, BRU, NCE, HAM, NCL, BHX and PRG considered environment as important as other considerations;
- Environment was less important than other considerations for AMS, ZRH, LGW, GVA, IST and EDI;

The above rating is based on a variety of reasons. For example, there are airports, like LGW, where environmental issues were generally considered in the context of compliance. In other cases, like ZRH, strategy was mostly focused on business development rather than mitigating environmental impact. Some other airports, like EDI, gave this rating as the level of funding given to environmental projects, in the past five years, was not high.

In some other airports the voluntary mitigation programs that were applied (e.g. BUD) or the broad range of measures that were implemented (e.g. HAM), or even the level of funding given to environmental projects (e.g. BRU) indicate that environment was considered as important as other considerations.

Finally, airports that during the past five years managed to improve their environmental performance, either by applying consumption control programs (e.g. OPO) or by setting higher standards of environmental performance compared to the previous years (e.g. FRA) rated environmental issues as considerations of above medium importance.

5.3 Airports' Environmental Comprehensiveness (AEC)

As analysed in the previous chapter, AEC is calculated taking into consideration measures to mitigate environmental impacts, management actions to reduce emissions or to deal with wastes and various targets towards sustainable development. In addition, the importance that airports give regarding the management of different environmental topics is taken into account.

In this research AEC is calculated based on the data identified in airports published environmental plans, airport operators' sustainability reports and other relevant reports published on airport operators' official web-site. In addition, further information was provided by airports environmental departments. The results are given in the following paragraphs.

5.3.1 Main Environmental Categories

As analysed in the previous chapter, the main environmental issues that airports need to deal with regard carbon emissions, energy, water, waste and air quality. Based on equation [1], in order to measure AEC, the score for each category is taken into consideration. In addition, the relevant importance multipliers are acknowledged.

Analytically, in order to score each category the number of sub-criteria covered is taken into consideration. For example, in the carbon emissions category, if an airport covers all sub-criteria it scores 10. For the AEC measurement, each sub-criterion is multiplied by the relevant importance multiplier (Table 15). The AEC scores for each airport are given in Table 16.

Table 15: AEC measurement components for the main environmental categories

Main Environmental Categories		Importance Multipliers
Category	Sub-criteria	
CARBON EMISSIONS	Target to reach carbon neutrality by the year 2020	3.6
	Short-term target to reduce carbon emissions	3.6
	Use of low carbon fuels (airport vehicles & ground support equipment)	3.6
	Green operational procedures and/or relevant technological innovations	3.6
	Airport collaborative decision making	3.6
	Carbon accreditation	3.6
	Carbon footprint reduction over the past year	3.6
ENERGY	Short-term target to reduce energy consumption levels more than 5%	3.8
	Short-term target to increase green energy consumption levels	3.8
	Energy efficient lighting	3.8
	Energy efficient cooling/heating systems	3.8
	Low-energy equipment (i.e. escalators, baggage belts, IT systems)	3.8
	Green energy generation on-site	3.8
	Use of co-generation systems	3.8
	Green energy covers more than 10% of the total demand	3.8
	Energy demand reduction over the past year	3.8
WATER	Target to reduce water consumption levels	3.4
	Target to increase water recycling levels	3.4
	Use of low-water devices and efficient distribution network	3.4
	Water leak detection devices	3.4
	Smart irrigation systems	3.4
	Rainwater harvesting system	3.4
	Spill traps and oil separators or other relevant systems	3.4
	Surface and underground water monitoring system	3.4
	Increase in water recycling usage over the past year	3.4
	Drinking water consumption reduction over the past year	3.4
WASTE	Target to increase waste recycling rate	3.3
	Target to reduce the amount of waste sent to landfill	3.3
	Sorting recycle bins at terminals	3.3
	Use of recycled/recyclable materials/substances	3.3
	Organic waste separation	3.3
	Hazardous waste management system	3.3
	Waste generation pricing or relevant financial incentives	3.3
	Increase in waste recycling rate over the past year	3.3
AIR QUALITY	Target to reduce noise complaints	3.8
	Target to sustain air quality related pollutants concentration below national norms	3.8
	Target to achieve a more than 40% transport model split	3.8
	Night flight restrictions	3.8
	Preferential runways	3.8
	Continuous descent approach	3.8
	Newer technology (e.g. Euro 5 engines) vehicle fleet (fossil fuels)	3.8
	Fixed electrical ground power systems	3.8
	Emissions landing charge	3.8
	Noise landing charge	3.8

Table 16: AEC results for the main environmental categories

Airports	Airport Environmental Comprehensiveness (AEC)					
	Carbon emissions	Energy	Water	Waste	Air quality	Sum
ARN	10.0	10.0	4.0	6.3	10.0	40.3
AMS	10.0	8.9	5.0	6.3	10.0	40.1
CPH	7.1	8.9	6.0	6.3	8.0	36.3
MUC	10.0	6.7	3.0	7.5	8.0	35.2
LGW	8.6	4.4	6.0	6.3	9.0	34.3
STN	5.7	5.6	5.0	8.8	8.0	33.0
ORY	7.1	7.8	7.0	3.8	7.0	32.7
ATH	7.1	6.7	6.0	7.5	5.0	32.3
FRA	7.1	5.6	5.0	3.8	8.0	29.4
EMA	7.1	6.7	5.0	5.0	6.0	29.8
GVA	4.3	6.7	4.0	7.5	6.0	28.5
ZRH	5.7	5.6	5.0	3.8	8.0	28.0
BRU	5.7	6.7	5.0	3.8	6.0	27.1
BCN	2.9	5.6	8.0	5.0	5.0	26.4
BHX	4.3	4.4	4.0	6.3	6.0	25.0
BLQ	4.3	4.4	5.0	6.3	4.0	24.0
HAM	5.7	3.3	4.0	3.8	7.0	23.8
EDI	2.9	3.3	6.0	5.0	5.0	22.2
OPO	4.3	4.4	4.0	3.8	5.0	21.5
IBZ	0.0	2.2	4.0	3.8	2.0	12.0
Average	6.0	5.9	5.1	5.5	6.7	29.1

(Source: author)

According to the results, even though airports recognise that their business activities have environmental consequences not all of them have applied specific mitigating measures, or have set specific targets, aiming at reducing the total environmental impact. As a result, none of the selected airports presents the highest score of environmental comprehensiveness.

ARN airport presents the best AEC score, due to the sensitivity the airport shows in managing its climate change impact; AMS and CPH airports are ranked in the second and third position respectively, while 50% of the sample presents scores above the average. On the contrary, IBZ is ranked in the last position.

Environmental categories that present the highest average AEC score include actions towards noise mitigation and local air quality. On the contrary, issues regarding water consumption control and waste (liquid and solid) management are not on the top of the agenda. It is noteworthy that in the water category only 30% of the sample presents scores above the average.

Figure 10 illustrates the AEC for the airport sample.

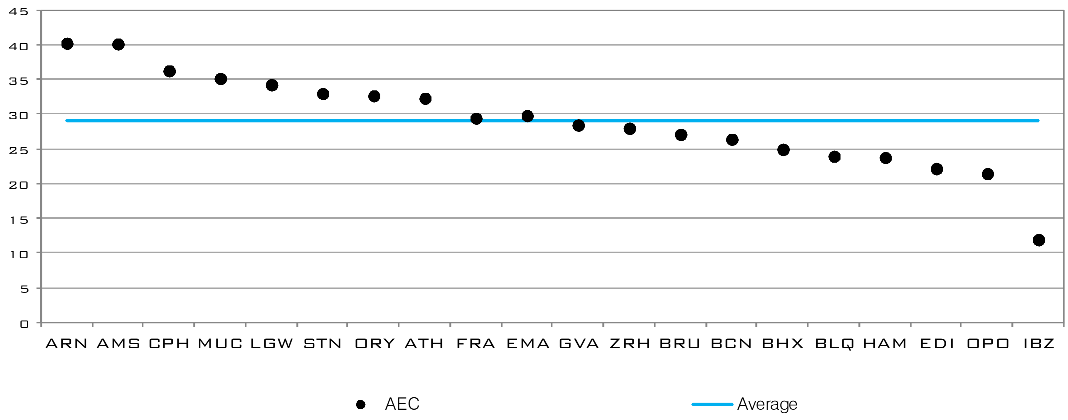

Figure 10: AEC score for the main environmental categories
(Source: author)

Figure 11 graphically presents each airport's AEC fingerprint, with reference to the main environmental issues. Each one of the axes represents the main environmental categories (i.e. carbon emissions, energy, water, waste, air quality). For example, ARN airport presents the highest score (10 out of 10) in 3 out of 5 categories; amongst the other two, a slightly preference on waste issues is noted. On the contrary, IBZ airport clearly shows low scores in almost all categories.

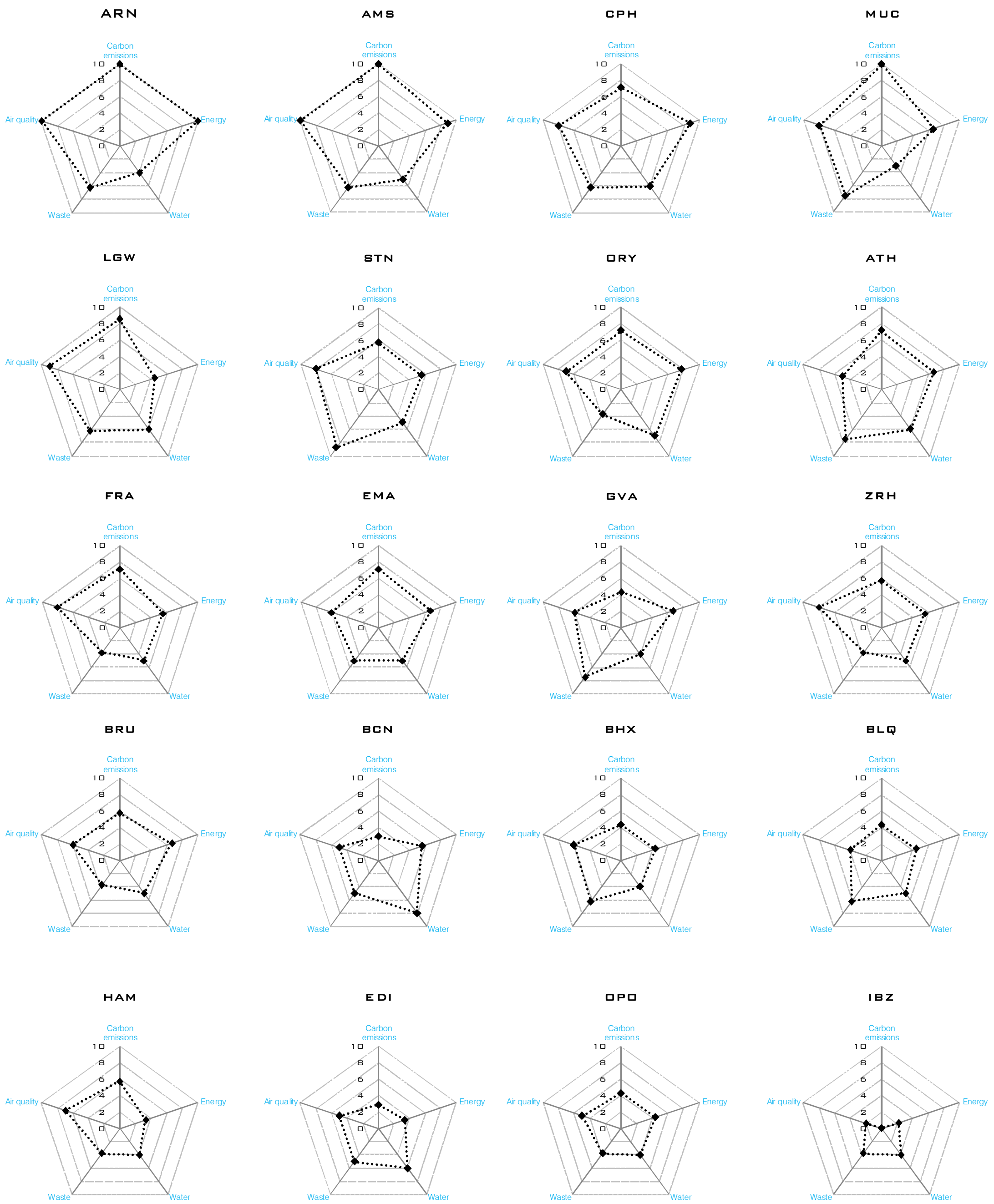

Figure 11: AEC fingerprint for the airport sample for the 5 environmental categories
(Source: author)

5.3.2 Local Environmental Categories

As analysed in previous paragraphs, this category includes environmental issues that mostly affect the local environment, like local air quality, noise, water, waste, land use, ecosystems and access systems. Based on equation [1], in order to measure AEC, the score for each category is taken into account. In addition, the relevant importance multipliers are acknowledged.

Analytically, in order to score each category the number of sub-criteria covered is taken into consideration. For example, in the local air quality category, if an airport covers all sub-criteria it scores 10. For the AEC measurement, each sub-criterion is multiplied by the relevant importance multiplier (Table 17). The AEC scores for each airport are given in Table 18.

Table 17: AEC measurement components for the local environmental categories

Local Environmental Categories Category	Sub-criteria	Importance Multipliers
AIR QUALITY	Target to sustain air quality related pollutants concentration below national norms	3.6
	Newer technology (e.g. Euro 5 engines) vehicle fleet (fossil fuels)	3.6
	Fixed electrical ground power systems	3.6
	Emissions landing charge	3.6
NOISE	Target to reduce noise complaints	4.6
	Night flight restrictions	4.6
	Preferential runways	4.6
	Continuous descent approach	4.6
	Noise landing charge	4.6
WATER	Target to improve the quality of water leaving the airport site	3.7
	Spill traps and oil separators	3.7
	Use of low-water devices and efficient distribution network	3.7
	Rainwater harvesting system	3.7
	Reduction in the total water demand over the past year	3.7
WASTE	Target to increase waste recycling rate	3.1
	Target to reduce the amount of waste sent to landfill	3.1
	Hazardous waste management system	3.1
	Waste generation pricing or relevant financial incentives	3.1
	Increase in waste recycling rate over the past year	3.1
LAND USE, ECOSYSTEMS AND NEW DEVELOPMENT	Target to redevelop areas to minimise environmental impact	3.5
	Fauna/flora monitoring system	2.7
	System to manage bird activity to ensure safe operations	2.7
	Control of development in the vicinity to maintain safety and efficient operations	3.5
ACCESS SYSTEMS	Short-term target to achieve a more than 40% transport modal split	2.8
	Cycling network	2.8
	Information systems and technological innovations	2.8
	Attractive pricing or other promotion measures (i.e. fast access, travel option)	2.8
	Car share scheme or discounted travel for airport employees	2.8

Table 18: AEC results for the local environmental categories

Airports	Airport Environmental Comprehensiveness (AEC)						
	Local Air Quality	Noise	Water	Waste	Land Use Ecosystems	Public transport	Sum
AMS	10.0	10.0	8.0	3.8	7.8	8.0	47.6
ARN	10.0	10.0	6.0	3.8	7.8	8.0	45.6
CPH	10.0	6.0	6.0	3.8	7.8	10.0	43.6
LGW	10.0	8.0	8.0	3.8	5.0	8.0	42.8
GVA	7.5	6.0	6.0	5.0	10.0	8.0	42.5
FRA	10.0	8.0	6.0	3.8	10.0	4.0	41.8
STN	7.5	8.0	6.0	5.0	7.2	8.0	41.7
MUC	7.5	8.0	4.0	3.8	10.0	6.0	39.3
EMA	5.0	8.0	8.0	3.8	7.8	4.0	36.6
ATH	5.0	6.0	6.0	5.0	7.2	6.0	35.2
BHX	5.0	8.0	6.0	5.0	5.0	6.0	35.0
ORY	7.5	8.0	8.0	1.3	5.0	4.0	33.8
BCN	7.5	4.0	6.0	3.8	7.8	4.0	33.1
ZRH	7.5	8.0	6.0	2.5	5.0	4.0	33.0
EDI	2.5	8.0	8.0	2.5	7.8	2.0	30.8
HAM	7.5	8.0	4.0	2.5	5.0	2.0	29.0
BRU	5.0	8.0	6.0	2.5	5.0	2.0	28.5
BLQ	2.5	6.0	6.0	3.8	5.0	2.0	25.3
OPO	5.0	2.0	4.0	3.8	5.0	2.0	21.8
IBZ	2.5	2.0	2.0	3.8	5.0	0.0	15.3
Average	6.8	7.0	6.0	3.6	6.8	4.9	35.1

According to the results, even though airports recognise that their business activities have environmental consequences on the local environment not all of them have applied specific mitigating measures, or have set specific targets, aiming at reducing the total environmental impact. As a result, none of the selected airports presents the highest score of environmental comprehensiveness.

AMS airport presents the best AEC score, while ARN and CPH are ranked in the second and third position respectively. 50% of the sample presents scores above the average. IBZ is ranked in the last position of the sample. It is noteworthy that in the water and waste categories, none of the airports get the highest score.

Environmental categories that present the highest average AEC score include actions towards noise mitigation and land use, ecosystems and new development. On the contrary, issues regarding waste management and public transport are not on the top of the agenda. It is noteworthy that in the access systems category only 45% of the sample presents scores above the average.

Figure 12 illustrates the AEC for the airport sample.

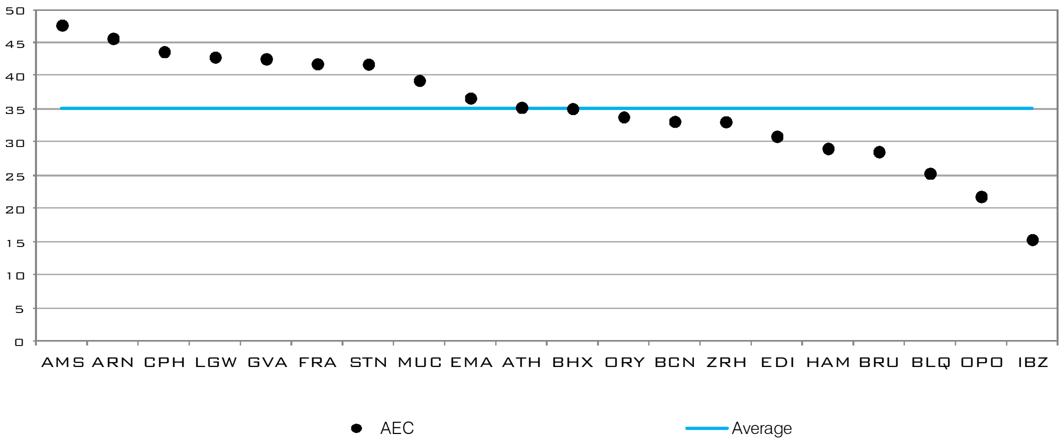

Figure 12: AEC score for the local environmental categories
(Source: author)

Figure 13 graphically presents each airport's AEC fingerprint, with reference to the local environmental issues. Each one of the axes represents the local environmental categories (i.e. local air quality, noise, water, waste, land use/ecosystems and access systems). For example, AMS airport presents the highest score (10 out of 10) in 2 out of 6 categories; amongst the other three, a slightly preference on access systems, water and land use/ecosystems issues is noted. On the contrary, IBZ airport besides land use and ecosystems clearly shows low scores in all other categories.

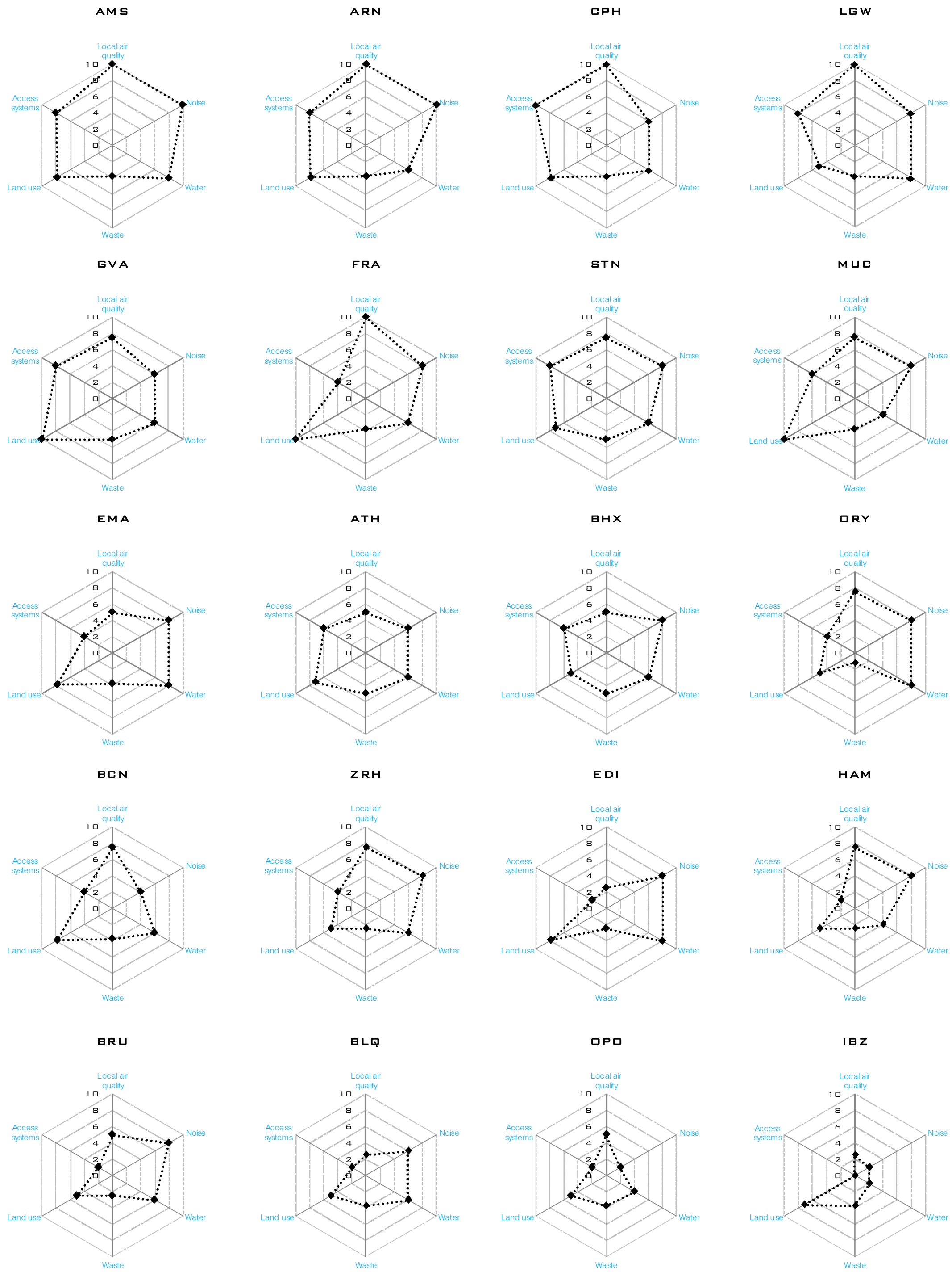

Figure 13: AEC fingerprint for the airport sample for the 6 local environmental categories
(Source: author)

5.3.3 Water Environmental Categories

As analysed in previous paragraphs, this category includes water issues, like water consumption control, water recycle and water quality. Based on equation

[1], in order to measure AEC, the score for each category is taken into account. In addition, the relevant importance multipliers are acknowledged.

Analytically, in order to score each category the number of sub-criteria covered is taken into consideration. For example, in the water consumption category, if an airport covers all sub-criteria it scores 10. For the AEC measurement, each sub-criterion is multiplied by the relevant importance multiplier (Table 19). The AEC scores for each airport are given in Table 20.

Table 19: AEC measurement components for the water categories

Water Categories Category	Sub-criteria	Importance Multipliers
WATER CONSUMPTION	Target to reduce water consumption levels	3.0
	Use of low-water devices and efficient water distribution network	3.0
	Water leak detection devices	3.0
	Smart irrigation systems	3.0
	Drinking water consumption reduction over the past year	3.0
WATER RECYCLE	Target to increase water recycling levels	2.3
	Separate water network	2.3
	Rainwater harvesting system	2.3
	Increase in water recycling usage over the past year	2.3
WATER QUALITY	Target to improve the quality of water leaving the airport	3.7
	Spill traps and oil separators or other relevant systems	3.5
	Surface water quality monitoring system	3.7
	Underground water quality monitoring system	3.7
	Absence of incidents of non-compliance to discharge consents	3.8

Table 20: AEC results for the water categories

Airports	Airport Environmental Comprehensiveness (AEC)			
	Water Consumption	Water Recycle	Water Quality	Sum
BCN	8.0	7.5	7.9	23.4
ATH	6.0	5.0	8.1	19.1
CPH	6.0	5.0	7.9	18.9
FRA	4.0	10.0	4.0	18.0
ZRH	6.0	5.0	6.1	17.1
BRU	2.0	5.0	10.0	17.0
ORY	6.0	5.0	6.0	17.0
EDI	8.0	0.0	8.0	16.0
LGW	4.0	5.0	5.9	14.9
MUC	4.0	2.5	8.1	14.6
EMA	6.0	2.5	6.1	14.6
AMS	6.0	2.5	5.9	14.4
ARN	4.0	0.0	10.0	14.0
GVA	4.0	0.0	8.0	12.0
STN	6.0	0.0	5.9	11.9
HAM	4.0	2.5	4.0	10.5
OPO	6.0	0.0	4.0	10.0
BHX	4.0	0.0	5.9	9.9
BLQ	6.0	0.0	3.9	9.9
IBZ	4.0	2.5	2.0	8.5
Average	5.2	3.0	6.4	14.6

According to the results, even though airports recognise that their business activities have consequences on the water resources not all of them have applied specific mitigating measures, or have set specific targets, aiming at reducing the water consumption or at sustaining good water quality. As a result, none of the selected airports presents the highest score of environmental comprehensiveness.

BCN airport presents the best AEC score, while ATH and CPH are ranked in the second and third position respectively. 45% of the sample presents scores above the average, while in 2 out of 20 airports the score is equal to the average. IBZ is ranked in the last position of the sample. It is noteworthy that in the water consumption category none of the airports get the highest score.

The categories that present the highest average AEC score regard mostly water quality issues; therefore, waste water and storm water management and the control of the water quality leaving the airport site constitute issues on top of the agenda. Water recycling presents the lowest scores; not many airports have considered water recycling as an option; thus only 40% of the sample gets an above average score.

Figure 12 illustrates the AEC for the airport sample.

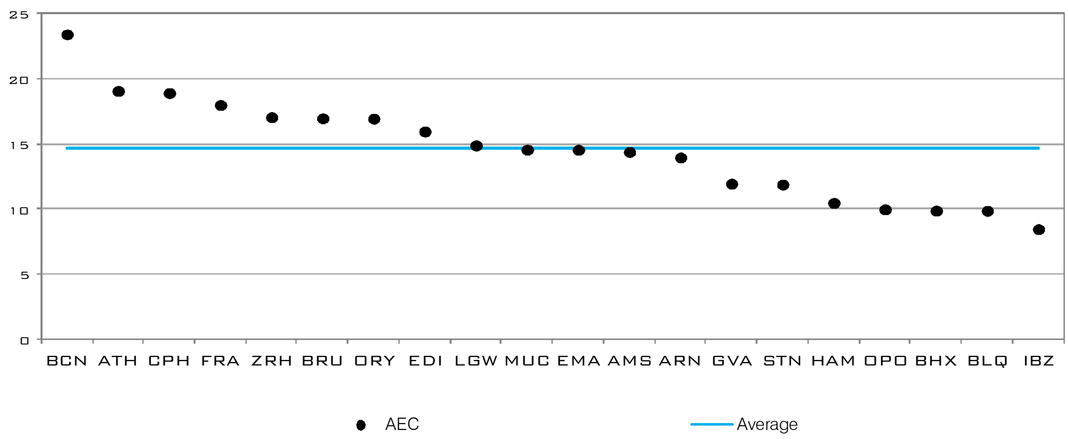

Figure 14: AEC scores for the water categories
(Source: author)

Figure 15 graphically presents each airport's AEC fingerprint, with reference to the water issues. Each one of the axes represents the main water categories (i.e. consumption, recycling, quality). For example, BCN airport presents the highest score of the sample, presenting at the same time a balanced approach on the whole water issues (it scores above 7.5 out of 10 in all 3 categories). IBZ airport presents the highest score; nevertheless a balanced approach amongst the water components is noted. Quite the opposite happens to airports like BRU, EDI, ARN and GVA; water quality issues seem to be on top of the agenda.

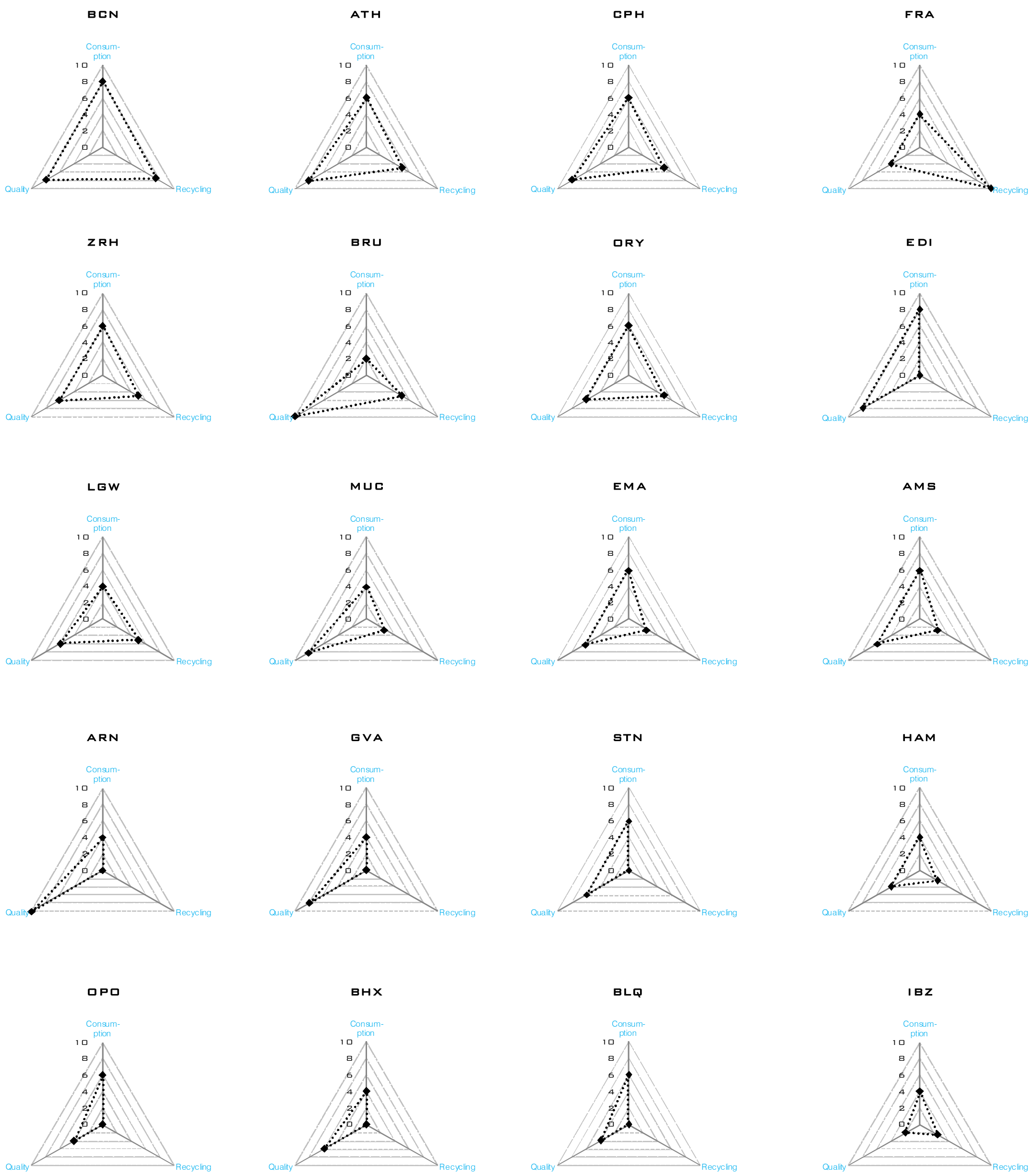

Figure 15: AEC fingerprint for the airport sample for the 3 water categories
(Source: author)

5.3.4 AEC Ranking

Based on the AEC results, airports' ranking regarding the first three positions is presented in Table 21.

Table 21: AEC ranking

Ranking	Main Environmental Issues	Local Environmental Issues	Water management Issues
1st	ARN	AMS	BCN
2nd	AMS	ARN	ATH
3rd	CPH	CPH	CPH

(Source: author)

Depending on the environmental category, different airports cover the first position. Regarding the evaluation on the main environmental issues ARN presents the best AEC scores; this happens mostly due to the sensitivity the airport shows in managing its climate change impact. AMS is ranked in the first position regarding environmental issues that mostly involve the local environment. However, it can be said that the airport on the whole shows a significant sensitivity to all environmental issues. Finally, BCN airport presents the highest AEC score on water management issues. This probably happens because of the airport location in a river delta; the area is designated as protected and the airport not only has to deal with water availability problems but also needs to apply sufficient measures to prevent water pollution.

5.4 Water Management Efficiency

As mentioned in the previous chapter, to measure how efficient the airport uses and controls water resources a ratio analysis is used. The analysis results are given in the following paragraphs.

5.4.1 Water Demand (W_1 and W_4 ratios)

One of the main elements of sustainable water management that determines airport's water efficiency is water consumption. The first ratio (W_1) measures the total annual water demand (in lt) per passenger. To enable comparison, the water demand for three consecutive years is taken into consideration; thus, the results are given in table 22.

ATH presents the highest average annual water demand, reaching 44.57 lt/pax while CPH presents the lowest around 9.12 lt/pax. In general, the average water demand for the three consecutive years is 24.36 lt/pax; 45% of the airport sample consumes water above the average.

It is noteworthy that although in year 2008 efforts were made towards water demand reduction, in 2009 almost all airports presented higher consumption rates; only 35% managed to reduce water consumption compared to the previous year.

Table 22: Water demand ratios for three consecutive years

Airports	Water Demand 2009 LT/PAX	Water Demand 2008 LT/PAX	Water Demand 2007 LT/PAX	Average Water Demand LT/PAX
CPH	9.35	9.03	8.97	9.12
BRU	10.92	9.86	7.02	9.27
HAM	11.86	10.63	10.62	11.04
FRA	14.39	15.39	14.34	14.71
EDI	15.03	15.83	15.83	15.56
BHX	15.39	15.14	14.25	14.93
GVA	18.10	17.60	20.10	18.60
ORY	20.12	22.40	22.27	21.60
IBZ	23.74	21.19	19.42	21.45
AMS	25.68	26.59	26.40	26.22
OPO	26.09	22.80	23.06	23.98
MUC	28.68	27.32	28.56	28.19
ZRH	29.42	29.40	27.92	28.91
EMA	30.01	30.06	30.06	30.05
BCN	30.11	19.07	28.59	25.92
LGW	32.70	30.93	28.61	30.75
BLQ	32.73	40.91	72.09	48.58
ARN	32.98	29.18	29.00	30.39
STN	34.11	32.26	34.03	33.47
ATH	41.10	47.10	45.51	44.57
Average	24.13	23.63	25.33	24.36

(Source: author)
(The water demand for EMA and EDI for year 2007 is determined based on 2008 demand)

Amongst airports with annual passenger traffic above 25 millions, FRA presents the lowest average water demand, while LWG the highest. Between airports with annual passenger traffic 25-10 millions CPH appears to have the lowest average water demand; on the contrary, ATH has the highest. Regarding airports with annual passenger traffic below 10 million, EDI consumes the least; on the contrary, BLQ consumes the most.

The ratio W_1 analysis results are graphically given in figure 16.

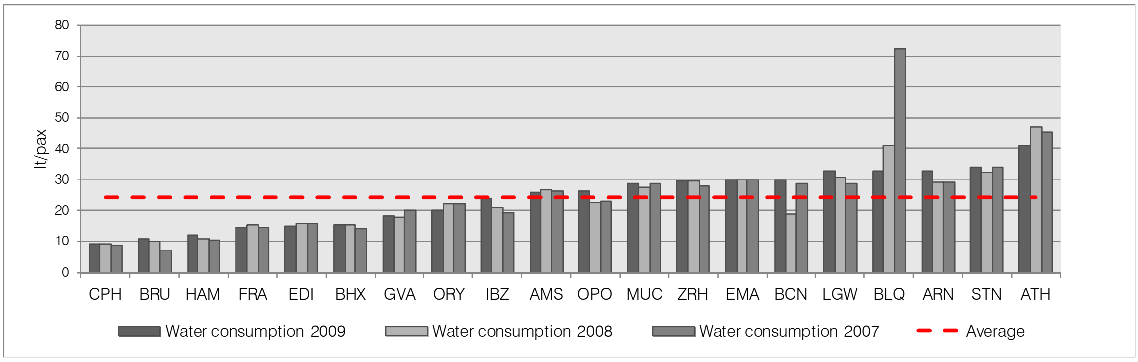

Figure 16: Water demand for the airport sample
(Source: author)

By definition, when ratio W_1 is high, it may indicate that the airport does not efficiently control water consumption. However, even though some airports appear to be less efficient, in terms of water consumption, the efforts they make to be more efficient must be acknowledged. W_4 ratio (Figure 17) provides information regarding the efforts made.

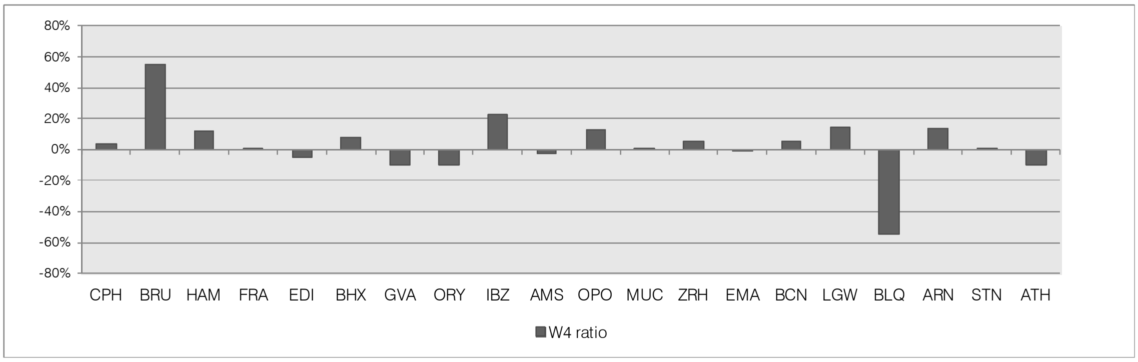

Figure 17: Airports' performance for the W_4 ratio
(Source: author)

As illustrated in the above figure although BLQ is a big water consumer, since 2007 it has managed to reduce the consumption around 55%. In addition ATH, GVA and ORY airports present a reduction around 10%. On the other hand, even though BRU is characterised as efficient, in terms of water demand, since 2007 presented an increase in the water demand around 55%. Also, IBZ presents an increase approximately 22%, while LGW, OPO and ARN show an increase around 13%.

An annual increase in the total water consumption may indicate either non effective measures, or various projects that probably took place during the years. It is noteworthy that the average change in total water demand tends to zero, indicating that only 50% of the airport sample made significant efforts to reduce their annual water consumption.

5.4.2 Drinking Water Consumption
(W_2 and W_5 ratios)

Besides annual water consumption, the proportion of drinking water should be taken into consideration. As already mentioned, even though airports present above average total annual water consumption, the corresponding annual drinking water consumption is below average. This may indicate either recycling or the use of industrial water; in addition, abstraction of low quality water might take place.

ATH is probably the best representative airport. Even though the annual water demand is the highest of the sample, less than half is potable; the rest is recycled water. Quite the same applies in the case of OPO; about one third of the total consumption is potable water; to cover the water demand low quality, not potable, water is used.

In general, 60% of the sample consumes drinking water below the average. The highest average consumption is noted at STN (31.79 lt/pax) and the lowest at CPH airport (7.62 lt/pax). The drinking water consumption for years 2009, 2008 and 2007 are graphically given in Figure 18.

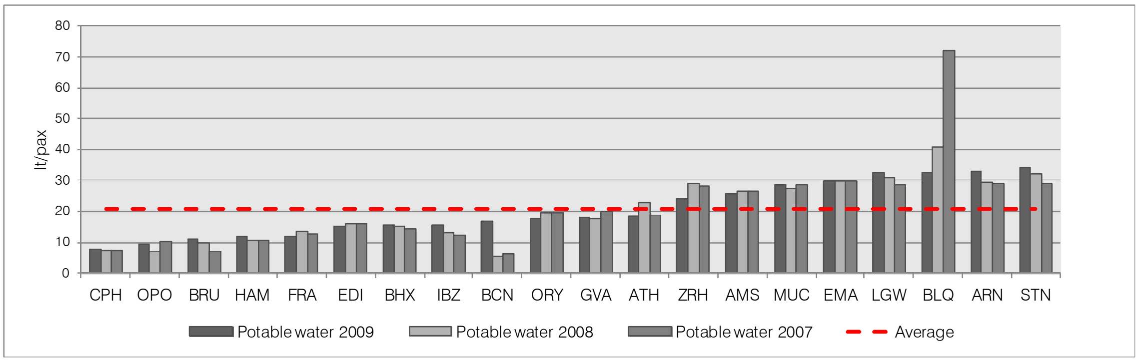

Figure 18: Drinking water consumption for the airport sample
(Source: author)

CPH seems to be the most water efficient airport in terms of drinking water consumption. In addition, it presents a roughly similar consumption during the three years. It is noteworthy that BCN airport was the most efficient airport in terms of drinking water consumption for years 2007 and 2008. However, in 2009 the treatment plant on-site was closed; the wastewater is now treated in a public facility outside the airport. This resulted in a significant increase in the annual drinking water consumption, more than 150% compared to 2007.

The second ratio (W_2) measures the percentage of the annual drinking water consumption per passenger, compared to the total annual water consumption. To enable comparison, the consumption for three consecutive years is taken into consideration; thus, the results are given in Table 23.

According to the results, 45% of the sample covers all the water needs by using high quality water. BCN presents the best results; drinking water covers only 35.10% of the total demand. OPO and ATH cover the second and third position respectively.

Table 23: Drinking water consumption ratios for three consecutive years

Airports	Drinking Water 2009 (%)	Drinking Water 2008 (%)	Drinking Water 2007 (%)	Average (%)
BCN	56.13%	28.05%	21.13%	35.10%
OPO	35.61%	31.37%	43.58%	36.85%
ATH	44.48%	48.62%	41.13%	44.74%
IBZ	64.91%	61.69%	62.41%	63.00%
CPH	84.71%	83.05%	82.92%	83.56%
FRA	83.29%	86.33%	89.21%	86.28%
ORY	86.14%	88.23%	87.63%	87.33%
ZRH	81.78%	97.96%	100.01%	93.25%
STN	100.00%	100.01%	85.22%	95.07%
EMA	99.50%	99.53%	99.53%	99.52%
BRU	100.00%	99.97%	99.96%	99.98%
LGW	100.00%	100.00%	99.99%	100.00%
BHX	100.00%	99.99%	100.00%	100.00%
AMS	100.00%	99.99%	100.00%	100.00%
MUC	100.00%	100.00%	100.00%	100.00%
GVA	100.00%	100.00%	100.00%	100.00%
BLQ	100.00%	100.00%	100.00%	100.00%
EDI	100.00%	100.00%	100.00%	100.00%
ARN	100.00%	100.01%	100.00%	100.00%
HAM	100.00%	100.00%	100.00%	100.00%
Average	86.83%	86.24%	86.54%	86.23%

(Source: author)

The efforts that airport make to reduce drinking water consumption are depicted in Figure 19. BCN airport presents a significant increase in the drinking water consumption; as already mentioned this probably happens due to the treatment plant closure (the airport used treated water). Around 50% of the sample seems to present an annual increase in the drinking water consumption; this is confirmed by the average of the ratio W_5, which is around 11%.

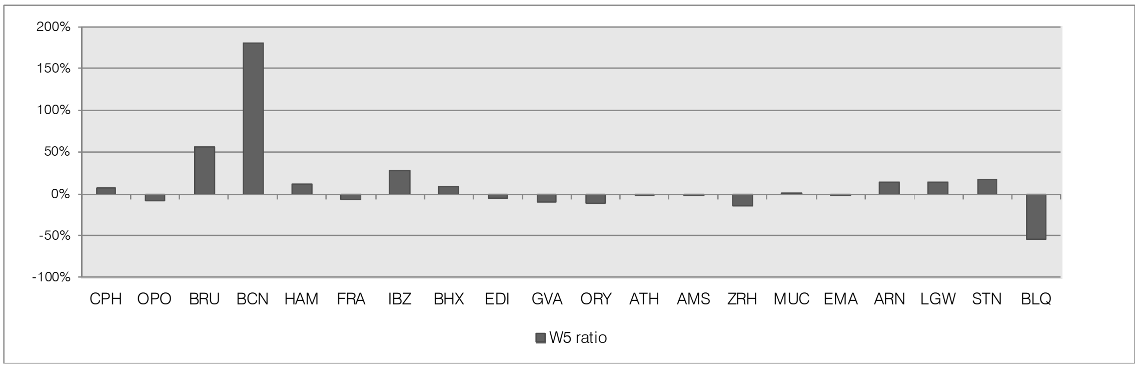

Figure 19: Airports performance for the W_5 ratio
(Source: author)

5.4.3 Water Recycle
(W3 and W6 ratios)

To obtain a comprehensive overview of water management efficiency, besides the total water demand and the drinking water consumption, water recycle should be considered.

According to the analysis results (Table 24) only 40% of the sample considers water recycling as an option. Amongst them, ATH presents the highest recycling rate. IBZ and CPH cover the second and third position respectively. The average recycling rate of the sample is 7.19%. The average recycling rate of the airports that apply water recycling is around 17%.

Even though recycling seems to be a necessity in regards to airports that are located in southern geographic latitudes, on islands or near Mediterranean coastlines, many central European airports consider using industrial water in many consumer sources rather than potable a good practice. For instance, FRA uses industrial water to the maximum possible extent, covering approximately 13% of the annual water demand. Additionally, CPH covers around 17% of the total annual demand through water recycling.

Table 24: Water recycle ratios for three consecutive years

Airports	Water Recycle 2009 (%)	Water Recycle 2008 (%)	Water Recycle 2007 (%)	Average (%)
AMS	0.00%	0.00%	0.00%	0.00%
ARN	0.00%	0.00%	0.00%	0.00%
BHX	0.00%	0.00%	0.00%	0.00%
BLQ	0.00%	0.00%	0.00%	0.00%
BRU	0.00%	0.00%	0.00%	0.00%
EDI	0.00%	0.00%	0.00%	0.00%
GVA	0.00%	0.00%	0.00%	0.00%
HAM	0.00%	0.00%	0.00%	0.00%
LGW	0.00%	0.00%	0.00%	0.00%
MUC	0.00%	0.00%	0.00%	0.00%
OPO	0.00%	0.00%	0.00%	0.00%
STN	0.00%	0.00%	0.00%	0.00%
EMA	0.49%	0.48%	0.48%	0.48%
ZRH	1.82%	2.05%	0.00%	1.29%
BCN	11.22%	5.62%	4.22%	7.02%
ORY	13.86%	11.90%	11.96%	12.57%
FRA	16.71%	13.67%	10.79%	13.72%
CPH	15.37%	16.93%	17.05%	16.45%
IBZ	35.07%	38.34%	37.58%	37.00%
ATH	55.49%	51.38%	58.86%	55.24%
Average	7.50%	7.02%	7.05%	7.19%

(Source: author)

The recycling rate for years 2009, 2008 and 2007 is graphically given in Figure 20.

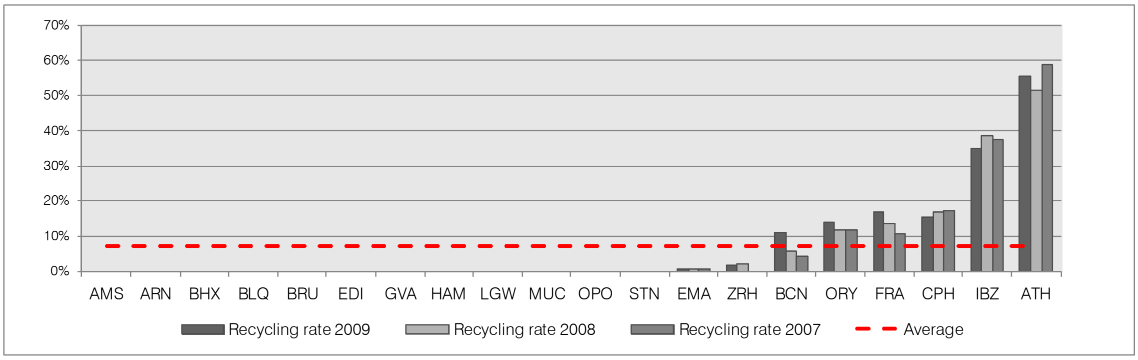

Figure 20: Recycling rate for the airport sample
(Source: author)

The efforts that airports make to increase their water recycling rate are depicted in Figure 21. BCN and FRA seem to have made significant efforts to increase the quantities of recycled water. It is noteworthy that although IBZ presents a relatively high recycling rate in 2009, the efforts made during this period lead to a reduction compared to 2007. Quite the same applied to CPH and ATH, which present a reduction 10% and 6% respectively.

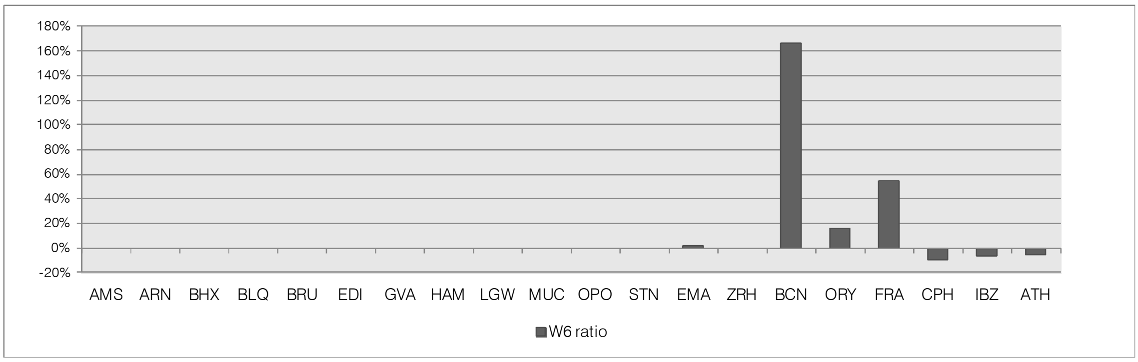

Figure 21: Airports performance for W_6 ratio
(Source: author)

5.4.4 Water Efficiency Ranking

Even though some airports appear to be less efficient, in terms of water consumption, the efforts they make to be more efficient must be acknowledged. As discussed in previous paragraphs although some airports are characterised as big water consumers, they have managed to reduce the water demand more than 55%. The best representative example is BLQ. At the same time ATH has managed to reduce annual water consumption more than 10%. On the other hand IBZ and LGW are airports that actually present an increase 22% and 14% respectively.

It is worth mentioning that BCN airport appears to be amongst the most efficient airports, in terms of water consumption for the year 2008; however, in 2009 relatively high water consumption is noted. On the whole, it is noted that even though the annual passenger traffic generally decreased in 2009, compared to 2008, the average water demand increased.

Based on the ratio analysis results airport ranking regarding the first three positions is presented in Table 25.

Table 25: Water management efficiency ranking based on the 3-year average ratios

Ranking	W_{1AV}	W_{2AV}	W_{3AV}
1st	CPH	CPH	ATH
2nd	BRU	OPO	IBZ
3rd	HAM	BRU	CPH

(Source: author)

Based on the above results CPH seems to be the most water efficient airport; it presents the lowest water demand, the lowest drinking water consumption and recycles water to cover part of the demand. ATH seems to be the most efficient airport in terms of water recycling; however, as already mentioned, the airport presents a relatively high water demand.

To depict the whole picture of the efforts that airport make to become more water efficient, W_4, W_5 and W_6 are outlined in a single chart (Figure 22).

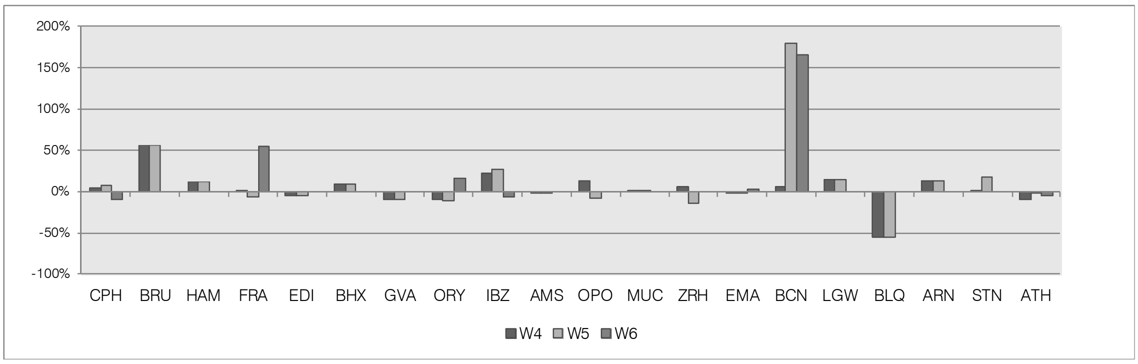

Figure 22: Water management efficiency
(Source: author)

According to the analysis, AMS, MUC, EMA and EDI present a balanced water management approach, as all ratios tend to zero; this implies that the applied measures keep consumption at a constant level, regardless airports passenger traffic changes. IBZ airport seems to be one of the least water management efficient airports, based on W_4, W_5 and W_6 ratios scores.

It is noteworthy that while airports with annual passenger traffic more than 25 millions present the minimum total water consumption per passenger, they have the smallest water recycling rate; in addition, they use potable water to cover the most of the water demand. On the contrary, airports with annual passenger traffic below 10 millions present the highest total water consumption per passenger; however, in cases where water recycling is applied, higher water recycling rates are noted.

5.5 Environmental Strategy Performance

The detailed analysis of the applied best practices, along with the level of importance of certain environmental topics, as identified in the questionnaire survey results, points out different environmental management profiles. Consequently, airports environmental strategy ranges from balanced to one-sided development model, mainly emphasising on efforts to manage or control impact on global or local scale.

To assess airports applied environmental strategies, the AEC scores for the identified environmental actions, are grouped into categories, as these categories are defined in the relevant paragraphs (Table 6). The sum for each category is adjacent to a 1 to 5 scale and the results are depicted in ESAD square (Figure 6). Analytically, taking into consideration the analysis of the main environmental topics, the following are assessed:

a) GLOBAL (G) vs. LOCAL (L) environmental issues

b) CONSUMPTION (C) control vs. POLLUTION (P) management actions (global & local)

c) ENERGY (E) vs. WATER (W) consumption issues

The results are illustrated in Figures 23-25.

5.5.1 GLOBAL (G) vs. LOCAL (L)

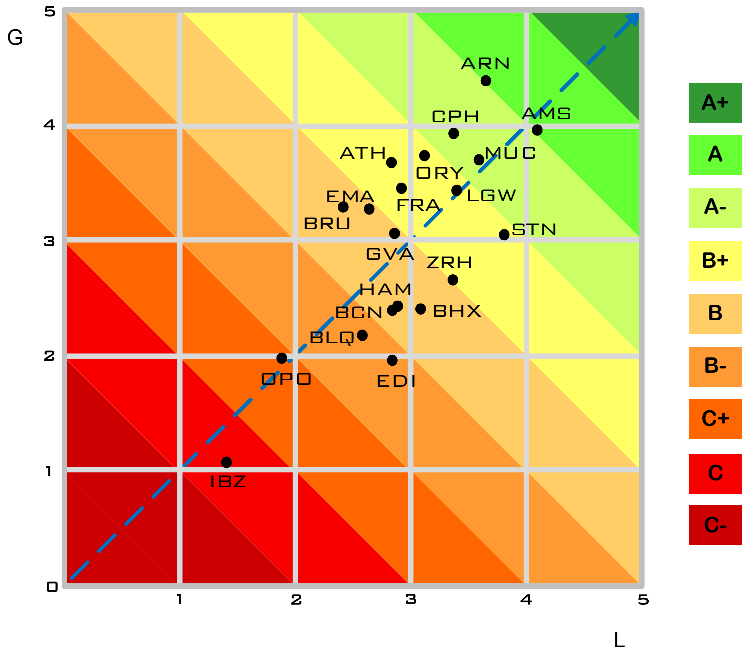

Figure 23: ESAD '*Global (G) vs. Local (L)*'
(Source: author)

On the whole, managing environmental issues is generally considered as a key strategic consideration for airports comprising categories A-, A and A+. According to the assessment results, none of the airports is rated as A+.

ARN and AMS are the only airports that are rated as A; they present the best performance in environmental comprehensiveness scale. These airports have identified all environmental issues associated with their activities. In addition, the applied measures aim at controlling environmental impacts at local and global scale. Both airports show increased environmental responsiveness in all topics; however AMS airport, presents a more balanced approach.

Managing climate change related issues seem to be the key priority for ARN airport for many years; as a result the airport has achieved its Airport Carbon Accreditation level at "Neutrality", since 2009 and was awarded as "ACI Europe Best Airport Award 2010" for the 'eco-innovation' category (ACI-Europe). It is worth mentioning that in order to achieve carbon neutral operation a wide range of measures were applied, the most important of which is the exploitation of geothermal energy.

Most of the airports are rated as B+, B and B-; based on the assessment the average score of the environmental comprehensiveness ranges from 2.0 to 3.5.

Their perception on sustainability varies, from limited to narrow. However, airports like LGW and GVA present a relatively balanced strategy, focusing its actions on mitigating the whole environmental impact. Nevertheless, additional measures should be applied to improve environmental performance at global and local scale.

Airports rated as C+ and C present poor perception on sustainability. Especially in the case of IBZ very few measures have been applied to reduce environmental impacts, mostly at local scale. It is noted that the airport does not present any targets towards a carbon neutral growth.

5.5.2 CONSUMPTION (C) VS. POLLUTION (P)

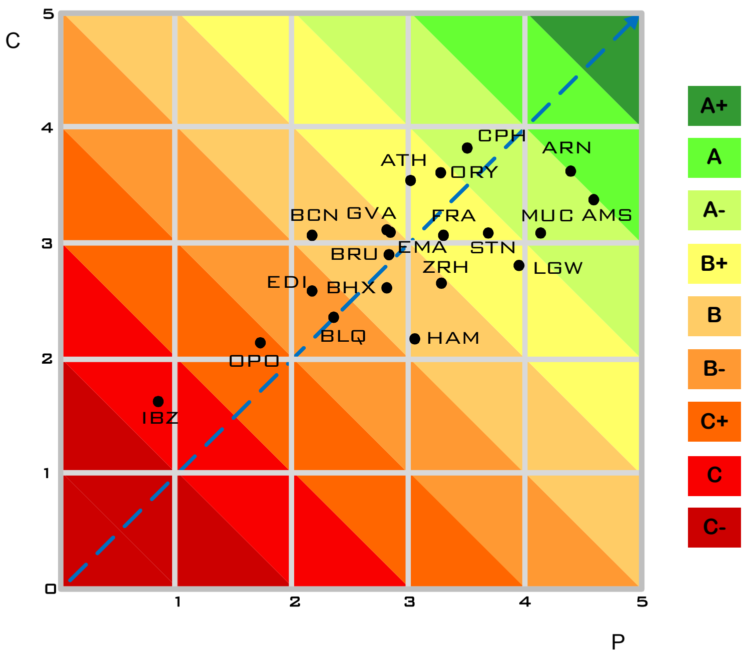

Figure 24: ESAD '*Resources consumption (C) vs. Pollution management (P)*'
(Source: author)

Like the previous assessment, according to the assessment results, none of the airports is rated as A+. ARN is the only airport that is rated as A; it presents the best performance in environmental comprehensiveness scale. AMS, CPH and MUC are rated as A-; although their environmental plans include targets and measures to improve environmental performance there are issues that need further improvement. For example, in the case of AMS and MUC more attention should be paid regarding consumption control issues.

Most of the airports are rated as B+, B and B-; even though this implies that additional or new measures should be applied, most of these airports present a relatively balanced strategy, trying to control consumption issues, while at the same time efficiently manage pollution issues.

As in the previous assessment OPO and IBZ are rated as C+ and C respectively; between them OPO presents a more balanced strategy, while IBZ should focus its environmental initiatives on managing pollution (air, water and soil).

5.5.3 ENERGY (E) vs. WATER (W)

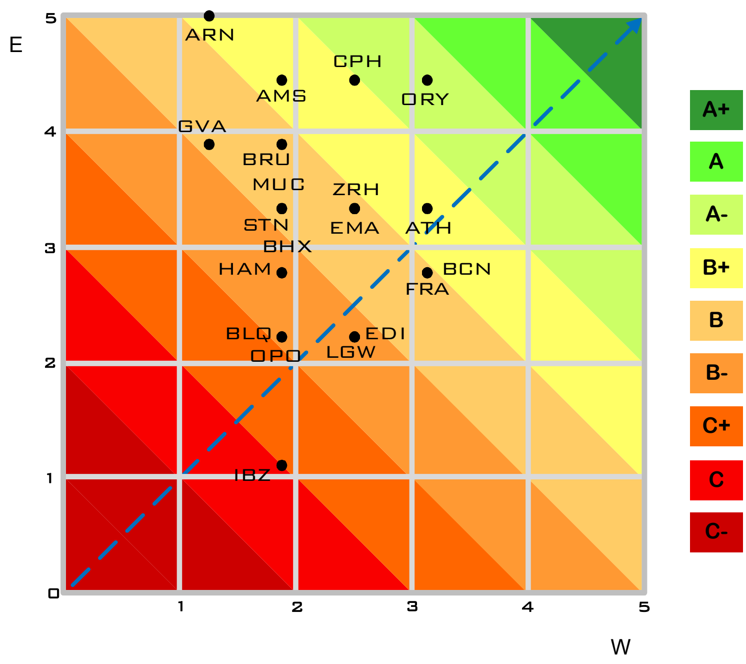

Figure 25: ESAD '*Energy (E) vs. Water (W) consumption*'
(Source: author)

Based on the assessment results, none of the airports are rated as A+ or A. ORY is the only airport of the sample that presents average score of the environmental comprehensiveness above 3.5. However its environmental strategy is mostly focused on controlling energy rather than water consumption.

On the whole, most of the airports are depicted above the blue diagonal line; this implies that their strategy is mostly focused on controlling energy consumption sources. Even though this may imply that they acknowledge their responsibility to control their climate change impact (e.g. control the consumption of fossil fuels), in some cases it is just a response to control expenses resulting from electricity needs.

IBZ is the only airport that is rated as C. To improve its performance, measures regarding energy consumption control; in addition, efforts to increase the green energy used should be considered.

5.5.4 Environmental Strategy Assessment

The results on environmental strategy assessment are given in Table 26. The scores of the environmental strategy assessment are given based on the best result that the airport has in the three categories. For example if an airport has an A, a B+ and a B then the score will be A.

Table 26: Environmental strategy assessment

Airports	Global vs. Local	Consumption vs. Pollution	Energy vs. Water	Score	
ARN	A	A	B+	A	A
AMS	A	A-	B+	A	
CPH	A-	A-	B+	A-	
MUC	A-	A-	B	A-	
ORY	B+	B+	A-	A-	
ATH	B+	B+	B+	B+	B
STN	B+	B+	B+	B+	
FRA	B+	B+	B	B+	
LGW	B+	B+	B-	B+	
ZRH	B+	B	B	B+	
BCN	B	B	B	B	
BRU	B	B	B	B	
EMA	B	B	B	B	
GVA	B	B	B	B	
BHX	B	B	B-	B	
HAM	B	B	B-	B	
BLQ	B-	B-	B-	B-	
EDI	B-	B-	B-	B-	
OPO	C+	C+	B-	B-	
IBZ	C	C	C	C	C

(Source: author)

Managing environmental issues is generally considered as a key strategic consideration for airports comprising category A; they have identified all environmental issues associated with their activities and have applied measures to control the impacts at global and local level.

ARN, AMS, CPH, MUC and ORY seem to have incorporated a sustainable environmental strategy that is focused on measures to control resources consumption (energy and water), as well as to manage pollution from airport's operation and development, minimising negative impacts at global and local level. However, there are still issues that need further improvement.

Both London's airports present an above average score; to incorporate a sustainable strategy they need to acknowledge their weaknesses and apply additional measures to improve their environmental performance. Quite the same applies to ATH, FRA and ZRH airports.

Even though environmental management is generally recognised as a necessary tool to overcome limitations on future growth, BCN, BRU, EMA, GVA, BHX and HAM present an average strategy. Therefore, some new measures should be applied and new targets should be set to improve their environmental performance.

BLQ, OPO and EDI airports appear to have incorporated a below the average strategy; to improve their performance a wide range of measures should be applied. Regarding BLQ it is noteworthy, that BLQ is the first Italian airport that covers a significant proportion of energy needs through renewable energy generation (photovoltaic modules); in addition, it has recently been awarded the accreditation level of Mapping (Airport Carbon Accreditation, 2010).

IBZ is the only airport that presents a non sustainable strategy; only a few measures have been applied to reduce its environmental impact. In addition, the airport seems to focus mostly on business development, without presenting any long-term targets towards a sustainable growth.

Based on the environmental strategy assessment results even though 50% of the airport sample presents an above average environmental strategy only 25% has incorporated a sustainable one (Figure 26); 30% presents an average environmental strategy.

It is noteworthy, that while 20% of the sample presents environmental strategies below average, only 5% can be characterised as unsustainable, based on AEC measurement.

None of the selected airports can be characterised as of the highest category of the environmental comprehensiveness scale. Only 1 out of 4 airports appears to have applied not only monitoring systems but also evaluation systems to assess environmental performance and whenever necessary to apply measures;

however, they need to improve the applied measures for further sustainable development.

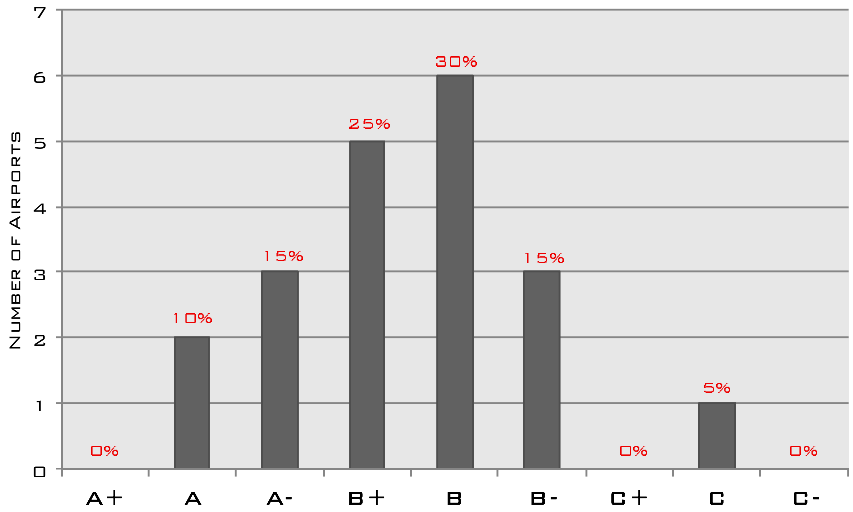

Figure 26: Environmental strategy assessment for the 20 airports
(Source: author)

It is worth mentioning that the geographical location contributes to the direction of incorporated environmental strategies; airport's location plays a major role not only to environmental management priorities but also to people's culture and expectations and the existing legislative and regulatory framework. For example, airports like ARN and CPH which are located in areas with significant geothermal energy potential, can easily use geothermal energy to cover all airport's needs with low cost. As a result, to achieve carbon neutral operations is easier and less expensive compared to other airports. In addition, the culture of people living in Scandinavia implies the need of carbon neutral operation, environmental-friendly transport means and other green initiatives. On the other hand, airports like BCN, which is located in area with scarce water, need to consider ways to secure the necessary water resources to operate, rather than apply measures towards a carbon neutral operation.

Furthermore, airport's age determines the ease with which the airport can improve its environmental performance. For example, ATH, which is built 10 years ago, present an efficient energy infrastructure. Therefore, implementing measures regarding building functions (i.e. lighting, heating, cooling, ventilation) to reduce energy consumption is easier compared to old airports.

Most of the airports need to improve their environmental performance, either by applying additional measures or by revising the existing ones. Over and above in many case, they need to expand their perception on sustainability. Only 1 out of 20 airports should revise its priorities and recognise environmental strategy as a tool to manage current and future business constraints.

5.6 Water Management Strategy Performance

To assess the balance between water management and other environmental topics, directly linked with local communities' tolerance, the AEC scores for the identified environmental actions are grouped into categories, as these categories are defined in the relevant paragraphs (Table 7). The sum for each category is adjacent to a 1 to 5 scale and the results are depicted in ESAD square (Figure 6). Analytically, the assessment takes into consideration:

a) WATER (W) vs. LOCAL (L) environmental issues

The results are illustrated in Figure 27.

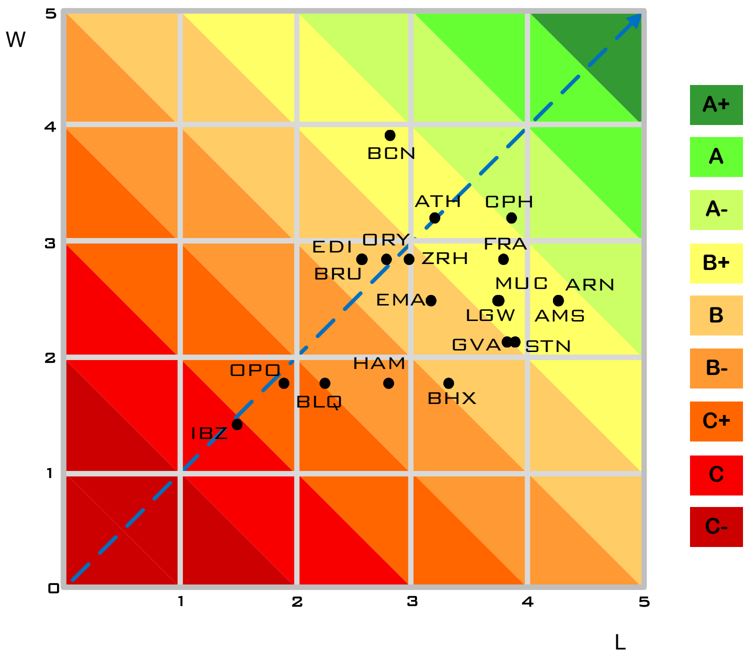

Figure 27: ESAD '*Water (W) vs. Local (L) issues*'
(Source: author)

Most of the airports present a balanced strategy, as regards managing their impact on the local environment. However, there are examples of airports that obviously prefer to apply mostly water management measures rather than take measures to reduce the total impact on the local environment.

BCN is a typical example of airport that due to its location, the applied measures are focused on water management. While it presents an above average score regarding noise, local air quality, waste and other local environment related issues; its comprehensiveness on water management issues is high.

On the other hand, there are many airports that mostly prefer to deal with noise, local air quality, public transport, wastes, ecosystems and land use planning, compared to water management issues. Airports like ARN, AMS, STN should pay more attention to water issues to achieve a sustainable further development. In the case of AMS, managing noise is probably airport's top priority; even though its water management strategy is above the average, additional measures to control water consumption should be applied for the airport to present a more balanced strategy.

None of the selected airports can be characterised as of the highest category of the environmental comprehensiveness scale. Water management is generally considered a key issue by one out of ten airports and there are significant issues that need improvement. Table 20 presents the assessment results.

Table 27: Water management strategy assessment

Airports	Score	
CPH	A	A
AMS	B+	B
ARN	B+	
BCN	B+	
FRA	B+	
ATH	B+	
LGW	B+	
MUC	B+	
STN	B+	
GVA	B	
ZRH	B	
EMA	B	
ORY	B	
BRU	B	
EDI	B	
BHX	B	
HAM	B-	
BLQ	B-	
OPO	C+	C
IBZ	C	

(Source: author)

It is noteworthy that all airports present an, at least, average environmental strategy, implying that measures to control their impact on the local environment have been applied. However, although most of the airports seem to make efforts to improve their environmental performance, they really need to develop and implement additional measures to be able to encourage sustainable further growth.

Based on the assessment results, 45% of the airport sample presents an above average water management strategy (Figure 28); based on AEC scale 5% is characterised as sustainable, 35% as average, 10% as below average and 10% as unsustainable. It is worth mentioning that none of the selected airports presents AEC score below 1.0, indicating that some measures to manage environmental issues that are directly linked with neighbouring communities are applied. This could be an option or an obligation by legislation or various local agreements.

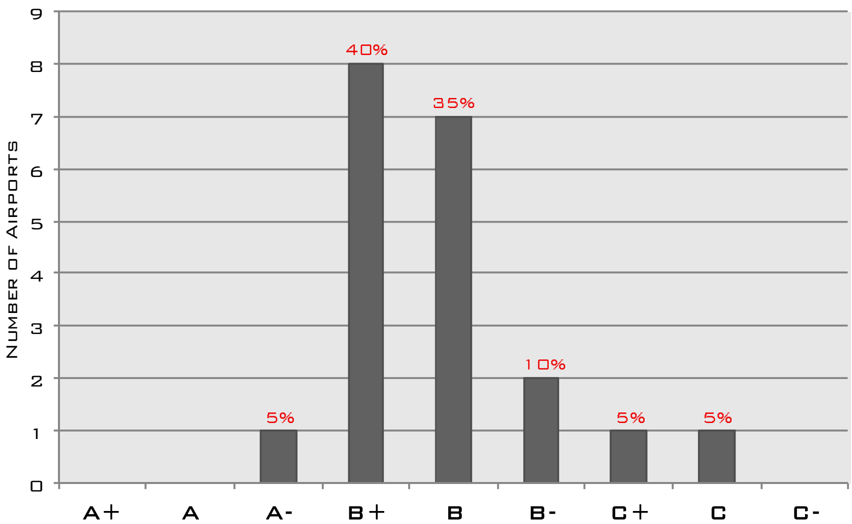

Figure 28: Water management strategy assessment for the 20 airports
(Source: author)

5.7 Sensitivity Analysis on Environmental Strategy Assessment

Saltelli (2002) mentions that "*Sensitivity analysis (SA) is the study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to the different sources of uncertainty in the model input*". In general, when a multi-criteria modelling framework is used, a sensitivity analysis can be performed to identify if there are significant changes in the conclusions of the analysis or in the evaluation process itself. Even though this research is basically focused on the development of the modelling framework rather than on the application results, the robustness of the results was tested by applying sensitivity tests. In the first test (-) 1 was abstracted from all importance multipliers, while in the second test (+) 1 was added. Based on the results, no change is noted in the environmental and water management strategy assessment results.

Besides the above mentioned tests, a third test is conducted. In this test, besides averaged importance multipliers, airport environmental strategy is assessed taking into consideration the following:

- importance multipliers that refer to the global environmental issues get the maximum scores and importance multipliers that refer to the local environmental issues get the minimum;
- importance multipliers that refer to the local environmental issues get the maximum scores and importance multipliers that refer to the global environmental issues get the minimum;

The maximum and minimum scores are obtained from the questionnaire survey responses. The results are depicted in Figure 29.

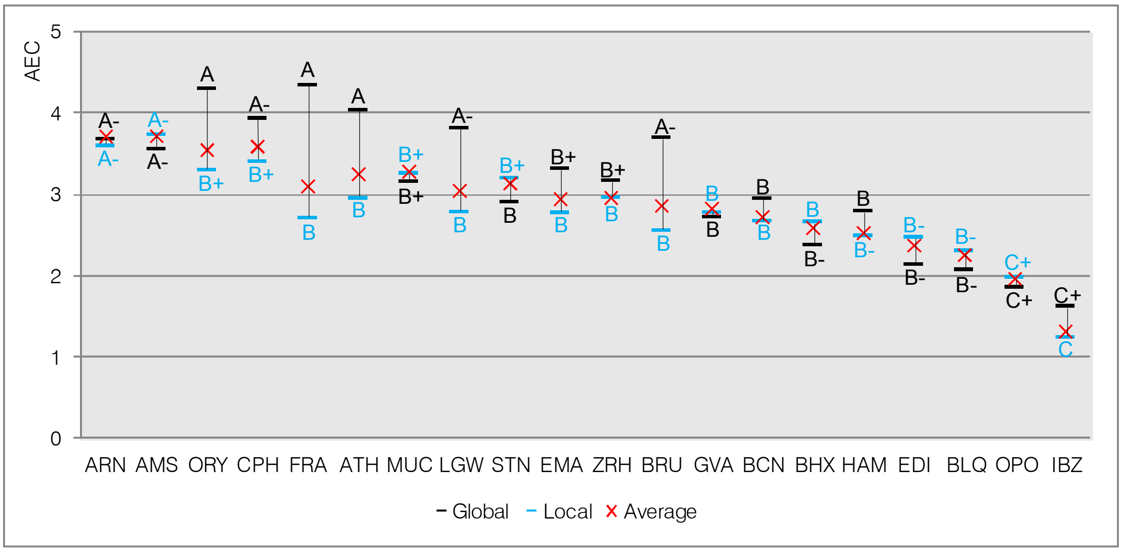

Figure 29: Sensitivity analysis results
(Source: author)

As illustrated, in some airports, regardless the changes in the importance multipliers, the environmental strategy rating remains the same. However, some airports, like FRA, ORY, ATH, BRU, LGW, depending on the importance multipliers used, present a greater range of rating. Considering that the multipliers used designate the importance of certain environmental issues in airports management priorities this change may imply that the applied measures or targets towards airports sustainable development are focused either on the global or on the local environmental issues.

6. Discussion

Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future (United Nations, 1987). By definition, it implies that the exploitation of natural resources, the direction of technological development and business investments, but also institutional change should be consistent with present and future needs; therefore the concept of sustainable development implies limits.

However, environment and development should not be considered as separate challenges; therefore the ability to anticipate and prevent environmental damage is the key issue for further business development. In the case of airports, effective airport management can help reduce the potential of environmental issues to become constraints to business growth (Thomas et al., 2009). Consequently, the most sustainable strategy for airports is the one that addresses the responsibility of management to maintain business growth, while at the same time encompasses efforts to improve airport's environmental performance at global and local level.

Even though environmental management is considered an issue of concern, little research exists regarding the importance that airports give to different environmental issues. The framework of this research deals with the strategies used by airport operators in regards to environmental management. In addition, a separate assessment tool has been developed in order to provide results regarding water management efficiency.

Based on research results, it can be surmised that airports recognise that environmental issues have the potential to constrain future development. However, the applied measures do not always result in minimising environmental impact as a whole, and therefore, the risks regarding airport business development. To encourage sustainable growth in the next decade airports should seek for a more balanced approach.

When prioritizing their main concerns, airports should take into consideration the anticipated importance of certain environmental issues in the future. Although climate change is recognised as the main upcoming constraint, the applied strategies in most of the cases need to be adjusted, to incorporate not only basic carbon management measures, but also to support long-term targets.

It is noteworthy that energy consumption is considered one of the most important issues that airports need to manage. However, the strategies applied in most of the cases have incorporated energy conservation measures, without focusing on the substitution of carbon based energy with renewable energy. In regards to older airports, with significant passenger traffic, where energy inefficient infrastructure exists, the use of renewable energy should be considered as an option.

As concerns local environment, noise is considered the airports' top management priority, directly linked with their further development; as a result a wide range of mitigation or compensation measures, have been applied. However, airports located in tourist destinations present average or below average strategies, focusing mostly on business development. The same applies to local air quality issues. In addition, even though encouraging the use of public transport appears to be a common practice, especially in the case of airports located in large cities, where a dense transport network exists, as concerns airports located in islands or other tourist destinations no such strategy is recognised.

On the topic of water management, even though it is not generally considered as a current top management priority, many airports, either due to the local environment, or due to strategic issues, have already incorporated an above average water management strategy. The identified strategies are focused not only on water resources quality, but also on water resources conservation; as a result, modern and efficient water management techniques have been incorporated. However, only a small proportion of the airport in the sample have already considered water recycling as an option; in addition, it is thought to be the least important issue to consider.

In the end, it should be noted that the analysis of the applied environmental strategies and therefore airports' environmental management priorities, depends in many cases mostly on the airport's location, that determines not only the geological and environmental status of the area, but also applied environmental legislation and restrictions that can set high standards to quality issues. Therefore, airports that are located in countries that have applied specific environmental restrictions regarding air, water or soil quality are expected to have applied more detailed measures to meet the terms of these standards. However, besides setting air, water or soil quality limits the environmental strategy encompasses airport's willingness to act in a responsible manner and this should be taken into consideration in relevant evaluation frameworks.

7. Conclusions

Regarding environmental management, the greatest challenge that airport operators face is to incorporate a sustainable strategy, to cope with expected traffic growth, whilst at the same time successfully managing sustainability and other environmental issues that may act as capacity constraints.

The evaluation framework, regarding the applied environmental strategies, is mainly based on the efforts that airports make to minimise their environmental impact, taking into account the importance of certain environmental issues, as it is recognised by airport management.

To define applied strategies, a three step assessment was selected; thus, airport industry's response in regards to a) global and local environmental issues, b) consumption and pollution issues and c) energy and water consumption issues was assessed. The developed framework identifies three main categories of strategies, relative to environmental issues; in addition, nine rating symbols are used, ranging from those used to designate sustainable strategies to those implying unsustainable ones.

The research's results indicate that airports' environmental strategies can be defined not only by using rates that regard the use of resources, the recycled rates or the emitted pollutants but also incorporating in the framework the airports' willingness to act in a responsible manner, as this is expressed through their efforts towards a sustainable environmental growth.

Based on the results so far, none of the airports presents the strongest strategy relative to environmental issues, implying that improvements that mostly regard carbon management, energy and water consumption need to be made. It is noteworthy that while 75% of the airport sample presents a carbon footprint, only 60% have joined a carbon accreditation scheme and have managed to reduce carbon emissions compared to the previous year; additionally, currently there is just one carbon neutral airport and only 20% have set a target to become carbon neutral until 2020. Quite the same applies to energy issues.

Airports that have annual passenger traffic of more than 10 millions consider managing their climate change impact as a key concern; this, along with the fact that airports with annual passenger traffic between 10-25 millions present a coherent and well defined environmental strategy, indicate that size is a significant factor that probably determines the ease with which these measures are implemented.

Although most of the airports present a balanced environmental strategy in regards to measures applied to control or compensate for local and global environmental issues, in the case of consumption control a different pattern exists; depending on the airport's location a clear preference on water or energy consumption control measures is noted. Thus, most airports located in southern Europe appear to make efforts to improve mostly in their water efficiency, while most northern European airports make efforts to improve mostly in their energy efficiency. This implies that the location of the airport that sets the meteorological, geological, hydrological and environmental framework determines not only energy and water demand but also the water availability and the potential of renewable energy use.

To analyse how well an airport uses and controls water resources, a ratio evaluation model is developed, providing not only the annual total and potable water consumption, but also the recycling rate and a comparison to the previous years. An improvement in the ratios implies respective improvement in the related water management efficiency.

The research results indicate that although some airports have applied sufficient water conservation measures, for at least three years, only 35% have achieved a reduction in their total water consumption; 50% have managed to reduce the annual drinking water consumption. The latter suggests that even though recycling is not yet a commonly applied practice, effective potable water consumption control solutions are currently examined. In addition, airports that are located in southern Europe appear to make efforts to improve their water efficiency, through water efficient infrastructure or water recycling. On the contrary, airports located in northern Europe, where water availability is not an issue, focus their efforts mostly on waste water and runoffs management, especially during the winter period, when de-icing and anti-icing agents are frequently used; even so, these airports present water consumption efficiency.

Recommendations for further research

In general, even-though an evaluation framework could enable airports to achieve a degree of outstanding environmental performance, most of the airports do not apply common environmental reporting procedures. The main recommendation of this research to the airport industry is the development of a common reporting system for all environmental management topics. This system will be useful to set goals and adapt airports' strategies to accomplish them; in addition, this system will be useful for the researchers as it will provide data for further environmental management research.

Another recommendation is the application of the developed framework in a larger airport sample, enabling comparison with non-European airports. This may provide more detailed results for the airport industry, at a national or international level. In addition, the evaluation framework could include either more sustainability topics (e.g. efficient terminal planning, land use control, biodiversity) or the applied topics choosing more detailed evaluation criteria. Also, the incorporation of environmental performance indicators (e.g. energy consumption (kWh/pax), carbon footprint (tn/pax), water consumption (lt/pax), waste generation (kg/pax), noise (number of complaints/aircraft movements), NO_2 concentration (μg/pax), public transport share (%), recycling rate (%)) could give useful results on performance issues. In addition, a comparison with other industries (e.g. energy, manufacture, agriculture, tourism etc) could provide significant outcomes as concerns applied environmental strategies in all industries.

At the end, as concerns airports' water management efficiency the development of an evaluation framework, that will take into consideration, amongst other issues, local hydrological, meteorological and hydrogeological data, water consumption sources, water demand, waste water quantity and quality, runoffs quantity and quality, local resources quality could provide useful information to planners and managers regarding the airport water efficiency.

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Appendix A

Questionnaire: Environmental Management Priorities

Airport:
Name:
Contact details:

The growing environmental sensitivity leads to discussion about airports' environmental management priorities. At the moment airport operators focus their interest on noise and local air pollution, as well as to measure and control climate change emissions.

1. How would you characterise your airport's strategic consideration of environmental issues during the past five years? Please rate taking into consideration the following rating scale:

1	2	3	4	5
Other considerations were much more important than environment		Environment was as important as other considerations		Environment was much more important than other considerations

2. What are the key measures, applications and procedures that have been applied to give this rate?

3. Please rate the following issues on airport environmental management priorities in terms of level of importance today and in the future:

1	2	3	4	5
Low		Medium		High

Key environmental issues		Now (up to date)	Future (2020)
1	Carbon emissions Carbon footprint and measures to reduce airport's carbon emissions		
2	Energy consumption Energy efficient infrastructure and energy demand reduction		
3	Water management Water consumption control and water management		
4	Waste management Waste minimization measures, recycling, hazardous waste management		
5	Air management Air quality related emissions monitoring and adapting measures to reduce emissions, Noise monitoring systems, noise abatement procedures, noise control measures		

4. Regarding local pollution control and quality, please rate the following issues in terms of level of importance in your airport management priorities:

1	2	3	4	5
Low		Medium		High

Local pollution control and quality management issues		Rate
1	Air quality Air quality related emissions monitoring and adapting measures to reduce emissions	
2	Noise Noise monitoring systems, noise abatement procedures, noise control measures	
3	Water Water consumption control, waste water & runoff management, water quality monitoring	
4	Waste Waste minimization measures, recycling, hazardous waste management	
5	Land use planning Land use planning in the airport area and in the airport vicinity to ensure that improper uses are prohibited	
6	Access systems Promotion of environmental friendly systems	
7	Biodiversity Measures to protect ecosystems and to promote biodiversity in areas where it does not impact on the safe aviation environment	

5. Regarding water consumption control and management, please rate the following issues in terms of level of importance in your airport management priorities:

1	2	3	4	5
Low		Medium		High

Water management		Rate
1	Water consumption control Water consumption measures at terminals	
2	Water recycle Use of recycled water (treated water, rainwater, greywater etc)	
3	Water management Sewage and wastewater management	
4	Runoff management Use and control runoffs, rainwater etc.	
5	Water quality Monitoring of surface and underground water quality, use of biologically degraded agents	

6. Do you have any further thoughts, comments or suggestions on water management at airports?

Thank you.