Carbon Management in Airports

by

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ABSTRACT

Airports are multi-stakeholder organizations that can be as complex to manage as small cities. Carbon emissions have begun to occupy an important place in airport environmental management plans. Proposed solutions to reduce carbon emissions from airports' landside and airside operations are diverse and contain different courses of action for emission sources located both on the ground and in the air. However, due to the complexity of airport governance, the implementation of carbon management policy faces technical, financial, and organizational challenges. Buildings, ground fleets, and ground support equipment (GSE) used at airports tend to be owned by different parties, including airlines, airports, and third-party sub-contractors, and the lack of coordination among those parties can be a challenge to developing emission-reduction goals. Emission-reduction goals in airports require collaborative environmental management, including emission monitoring, and designated personnel who can supervise the progress of the policy's implementation. The study conducted for this thesis examined the following topics:

- The ways airports report and monitor carbon emissions
- Airports' perceived environmental management priorities
- Constraints on carbon management in airports
- Currently incorporated elements of collaborative carbon management in airports.

The study involved two parts. The first part is a review of current GHG emission reports published by airports, and the second part is an internet-based survey that was sent to airports. The analysis conducted for part 1 (reported in chapter 2) reveals the need for new harmonized GHG reporting standards for airports that better reflect the technological interdependence between airplanes and airports. The findings of part 2 (reported in chapter 3), based on the responses received from airports (n=31), reveal a growing willingness to allocate more resources to reduce carbon emissions in airports, in addition to constraints on carbon management. The constraints are in the form of lack of government regulation that requires airport authorities to engage tenants in the carbon management process, lack of access to tenants' emission data, and high costs of implementing technological solutions currently available for carbon reduction. The results highlight the importance of developing strategies to address carbon emissions in inter-organizational levels.

PREFACE

This dissertation is an original intellectual product of the author, Yaron Cohen. The survey reported in Chapters 3 was covered by UBC Ethics Certificate number H15-00376.

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LIST OF ACRONYMS

ACA Airport Carbon Accreditation

ACI Airport Council International

ACI-NA Airport Council International, North America

ACRP Airport Cooperative Research Program

APU Auxiliary Power Unit

ATC Air Traffic Control

BREEAM Building Research Establishment Environmental Assessment Methodology

EGSE Electric Ground Support Equipment

FAA Federal Aviation Administration

EU European Union

EU ETS European Union Emissions Trading Scheme

EV Electric Vehicle

GAV Ground Access Vehicles

GHG Greenhouse Gas

GSE Ground Support Equipment

LAQ Local Air Quality

LCA Life Cycle Assessment

LCC Low-Cost Carriers

LEED Leadership in Energy and Environmental Design

LTO Landing and Take-off

SOP Standard Operating Procedure

VFR Visiting Friends and Relatives

WBCSD World Business Council for Sustainable Development

WRI World Resources Institute

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1 - INTRODUCTION

1.1 BACKGROUND

Airports have been critical to the airline industry since the early days of aviation, and both technological systems, airports and airplanes are mutually dependent (Grübler, 1998). Airline deregulations in the US and the EU have contributed to the rapid transformation of the air travel and it is hard to imagine travelling over long distances internationally and domestically without jet airplanes (Freeman, 1978; Grübler, 1998; Nilsson, 2009; Perl, 1998). In 2013 alone, airlines carried 3.1 billion people and 50 million tonnes of freight on scheduled services worldwide. Passenger traffic is expected to grow at an average rate of 4.8% per year through the year 2036, most of that growth will occur in developing countries (IATA, 2014; ICAO, 2010) . In accordance with the demand, the airport industry has an important role in the global economy. In the US alone, 490 commercial airports supported 10.5 million jobs, and created revenues of $365 billion in the year of 2012 (Airport Council International - North America, 2012).

As cities have geographically expanded, airports and cities are now physically closer than ever before, a trend that has led to impacts on the environment and on nearby communities, in the form of noise and local air pollution (Antweilier, 2013; Eurocontrol, 2015; Tumlin, 2012). Mandatory regulation, "NIMBY" groups, and legal class actions against airport noise have created a new reality for airports that want to maintain their economic activity while taking into account the needs of those who live nearby (City of Richmond Planning, 2009; Suau-sanchez, 2010; Vancouver Court, 2001b). In addition, recent studies have demonstrated the adverse impacts airports have on local air quality, respiratory, and cardiovascular problems in exposed populations (Simonetti, Maltagliati, & Manfrida, 2015; Walker, 2015). In response, airport authorities have formed departments dedicated to managing environmental concerns (or granted this responsibility to other departments), and started hiring internal and external specialists who can help respond these new environmental challenges that airports face (Antweilier, 2013; GTAA, 2013; The Port Authority of New York and New Jersey, 2013; YVR Airport Authority, 2008). Figure 1 is a concept map that describes how environmental management was evolved in airports, in response to a growing number of airplane movements, and closer geographic proximity between airports and cities' municipal boundaries.

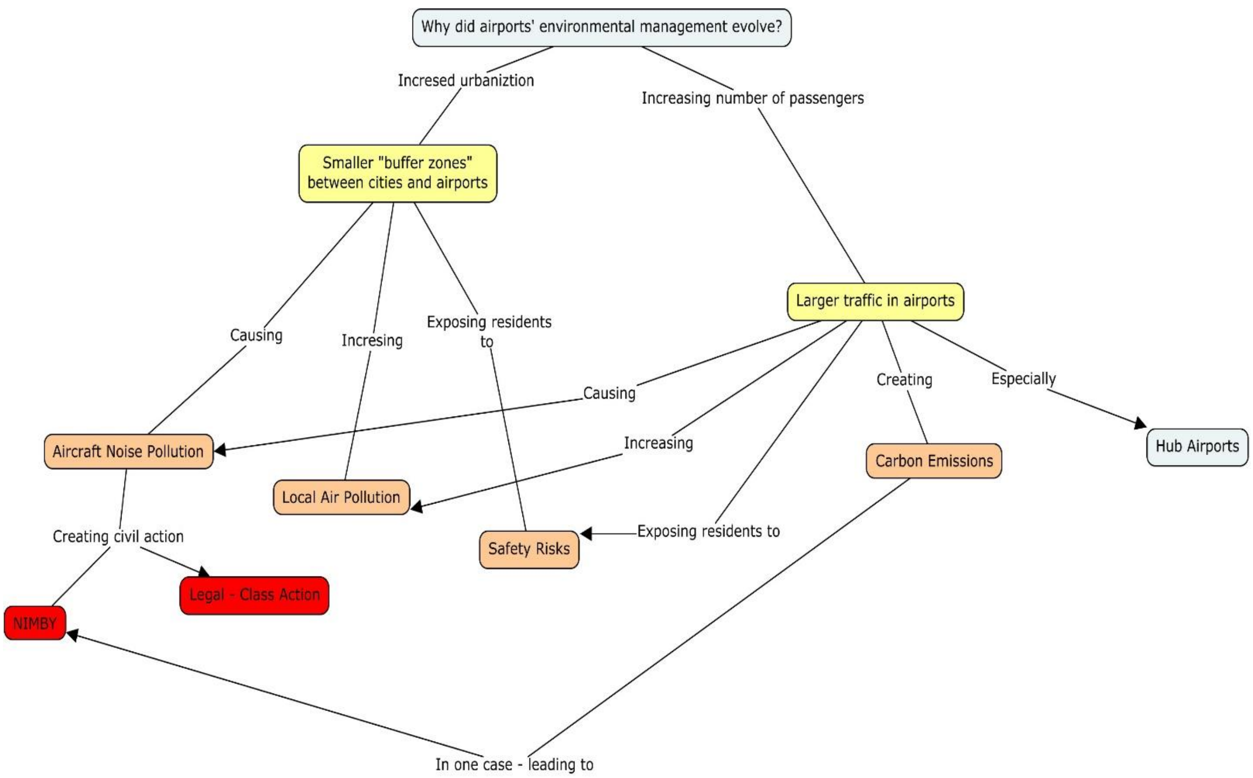

Figure 1 - Concept map explaining how airports' environmental management evolved

Carbon emissions are an emerging concern for airports. Airports, being a part of the aviation sector, have started incorporating carbon-reduction targets into their environmental management plans in the past few years. The establishment of the Airport Carbon Accreditation program (ACA) by Airport Council International – Europe (ACI-Europe) in 2009 contributed to greater awareness, and has provided airports with clear guidance on how to monitor and manage carbon emissions and gain accreditation for their endeavors (ACRP, 2009; Airport Council International, 2014b; Airports Council International, 2010). Aviation contributes about 3% to the global anthropogenic GHG emissions, and since air-travel is a fast-growing sector in an interconnected world that enhances patterns of hypermobility, it is anticipated that the sector's contribution will increase in the near future (Stefan Gössling, Ceron, Dubois, & Hall, 2009; Stefan Gössling & Upham, 2009; ICAO, 2010).

Carbon management in airports faces two key challenges. The first challenge is the global nature of carbon emissions. While noise and local air pollution affect locally, carbon emissions have more abstract global effects (Stefan Gössling & Upham, 2009). As a result, airports, for the most part, do not face immediate resistance from residents living nearby in regards to their carbon emissions, and have less of an incentive to respond quickly. However, concerns are growing and there has been one documented case of a projected airport expansion (London-Heathrow) that was stopped due to a climate campaign, and that case might be replicated in other places (Hayden, 2014). The second challenge is related to the inter-organizational structure of most contemporary airports. Historically, airports saw themselves serving only one type of clients, airlines, in order to stimulate aviation growth (Perl, 1998). Nowadays, however, airports see themselves as a two-sided 'platform' that serves two types of clients – the airlines and their passengers (Gillen, 2010). In order to serve the needs of both airlines and passengers, an increasing number of tenants have become involved in airport operations. For instance, airlines are sometimes served by their own ground teams during their airplanes "turnaround" times in airports (the time dedicated for an airplane maintenance on the ground), and sometimes by third parties that specialize in providing airlines with ground services using Ground Support Equipment (GSE), in case an airline has no ground team in a particular airport (Davidson, 2006;

International Association of Airports Executives Canada, 2014; Kazda & Caves, 2000). Passengers are offered a broad range of services, such as retail shopping, food, hotels, parking, and ground transportation. As a result of this, non-aeronautical revenues at airports are nearly as high as aeronautical revenues in North American airports (ACI-North America, 2013; Zenglein & Müller, 2007). The involvement of different parties in airport operation requires inter-organizational coordination in order to achieve efficient carbon monitoring and management, since those parties might have different economic goals, and they all own carbon emission sources.

1.2 RESEARCH OBJECTIVES

The objectives of this study are to:

- Understand the way airport authorities monitor and report their carbon emissions, in accordance with the organizational GHG accounting methodology.
- Identify perceived environmental management priorities for airports (including those related to carbon management).
- Identify perceived barriers for carbon management in airports.
- Identify which elements of collaborative management are already incorporated in airports' environmental management plans.

1.3 METHODOLOGY

This study takes a mixed-method approach to understand the way airports manage carbon emissions. Using a predefined list of the 100 busiest airports around the world by passenger volume (published by ACI-World), a study on the manner in which airports report their GHG inventories was conducted by reviewing publicly available airport environmental reports published online in the English language. The results of this study provided an indication of the potential barriers and constraints on airport carbon management.

The second part of the study included an internet-based survey that was designed around the available literature and the results of part 1. The survey was distributed to airport managers in North America and around the world with the help of ACI-NA, ACI-World, and the airport department of the FAA. The internet-based survey sought to elicit both quantitative and qualitative information (see Appendix C). The survey was aimed at learning how airport authorities manage carbon emissions together with their tenants, and the kind of challenges they encounter in forming inter-organizational collaboration on carbon management. Figure 2 summarizes the methodology of the entire study using a flowchart.

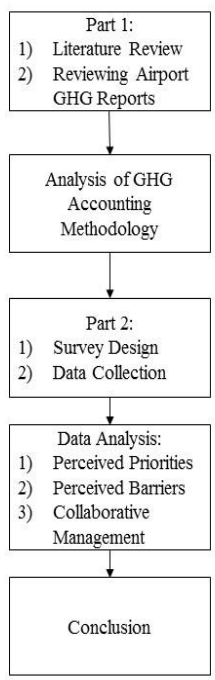

Figure 2 - A flowchart of the study's methodology

The study focuses on airports for two reason. The first reason is the complexity of airport management that requires inter-organizational collaboration in all aspects (Buuren, Boons, & Teisman, 2012; de Arruda, Weigang, & Milea, 2015; Fields, Amaldi, & Tassi, 2005). It is interesting to study how carbon emissions are managed in an inter-organizational level and to examine the challenges that can occur when several parties are involved. For this reason, airports provide a good environment to study inter-organizational carbon management. The second reason is the ongoing negotiations moderated by the International Commercial Aviation Organization (ICAO) to find a solution to the problem of unregulated GHG emissions from international aviation (EuroActive, 2014; Keating, 2013). Due to the technological interdependence of airports and airplanes, airports can play a role and be part of the global solution (Grübler, 1998).

This thesis contributes to our understanding of the way airports are currently managing their carbon emissions together with their tenants in order to inform governmental and non-governmental organizations that take part in the airports and the aviation community. It shows that challenges to carbon management in airports can be found in every one of the stages involved in environmental management, from understanding how to attribute carbon emissions to different parties involved in airport operations, to financial costs of currently available technological solutions.

2 - CARBON MANAGEMENT IN COMPLEX AIRPORTS– INDICATION AND ANALYSIS OF THE CURRENT SITUATION

2.1 INTRODUCTION

In the years before the two main airline deregulations that occurred in two different parts of the world (The US – 1978, Europe 1987-1993) airports saw themselves primarily serving airlines as their main clients, offering the lowest possible operations costs, while air-travel passengers were given a lower priority than airlines (Perl, 1998). Airline deregulations, however, led to a bigger competition and general growth in the air-travel sector in both the US and the EU markets, especially with the introduction of Low-Cost Carriers (LCCs), such as Southwest Airlines in the US, EasyJet, and Ryanair in Europe (Francis, Fidato, & Humphreys, 2003; Freeman, 1978; Nilsson, 2009; Scharpenseel, 2002). In addition, airline deregulations made the hub-and-spoke model popular, causing the emergence of several hub airports around the world that deal with extremely large volumes of passengers, in some cases up to approximately 90 million passengers annually (Gillen, 2010; The Port Authority of New York and New Jersey, 2014). As a result, airports started seeing themselves as a two-sided market serving two types of customers, airlines and passengers, and their organizational structure became more complex to enable an efficient service for both airlines and passengers (Gillen, 2010).

The new situation is reflected in the revenue model of many airport authorities. For instance, in North America, airports' non-aeronautical revenues (e.g. retail, food, hotels, parking, and ground transportation) are almost as high as aeronautical revenues in the recent years (ACI-North America, 2013; Zenglein & Müller, 2007). On the one hand, airport authorities hope to attract new airline carriers in order to offer a wide variety of connections to new destinations to their potential passengers, while increasing the catchment area as well as the aeronautical revenues

(IATA, 2013; Lieshout, 2012; Tae H. & Fu, 2008). Airports are primarily dependent on sufficient passenger volumes, and in the absence of passengers, airports can find themselves out of business, turning into “ghost” airports (Kalis, 2015). In both Europe and the US, oversupply of previously-owned military airports has led to fierce competition, especially amongst regional airports. Increased competition has led to a race for attracting airlines and LCCs in order to compete with bigger airports in the same region or in nearby neighbouring countries (CTV, 2014; Nilsson, 2009). Linguistic definitions of airports support the claim. The Oxford dictionary defines airports as a “complex of runways and buildings for the take-off, landing, and maintenance of civil aircraft, with facilities for passengers” (Oxford Dictionaries Online, 2015a). The definition emphasizes the main function served by airports, flights. The Merriam-Webster dictionary’s definition is quite similar, and emphasizes the same function: “a place from which aircraft operate that usually has paved runways and maintenance facilities and often serves as a terminal” (Merriam-Webster Online, 2015).

On the other hand, in order to keep up their economic competitiveness, airports create new forms of non-aeronautical revenues, most often by using their land reserves. For example, some airports may offer access to retail stores to reduce dependence on regular aviation business cycles (Meiszner, 2014; YVR Airport Authority, 2014c). Other airports offer high-speed rail connections to a network of relatively close destinations, forming air-rail integration (Air France, 2014; Costa, 2012; Givoni & Banister, 2006; Shnell & Mandel, 2010). The air-freight transport revolution that occurred in the 1980s , whose demand further increased with the emergence of E-commerce, is an additional source of revenue for airports that profit from co-located warehouses and distribution centers (Gilbert & Perl, 2010; Nieberger, 2009). These sources of non-aeronautical revenues tend to enlarge the geographical boundaries of airports, turning them into airport-cities that involve elements of urban planning (Kasarda, 2014).

An airport's inter-organizational expansion creates a complex reality for airport authorities in terms of governance structure, since these airports contain a growing number of specialized tenants that serve both airlines and passengers. Airport authorities that are often the leading organization in charge of airports have to coordinate inter-organizational efforts in order to successfully implement economic and environmental policies, dealing with different parties that might sometimes have different interests (Alexander, 1993; Buuren et al., 2012).

This chapter examines the problem of carbon dioxide emissions from the airline industry in general and airports in particular, assessing existing data from airports in order to understand how airports respond to calls for carbon emissions management and reduction. The focus of this chapter is on the role and importance of greenhouse gas accounting methodologies in the airport industry.

2.2 GREENHOUSE GAS EMISSIONS, AIR-TRAVEL, AND AIRPORTS

Greenhouse gas (GHG) emissions are one of the most prominent negative externalities of air-travel, together with aircraft noise, and local air pollution (Eurocontrol, 2015; Stefan Gössling & Upham, 2009; ICAO, 2010). Unlike aircraft noise and local air pollution that affect only airports' surrounding communities, GHG emissions have global consequences. Aviation contributes about 3% to the global anthropogenic GHG emissions, while two-thirds of aviation emissions can be attributed to international flights (Stefan Gössling & Upham, 2009; ICAO, 2010). While the contribution of aviation to the global anthropogenic GHG emissions is relatively low, because air-travel is a fast-growing sector in an interconnected world that enhances patterns of hypermobility, it is anticipated that the sector's contribution will increase in the near future (Stefan Gössling et al., 2009).

Passenger traffic is expected to grow at an average rate of 4.8% per year through the year 2036, due to growth in tourism, visiting friends and relatives (VFR), and other activities that require rapid means of long-distance travel, with the highest growth projected to occur in East Asia (Backer, 2008; IATA, 2015; ICAO, 2010; UNWTO, 2014). In addition, the impact of those emissions caused in high altitudes (the lower stratosphere and the upper troposphere) may be multiplied by a factor of 2, due to altitude effects of non- CO_2 gases realised by aircrafts (Grassl & Brockhagen, 2007; IPCC, 1999).

Using the current ICAO methodology to calculate GHG emissions from flights (ICAO, 2014), it is found that air-travel, especially long-haul flights, is carbon-intensive on a per passenger basis. For instance, a passenger taking a round trip in economy class from London-Heathrow airport to Hong Kong will generate an average of 1,347 Kg of CO_2 (1.34 metric tonne), accounting for the current type of aircrafts used on the route, passenger load factor, and passenger to freight factor (ICAO, 2015). This quantity is almost the same as the annual amount of CO_2 emissions *generated per capita* in developing countries such as Moldova, Armenia, Columbia, and Vietnam in the years 2010-2014, with ranges of 1.4-1.7 metric tonne of CO_2 (The World Bank, 2015). Another example of the carbon intensity of transporting people and goods over long distances, can be found in a Life-Cycle Assessment (LCA) study that looks at products' entire production and supply chain, and analyzes the energy intensity of each component, with air-transportation being significantly more energy-intensive than other means of transport, creating high amount of CO_2 emissions as a result (Gleick & Cooley, 2009).

The attempts to deal with GHG emissions from air-travel have been regional and international in scope. The European Union has included airlines in the list of emitters under the EU ETS in 2012 (European Comission - Climate Action, 2012). The purpose of that inclusion was to establish a cap-and-trade program as a cornerstone for a global trading scheme. However, for a number of reasons including the lack of trust in the EU carbon market and the plummeting price of coal, the price of one carbon credit collapsed from 30 Euros in 2008 to 3 Euros in 2013 (Heinemann, 2013). This price is too low to have any effect, and the framework of a new market-based mechanism for the global aviation sector will need to be carefully designed if it is to influence consumption-driven and service-oriented air-travel (Grübler, 1998). The 2013 negotiations at the ICAO headquarters to create a global mechanism to mitigate GHG emissions from international flights resolved in an agreement to reach a deal for a global market-based mechanism by 2016 that will take effect in 2020 (EuroActive, 2014; Keating, 2013; Pardee & Hemmings, 2015).

Airports contribute around 5% of the overall aviation CO_2 emissions. CO_2 is the most prevalent greenhouse gas generated by airports, since 95% of the GHG emissions from airports, are CO_2 emissions (Airport Council International, 2014b). Airports' emission sources that are geographically located within the control boundaries of an airport can be either stationary (e.g. boilers in terminal buildings, power plants), or mobile, such as GSE fleets, aircrafts taxiing, and aircrafts being in different phases of their landing and taking off cycle (LTO) (Airports Council International, 2010). Even though the contribution of airports to the total GHG emissions from aviation is small, it is still important to address it for two main reasons:

1. Technological interdependence – air-travel would not be able to exist without airports (and vice-versa), since aircrafts need runways on which they can land and from which

they can take off , and other technical capabilities that are provided by airports (Grübler, 1998; Hornojeff, Mckelvey, Sproule, & Young, 2010). In addition, passengers and cargo need to go through several processes before they can board or be loaded on an airplane. Those types of operations are managed collectively by airport authorities, airlines, and third-party service providers, and their success depends upon the mutual contribution of each party (Buuren et al., 2012; Gillen, 2010; Poirier, Rakas, & Perry, 2007). Therefore, we believe that airports could share the responsibility for air-travel emissions together with airlines, since airport-level initiatives can help mitigating aviation CO_2 emissions to some extent.

2. Domestic Scale Impact - Main hub airports that serve large volume of passengers annually, can generate CO_2 emissions that are as high as the ones generated by medium-sized cities (Vey & Forman, 2002). For instance, Frankfurt international airport generated roughly 1.728 million tonnes of CO2 emissions in 2013 (including the emissions generated by airplanes' LTO cycle), and was ranked the world's 12 busiest airport by passenger volume that year, serving 58,036,948 passengers (Fraport, 2014; The Port Authority of New York and New Jersey, 2014). The CO_2 emissions generated by Frankfurt airport were slightly higher than the CO2 emissions generated by the entire city of Kingston, Ontario in Canada in 2011, roughly 1.498 million tonnes of CO_2 emissions, with a population of 141,393 inhabitants (TriEdge & Associates, 2012). When setting emission reductions targets on regional or national levels, it is important for policy makers and planners to account for the CO_2 emissions generated by main hub airports in

their territory, region, and national borders, since these airports can generate significant volumes of GHG emissions that affect the entire local GHG emissions inventory.

Contemporary organizational theories describe organizations as open-systems that are influenced strongly by their environments and adapt to it (Mcfarland & Gomez, 2014; Scott, 2003). In the case of airports, there are two types of external drivers that can influence an airport's operator to measure and manage its carbon emissions: regulatory, and voluntary (Airports Council International, 2010). International, national, and sub-national regulation on carbon monitoring and management can be considered a regulatory driver. A good example is the US mandatory GHG reporting for facilities that emit 25 metric tonnes or more of CO_2 equivalent emissions per year to submit annual reports starting in 2011, and mandated by the US Environmental Protection Agency (EPA) (EPA, 2015).

Voluntary drivers can be either in the form of incentives to reduce and manage carbon emissions or disincentives to expand an airport's traffic in a way that can increase the total GHG emissions significantly. One of the incentives for airports to manage and reduce carbon emissions is an eco-certification provided by the program of Airport Carbon Accreditation (ACA) run by Airport Council International – Europe (ACI-Europe) (Airport Council International, 2014b). The program started in 2009 in Europe and was expanded to the Asia-Pacific region in 2011, allowing airports to be accredited in different levels, due to the processes they put in place to manage and reduce their carbon emissions (Airport Council International, 2014b). Another voluntary driver is reduced operating costs due to increased energy efficiency of an airport's stationary and mobile sources (Airports Council International, 2010; Zebra Enterprise Solutions, 2010). A disincentive to expand an airport's capacity could come in the form of activism against the expansion of runway capacity, given the possible future environmental implications. In the case of London-Heathrow airport, an aggressive campaign stopped, at least temporarily, the airport's planned expansion and the construction of a 3rd runway and the foreseeable induced demand, due to the implications it can have regarding the UK's total GHG emissions inventory (Hayden, 2014).

2.3 ORGANIZATIONAL GHG ACCOUNTING IN THE CASE OF AIRPORTS

Organisational GHG accounting is a method that helps quantifying the total GHG emissions generated directly and indirectly from an organisation's activities (Ecometrica, 2014). Based on this method, an organization can create an inventory of its emission sources and GHG emissions as a first step to report and manage climate change impacts by reducing GHG emissions, and tracking performance over time (GHG Managment Institute, 2008). Data is collected from primary and secondary sources, and the main source of guidance regarding the technical aspects of organizational GHG accounting can be found in the GHG Protocol which was developed by both the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) (Schmitz et al., 2000). In addition, the International Organization for Standardization (ISO) provides guidance on preparing GHG emissions inventory (ISO 14064 -1) at the organizational level (ISO, 2006).

Emission sources owned by organizations are classified by the GHG Protocol, and can be considered either sources of direct GHG emissions (Scope 1), or indirect GHG emissions (Scope 2 and 3). Direct emissions under scope 1 occur from sources that are owned or controlled by a company, such as vehicles, boilers, and furnaces, including leased assets (Schmitz et al., 2000). Scope 2 emissions are attributed to the generation of purchased electricity and/or heating , and Scope 3 emissions are attributed to other indirect sources, such as customers' vehicles entering a company's retail store, and employees' business travel (IKEA, 2013; Schmitz et al., 2000).

Since every industry or "class" of organizations has a different organizational structure and modes of operations, adaptations of the GHG Protocol have been made in order to give industry-specific guidance. In the case of airports, the major adaptation was done by the Airport Cooperative Research Program (ACRP) in 2009, in order to provides airports with methodology to calculate or estimate their GHG emissions, with further adaptation in an ACI manual in 2010 (ACRP, 2009; Airports Council International, 2010). Moreover, based on the adaptations, Transport Canada created a do-it-yourself airport GHG inventory tool called ACERT, together with its consultant EBA and the Canadian Airport Council (CAC), in order to facilitate the process for airports with budget constraints that do not allow them to have a dedicated personnel to deal with that task, especially in non-regulated cases (Airport Council International, 2014a).

According to the currently used methodology, airport's scope 1 ("direct emissions") can include sources that are owned or controlled by the governing entity of the airport, such as fleet vehicles, airport-owned GSE, diesel generator, and power plants, as well as activities performed by those entities, such as maintenance (cleaning, repairing, etc.) and waste disposal on-site (Airports Council International, 2010). Indirect emissions from scope 2 include purchased electricity and heating, while scope 3 includes other indirect emissions, such as aircraft LTO cycles, ground access vehicles (GAV), and tenants-owned GSE (Airports Council International, 2010). This recommendations were made by both ACI and ACRP reports about managing GHG emissions in airports, and they serve as guidance that is not strict, and that allow airports to report GHG emissions in areas where data is available. Figure 3 summarizes the sources of scope 1, 2, and 3 emissions in airports.

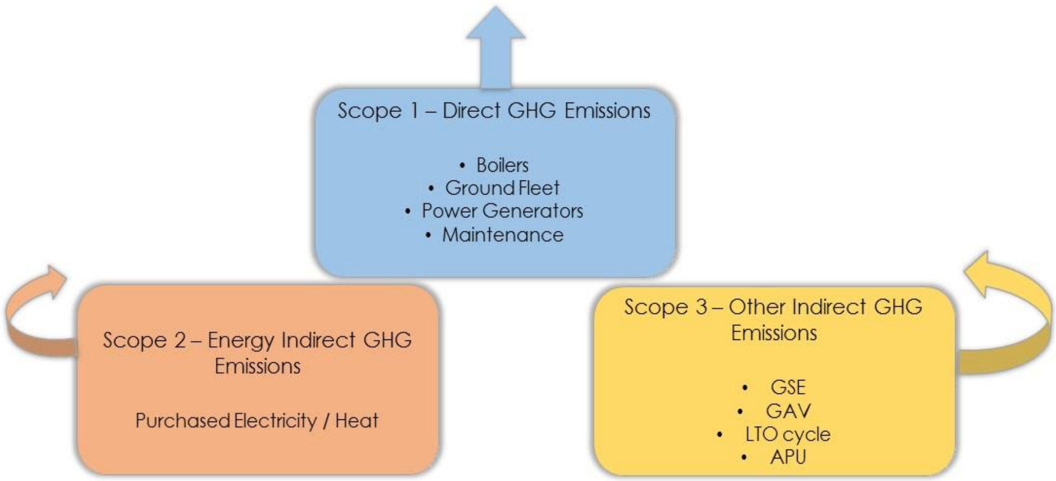

Figure 3 - Emission sources in airports by scope

2.4 DATA AVAILABILITY

The list of the top 100 busiest airports around the world by passenger volume for 2011 was obtained using a free database by Airport Council International (Rogers, 2012). Using these data, the 100 airports' websites were reviewed in order to look for publicly available information regarding their GHG emissions. Table 1 summarizes the distribution of these airports across the world's main geographic regions, and the number of online published reports about these airports' GHG emissions.

Region	Africa	Asia-Pacific	Europe	Latin America	Middle East	North America	Total
Number of airports	1	29	30	6	4	30	100
Published reports		5	17			9	31

Table 1 - Number of airports and online published reports by geographic region

As indicated in table 1, the vast majority of the world's top 100 busiest airports is concentrated in Europe, North America, and the Asia-Pacific regions. Of the 100 airports, 31 made their GHG inventories available online either as part of a broader sustainability reporting strategy or as an independent document, after conducting these inventories during 2009-2013 (See Appendix A). The highest proportion of airports reporting their GHG emissions online is in Europe, where roughly 57% of the airports reported their emissions and presented them online, followed by North America (30%) and, Asia-Pacific (17%). One limitation of this method might be the language barrier, since not all airports publish their reports in the English language.

An explanation for the high rate of GHG reporting in Europe is the voluntary airport carbon accreditation program (ACA) by ACI-Europe, that was initiated in 2009, and requires airports to report their GHG emissions in order to be accredited (Airport Council International, 2014b). Europe is the first region in the world to start a carbon accreditation program tailored specifically for airports, and in 2014, 85 airports in the continent were accredited in 4 different levels. In 2011, the program was expanded to the Asia-Pacific region by ACI, with 16 airports accredited in 2014 (Airport Council International, 2014b). In addition, 4 North American airports has already been accredited , and one African airport (ACA Website, 2015).

A brief explanation of the ACA levels of accreditation is as follows (Airport Council International, 2014b):

- Level 1 - requires to only map the GHG emissions generated by an airport's scope 1 and 2 emissions.
- Level 2 - requires setting emission reduction targets and showing evidence of improvement.
- Level 3 – requires to map GHG emissions including scope 1, 2, and 3, and a verified evidence of a stakeholder engagement plan.
- Level 3 + - requires offsetting GHG emissions generated from scope 1, and 2 by buying carbon offsets.

Table 2 shows the number of accredited airports by level of accreditation (1, 2, 3, 3+) of the 100 largest airports.

Accreditation Level	**1**	**2**	**3**	**3+**	**Total**
Number of Airports	5	10	15	4	33

Table 2 - Number of accredited airports by level of accreditation

Of the 33 airports that were accredited with the ACA program in the period of 2013-2014, 22 made their GHG inventories available online, 16 of them were in Europe (out of 17 airports that published their reports online), 5 airports were in the Asia-Pacific region, and one airport in North America. Since the ACA program does not oblige airports to make their GHG inventories publicly available, a third of the airports (11) did not make their reports available online, 10 airports in Europe, and 1 in the Asia-Pacific region. In addition, 10 non-accredited airports published their GHG inventories online, 9 airports in North America, as well as one European airport that was previously accredited but withdrew from the program.

Out of the 31 airports that made their GHG inventories publicly available online, 8 airports reported scope 1 and 2 emissions, 14 airports reported their scope 1, 2, and 3 emissions, and 9 airports reported only the total GHG emissions without providing a breakdown by scope. Scope 3 is more difficult to track because it requires collaboration with other parties outside the organization to some degree, and in the case of airports it can include airlines, and 3rd party service providers (ACRP, 2009). Out of the 14 airports that published scope 3 emissions, 6 airports were not accredited with the ACA program (5 North American airports, and 1 European airport), 5 airports were accredited in level 3, and 3 airports were accredited in level 3+ (both levels require tracking scope 3 emissions). In addition, 5 more airports are accredited in level 3 and 3+ but did not publish their GHG reports online. Therefore, we can assume that 19 of the world's largest airports know their tenants' emissions, and even engage them to some extent in ways to reduce these emissions.

The definition of scope 3 is flexible, and airports as well as other organizations can choose what sources to include in reports. 11 airports provided a breakdown of their scope 3 emissions, as depicted in table 3.

RANK	Airport	Passengers 2011	APU	GSE	GAV	LTO
1	ATLANTA GA, US (ATL)	92365860	Yes	Yes	Yes	Yes
3	LONDON, GB (LHR)	69433565				Yes
9	FRANKFURT, DE (FRA)	56436255			Yes	Yes
27	MUNICH, DE (MUC)	37763701	Yes		Yes	Yes
37	NEWARK NJ, US (EWR)	33577154	Yes		Yes	Yes
40	MINNEAPOLIS MN, US (MSP)	33074443	Yes	Yes	Yes	Yes
43	PHILADELPHIA PA, US (PHL)	30839130	Yes	Yes	Yes	
48	BOSTON MA, US (BOS)	28866313	Yes	Yes	Yes	
62	COPENHAGEN, DK (CPH)	22673477	Yes	Yes	Yes	Yes
67	OSLO, NO (OSL)	21092873			Yes	Yes
97	HELSINKI, FI (HEL)	14851675		Yes		Yes
Total			7	6	9	9

Table 3 - Scope 3 emission sources published by airports

A large number of airports reported their emissions from Ground Access Vehicles (GAV) and Landing and Take Off cycles (LTO) possibly because it is easier to approximate those emissions without getting actual data from tenants , as in the case of tenants-owned GSE (ACRP, 2009). APU is still difficult to calculate, due to the technical challenges of distinguishing relevant emissions from the total aircraft emissions (ACRP, 2009).

2.5 ANALYSIS OF REPORTED AIRPORT EMISSIONS

Flights are considered carbon-intensive activity on a per passenger basis, and it is also reflected in carbon emissions from airports. Calculations from 7 large airports that self-reported their GHG emissions (See Appendix B) show that GHG emissions from LTO (Landing and Taking off) cycles account for more than 50% of the total GHG emissions generated by an airport on average, with a range between 44-70% of the total GHG emissions . Figure 4 shows the distribution of GHG emissions for scope 1 and 2 combined (S1+S2), Scope 3 excluding LTO cycles (S3) as well as LTO Cycles (LTO).

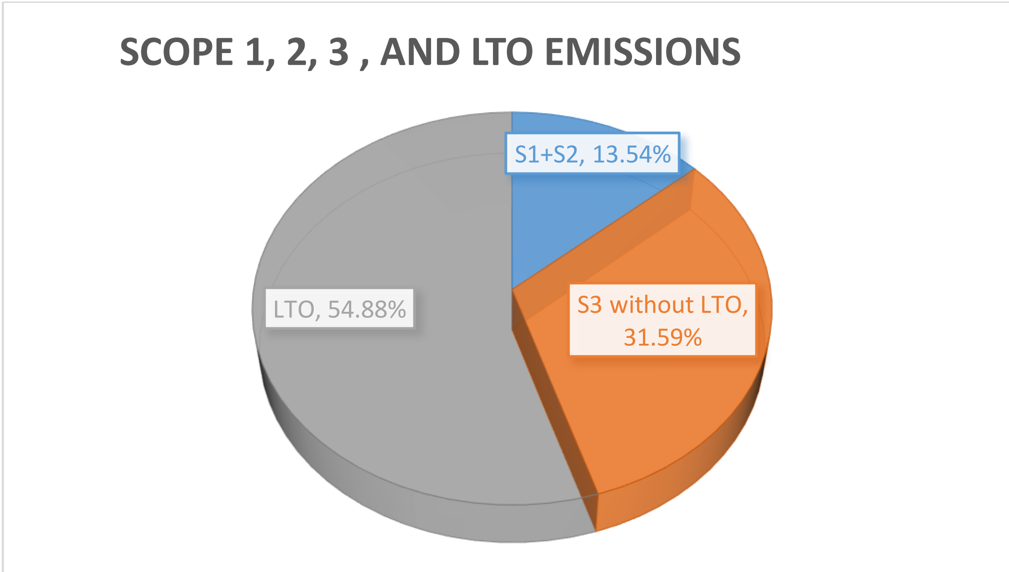

Figure 4 - Emissions from scope 1, 2, 3, and LTO cycle (Appendix B)

The industry-oriented literature about GHG management in airports sees LTO cycles as scope 3 emissions (“indirect emissions”) that cannot be influenced by an airport operator, with the exception of taxiing, where airports can still enforce standard operating procedures (SOPs) to reduce carbon emissions, such as single-engine taxiing (ACRP, 2009; Airports Council International, 2010). While reviewing data and literature for this chapter, it was noticeable that a few of the busiest airports in the world that included scope 3 emissions in their sustainability reports, reported their LTO-related emissions separately from any other scope, and did not even include them under scope 3 as suggested by the professional literature (Fraport, 2014; The Port Authority of New York and New Jersey, 2013).

The way carbon emissions are measured and reported in airports raises some serious questions about which emissions should be classified as airports’ direct emissions (scope 1). We would like to suggest a different approach and to examine if LTO cycles should be indeed included under scope 3 or under a different category. First, it is important to understand that organizations need to define their organizational boundaries in terms of emission sources in order to conduct a

GHG inventory. Chapter 3 in the GHG protocol defines the two consolidation approaches for defining organizational boundaries, the control approach, and the equity share approach (Schmitz et al., 2000). The GHG protocol mentions that the control approach is commonly used amongst industrial and commercial organizations, and only those organizations that have a more complex structure, such as electric generating companies or companies in the Oil and Gas industry, use the equity approach. Therefore, the assumption is that airports use the control approach that defines how to attribute emission sources: “Under the control approach, a company accounts for 100 percent of the GHG emissions from operations over which it has control”. This type of control can be either operational or financial (Schmitz et al., 2000). According to the GHG protocol, a company has operational control if it has the full authority to introduce and implement its operating policies at the operation. On top of defining organizational boundaries, organizations need to define their operational boundaries by classifying emission sources by scope 1, 2, and 3, as described by chapter 4 of the GHG protocol. Scope 1 refers to “sources that companies own or control”.

In accordance with the definitions above, further discussion regarding how to define emissions from LTO cycles is needed due to a few reasons.

First of all, airports especially small and regional ones, are dependent on aeronautical revenues to survive, and serving airlines is a major part of most airports’ business models. For instance, in the US, even though non-aeronautical revenues are almost as high as aeronautical revenues, they still account for 55% of a typical airport’s total revenues (ACI-North America, 2013). Small airports always compete and struggle to attract more air-carriers , since an unserved airport can turn into a “ghost airport” (Kalis, 2015). With that fact in mind, comes the understanding that airports do have control over the amount of arrivals and departures and routes served, as they are all subject to contracts that are signed with airlines. An analogy with city governments further reinforces this idea. City government GHG inventories include sources like cars owned by residents in order to capture the big picture and setting feasible reduction targets focused on key sources that generate GHG emissions (ICF International, Toronto Atmospheric Fund, & Toronto Environment Office, 2007). An emphasis on LTO-related emissions in GHG inventories is an appropriate focus because LTO emissions are the largest single source of airport emissions, aircraft movements are an integral part of airports' business model, and airport authorities can enforce specific standards for airplanes in terms of air-pollution (ACRP, 2009). Including LTO emissions in inventories would help make airports responsible for the largest category of emissions that clearly contributes to their business.

Secondly, when an airplane is still on the ground, taxiing with one engine ("single-engine taxiing) became an acceptable way of maneuvering an airplane on the ground while saving energy and fuel while reducing GHG emissions, and an airline or an airport authority can incorporate this standard operating procedure into their policies (AviationPros website, 2011). An airport authority can create a single-engine taxiing standard that is mandatory for all airlines served by the airport, or even tow all airplanes to and from the terminal buildings instead of using their engine power, using specialized push-back tractor such as the "Taxibot" used by Lufthansa in Frankfurt international airport (Airports Council International, 2010; Taxibot Website, 2015). It seems that on the ground, an airport authority can fully control the "emission sources", accounting for the current technologies available for airplanes in the market.

Lastly, in the air, when an aircraft is approaching an airport for landing, it is handed to air-traffic control (ATC) at an airport from the local air-navigation service provider (e.g. NAV Canada, Eurocontrol – EU), and they guide it towards landing, accounting for the weather conditions, and the traffic around the airport at any given moment (Hornojeff et al., 2010). Every airport has a different diameter for its controlled area, and it depends on many factors that are determined by aviation authorities in each and every country. For instance, in the US, the FAA defines the busiest airports as “Class B” that contains the area from the surface up to 10,000 feet (Faa, 2008). However, in Canada the definition for “Class C” by Transport Canada is slightly different, and it applies to the same activities of the LTO cycle below 12,500 feet above an aerodrome (Transport Canada, 2010). LTO cycles are normally considered every activity below 3000 feet, including taxi-in and out, take-off, climb-out, and approach-landing (Rypdal, 2001) . Therefore, the conclusion is that LTO cycles are contained in the geographic area controlled by an airport authority. Moreover, a few Canadian airports proactively respond to noise complaints that occur within a radius of 10 nautical miles (NM) around the airport (GTAA, 2013; YVR Airport Authority, 2014a). Noise is considered a classic airports-related environmental issue, and the same rule can be applied to GHG emissions that occur in that area, typically as a result of the LTO cycle. Environmental policy that will shift the responsibility for LTO cycles from scope 3 to scope 1 will put airport authorities in a situation in which they need to take responsibility for roughly 69% on average of their airport’s total GHG emissions, as shown by figure 5.

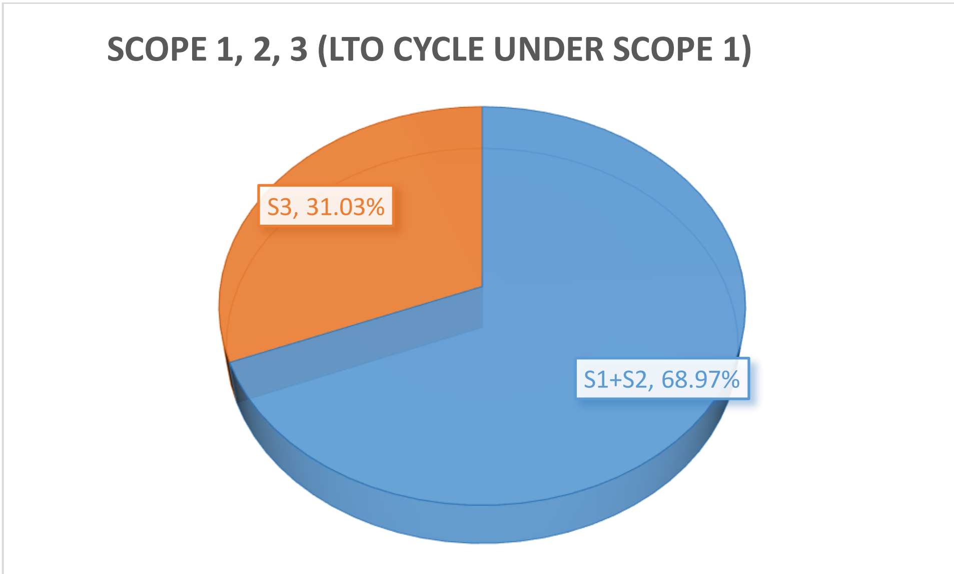

Figure 5 - Scope 1, 2, 3 emissions with LTO under scope 1

The characteristics of airports that are comprised of different organizations involved in operation processes will require a re-examination of the current GHG reporting practices. APU and GSE normally have a smaller contribution of GHG emissions out of the overall scope 3 emissions, and due to the lack of data, their influences couldn't be part of this study. It is recommended to look at those two areas in future studies, since they occur inside the geographic area of a typical airport, unlike the journeys of GAVs to and from airports, a situation that makes them a classic choice for indirect emissions under scope 3.

2.6 CONCLUSIONS

The results of the study serve as an indication of some organizational barriers for airport authorities to see the big picture when it comes to carbon management. Of the top 100 busiest airports in the world , only 31 airports made their GHG inventories online, and only 19 airports know their scope 3 emissions that represent GHG emissions generated by airports' tenants. When airports join the ACA program, many airports start with the basic levels (1 and 2) that do not require gathering data from their tenants (Airport Council International, 2014b). That situation might reflect an understanding within the environmental airport professionals' community that it can be difficult to gain access to information provided by tenants about their energy performance and GHG emissions. However, eco-certifications such as ACA can serve as a driver for collaborative carbon management in airports, since it requires some sort of collaboration from airports' tenants in order to move to level 3 and beyond (Airport Council International, 2014b). The diffusion of those airport specific standards matches Grübler's theory about the diffusion of new technologies that starts in an innovation center which is Europe in the case of ACA, while the periphery (or a subcenter) catches up faster but to smaller extent (Grübler, 1998). In Europe, where the program started in 2009, there were 85 accredited airports in 2014, while in Asia only 16 airports were accredited as well as one airport in Africa, since the program started running outside Europe a few years later (ACA Website, 2015).

It was noticeable from this work that different airports come up with different ways to define carbon emission sources, even within the same scope. For example, GAV (passenger traffic) was defined as "Travel to and from the airport by originating passengers, travel in private vehicles, and public transport" by one airport, and as "Public transportation" by another airport, both airports located in Germany (Fraport, 2014; Munich Airport, 2013). Therefore, unified reporting standards for airports that will take into account the current ambiguities should be developed, taking into account which sources should be under scope 1 or 3. Special attention should be given to LTO cycles as part of the overall global effort to come up with a solution to regulate GHG emissions from international aviation. By coming up with new reporting standards , it will be possible to make airports more involved in sharing the responsibilities for those LTO-related emissions that occur in their territory together with airlines, and even develop a benchmark for the industry in order to facilitate an ongoing improvement.

3 – CONSTRAINTS ON CARBON MANAGEMENT IN AIRPORTS

3.1 INTRODUCTION

Every organization requires an internal coordination amongst its functions to some degree, in order to achieve future goals, including GHG emission reduction. This study aims at understanding how airports manage their GHG emissions, in addition to understanding the challenges and constraints that they can face.

The word “constraint” that had the meaning of a “limitation or restriction” can be understood differently in specific contexts (Oxford Dictionaries Online, 2015b). According to Goldratt’s ‘Theory of Constraint’s, organizations face constraints that affect their performance, and can sometimes lead to outputs that are not optimal (Goldratt, 1998). According to the theory, in every organization there is at least one constraint that is defined as a “bottleneck”. The theory offers ways to deal with internal constraints in organizations by identifying those bottlenecks, and making decisions that exploit them and maximize the organization’s performance given those constraints (Goldratt, 1998). In addition, Goldratt argues that organizations normally face a small number of constraints, and not tens or hundreds.

The operational definitions of “organizational constraints” are somewhat broad and depend upon the context. For example, Kaefer & Bendoly (2004) evaluate the impact of organizational constraints which they defined as “technological compatibility” as well as “operational capacity” on the success of business-to-business E-commerce efforts (Kaefer & Bendoly, 2004). In the context of collaborative planning, organizational constraints refer to internal and external uncertainty, lack of coordinating units and lack of coordination between an organization’s functions in general (Windischer, Grote, Mathier, Meunier Martins, & Glardon, 2007).

Manimala, Jose, & Thomas (2006) define 15 organizational constraints on innovation and intrapreneurship in the public sector. The list included technical constraints (e.g. absence of failure-analysis systems), financial constraints (e.g. inadequacy of rewards and recognition), and constraints caused as a result of the organizational structure (e.g. lack of facility for pilot testing) (Manimala et al., 2006).

Airports, like all types of other public or private organizations, face their unique constraints in implementing policies aimed at reducing their GHG emissions. Here I classify these constraints into three categories: technical; financial; and organizational, and describe them below.

Technical constraints emerge from the built infrastructure of airports. Different airports are built in different forms, and serve different types of airplanes that require different types of ground fleets, terminal gates, runways, and aprons (Hornojeff et al., 2010; Poirier et al., 2007). Special attention should be given to specific vehicles that are used to serve airplanes on the ground (i.e. loading airplanes with cargo, food, and fuel), since they have their specific technical requirements in accordance with the type of airplanes they serve, and the distances they have to travel around certain types of airfields and runways. Moreover, an operations manager would need to take into account the weather in the airport's geographic zone. In Canada, for example, airside buses aren't common to transport passengers between terminals and airplanes, due to extreme weather conditions during the winter. Most airports use passenger bridges instead (International Assosciation of Airports Executives Canada, 2014). In addition, airplanes are required to go through de-icing processes through the winter in many European, Canadian, and American airports, and it requires additional equipment on the apron.

Different airplanes have different turnaround times, normally stated by the manufacturer. For instance, a turnaround time of a Boeing 747-8 (a wide-body aircraft) can take around 120 minutes, while the same process takes only 43 minutes for an Airbus-320 (a narrow-body aircraft) (Airbus, 2005; Boeing, 2012). A single change in one of the components (e.g. switching to hydrogen-fuel fleet) can result in an entire change of the fleet's supply chain, its "cluster", and an airport's organizational structure. Arnulf Grübler argues in his book "Technology and Global change" that in order to understand technological change, growth, and diffusion "one cannot only look at an artifact or product itself, but also has to look at the interaction with its surrounding environment, including interdependent technologies" (Grübler, 1998). For instance, an airport that is exploring an option to switch either part or its entire ground fleet to Electric Vehicles (EVs) will have to take into account working with a new supplier of EVs. Those new EVs might require different maintenance procedures. In addition, the airport authority or a third party service provider will have to install chargers for EVs, train their crews on how to use those vehicles on the apron, and plan their ground operations in advance. These 'network effects' can serve to constrain the decisions that airports can make.

The second type of constraint is linked to financial performance. The way airports are defined as economic and legal entities can influence their business models. For instance, Vancouver International Airport (YVR) is considered a private entity and is legally defined as a "not-for-profit organization" (YVR Airport Authority, 2014b) while other airports may be publicly or privately owned and funded (Janic, 2007). Some airports might have economic incentives, positive or negative, to become carbon efficient. In addition, airports have different sources of revenues, and the ratio between aeronautical and non-aeronautical revenues is different in each airport (ACI-North America, 2013). The sources of revenues and funds available to airports operating in a competitive world impact their ability to allocate a budget for carbon management.

The third type of constraints can be linked to airports' organizational structure and internal coordination. Coordination Theory tries to explain how good practices of coordination can be achieved, since "good coordination is sometimes invisible, and we mostly notice coordination when it's missing" (Malone & Crowston, 1990). The theory can be applied in many fields, from computer science, to linguistic, economics, and management (Malone & Crowston, 1993). The narrow definition of coordination is "managing interdependencies between activities performed to achieve a goal" (Malone & Crowston, 1990).

An instructive example of airline-airport interdependencies is provided by the experience of the Canadian airline WestJet. In Calgary airport, WestJet piloted a new type of electric baggage tug back in 2011. In the airline's website, WestJet reported the results:

"A new addition to WestJet's ground fleet is the rechargeable lithium polymer battery-powered baggage tug. Because the tug demonstrated excellent performance and reduced maintenance requirements, two electric tugs were subsequently positioned in Whitehorse in May 2012 to comply with the Whitehorse Airport directive to not operate petroleum based fuel-powered tugs in the airport's ground-level baggage areas." (WestJet, 2014).

This is an example of how an airline can manage its ground fleet and independently test new technologies to reduce its GHG emissions. The case of Whitehorse airport demonstrates how some airport authorities can enforce airlines and other tenants operating in their airports to adjust their GSE to a certain standard using policy tools.

This chapter aims at understanding how airports monitor and manage their carbon emissions together with their tenants, and what kind of constraints they can face, by surveying actual environmental departments located in airports.

3.2 METHOD

An online survey was designed to learn about carbon management in airports, and organizational constraints on carbon policies. The survey was distributed to environmental departments in airports (or other departments that were assigned that responsibility) that are mainly located in North America (US and Canada) but also in other parts of the world. The survey was distributed through ACI-World, ACI-NA, and the FAA-Airports Division.

The survey was developed in a way that addresses the structure of Environmental Management Systems (EMS): 1. Plan 2. Do 3. Check 4. Act, as stated by ISO 140001 standard (ISO, 2015). Respondents were asked about current and future policies in order to address the "plan" and "do" stages. In addition respondents were asked about their GHG monitoring processes in order to address the "check" and "act" stages.

Since airports can use one of four strategies mentioned as the "Four-pillar strategy" by ACI, the survey was designed to cover all options in order to learn about the implementation of these solutions to tackle the issue of carbon management and possible barriers for implementation (Airports Council International, 2010). The "Four-pillar strategy includes":

- Regulatory measures (standards) that can be enforced.
- Technical measures for installing different equipment pieces to monitor GHG emissions and increase energy efficiency.

- Operational measures for changing the operations of emission sources to increase efficiency.
- Economic measures for providing incentives for energy optimization.

Since the aim of this study is to understand organizational constraints as well as other barriers, the respondents were asked specific questions about elements of airport operations in airports that involved several parties, and where potential conflicts about the implementation of environmental policies may arise: a. Terminal building operations/renovation/construction b. electricity purchase/on-site production c. GSE operations d. GAV – ground vehicle access.

3.3 SAMPLE

An online survey was distributed to 45 airport authorities in North America and other geographic regions by both ACI-World and ACI-NA who targeted airports that already developed environmental management plans. In total, 31 surveys were received from environmental personnel in airport authorities (N=31). The topic of carbon management in airports is relatively new in both industry and academia, with a first guidance manual for airport authorities published in 2009, and it is assumed that only these airports who already take action to manage carbon emissions answered the survey (ACRP, 2009). The results were collected into an Excel spreadsheet, open ended answers were coded, and the data were analyzed using SPSS software.

3.3.1 Location, Governance Structure, and Type of Airport

The majority of airports that participated in the survey is located in North America (The US and Canada) totalling 26 airports, which accounts for 83.8% of all surveyed airports. Table 4 summarizes the respondents' location.

Location	Frequency	Percent	Cumulative Percent
USA	18	58	58
Canada	8	25.8	83.8
EU	2	6.5	90.2
Asia-Pacific	2	6.5	96.8
Africa	1	3.2	100
Total	31	100	

Table 4 – Geographic location of surveyed airports

Respondents were asked to choose the governance structure of their airports from the following options: 1. Government owned and operated 2. Government owned – privately operated 3. Independent – not-for-profit and 4. Private-for profit. Table 5 shows that the majority of the airports that participated in this study are government owned and operated – about 20 airports that account for 64.5% of the respondents of the survey.

Governance Structure	Frequency	Percent	Cumulative Percent
Government owned and operated	20	64.5	64.5
Government owned - Privately operated	4	12.9	77.4
Independent - Not-for-profit	5	16.1	93.5
Private - For Profit	2	6.5	100
Total	31	100	

Table 5 - Governance structure of surveyed airports

Respondents were also asked if they are considered a hub airport (primary or secondary) and which airlines use their airport as a hub. Of the 31 respondents, 18 airports considered themselves hubs, and 13 airports did not considered themselves hubs that serve any regional or international airline.

3.3.2 Number of Passengers and Tenants in 2014

Airports were asked to provide the total number of served passengers in 2014, as well as the number of tenants involved in the airport's operations. The range was between 125,000-71,000,000 passengers in 2014, with a mean of 22,397,078 passengers (See Appendix D). The number of tenants involved in operations (airlines, and small tenants) ranges between 0-230, with a mean of 43 tenants. In order to graphically show the positive correlation between the number of tenants and number of passenger, a new categorical variable was created for airports size. Airports that had less than 8 million passengers were classified as "small", airports with between 8 and 25 million passengers were classified as "medium", and airports that had more than 25 million passengers in 2014 were classified as "large" airports. The distribution of the new categorical variable was almost uniform, with 11 small airports, 9 medium airports, and 11 large airports.

Figure 6 shows the correlation between the airport's size, and the mean of the tenants' number. It is noticeable that the large airports that participated in the survey had a significantly higher number of tenants.

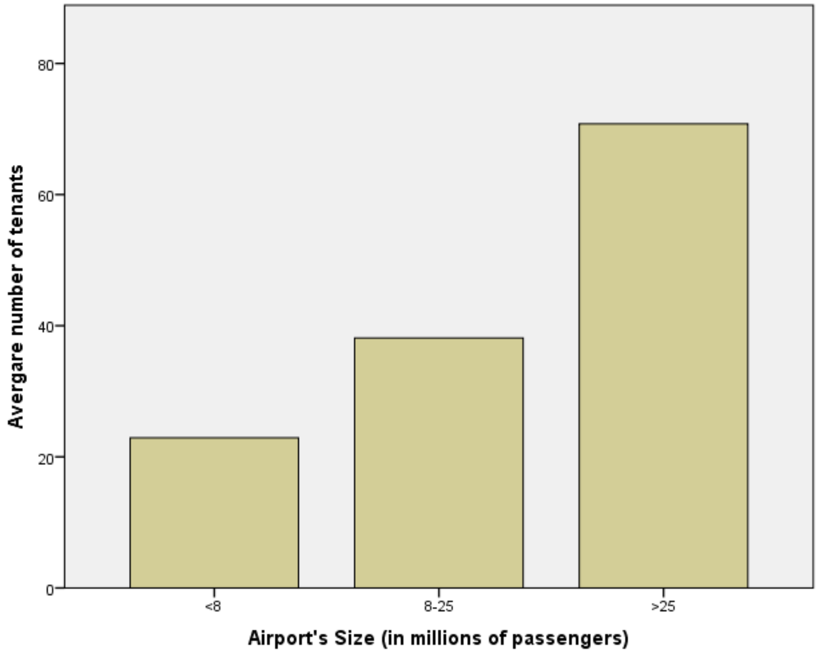

Figure 6 - Correlation between the number of passengers and tenants

3.4 RESULTS

3.4.1 Perceived Environmental Management Priorities

Understanding environmental management strategies that address all environmental issues is essential in understanding how airports manage their carbon emissions, and how important the issue is perceived by environmental departments in airports.

In order to understand how airports perceive their environmental priorities we asked them to rank four different options on a scale 1-4, with 1 being the most important priority, and 4 being the least important priority. The answers were exclusive, and airports could not give the same rank to two different priorities. In addition, since airports might have different priorities in their master plans for the future from what they have now, respondents were asked to rank the options two times, one time regarding their current policies, and a second time regarding their planned policies.

The options were given in the following order: 1. Aircraft Noise 2. Climate Change – Carbon Emissions 3. Local Air Quality 4. Third Party Risk (airplane accidents in nearby communities). The options given were based on the environmental section of the Eurocontrol website, since the definition includes carbon and emissions and 3rd party risk , both topics are relatively new to be dealt by airport authorities (Eurocontrol, 2015).Table 6 shows the results of this question (N=31) regarding both current and future policies.

Priority	**Current Policy**	**Future Policy**
1st	Aircraft Noise	Aircraft Noise
2nd	Local Air Quality	Local Air Quality
3rd	3rd Party Risk	Carbon Emissions
4th	Carbon Emissions	3rd Party Risks

Table 6 - Perceived environmental priorities in current and future policies

It is noticeable that the option “carbon emissions” was ranked as a lower priority in relation to both aircraft noise and local air quality, both in current and future policies. However, it seems that carbon emissions gets more attention in future policies, due to the fact that it is ranked as a 3rd priority in the future, rather than 4th. Another explanation could be linked to the fact that in North American airports, which were the majority of the respondents to this survey, 3rd party risk is not seen as an “environmental issue” per se and therefore, not dealt by environmental departments, while in Europe the situation is different and that could cause a misunderstanding (J. Bogusz, personal communication, May 29, 2015). Based on that perception, it is possible to explain the relatively low score that 3rd party risk received. Aircraft noise and local air quality

(LAQ) are both environmental issues that affect the surroundings of airports, and it therefore, makes sense to understand the higher rank that these two options consistently received regarding current and future policies. Figures 7 and 8 show the frequency of each environmental issue per each rank in current and future policies.

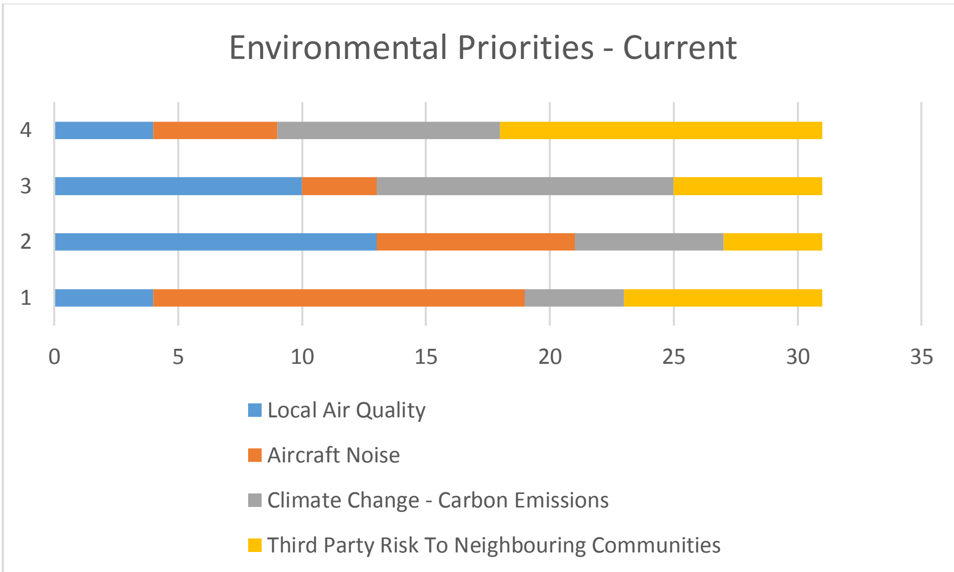

Figure 7 - Frequency of current environmental issues per rank

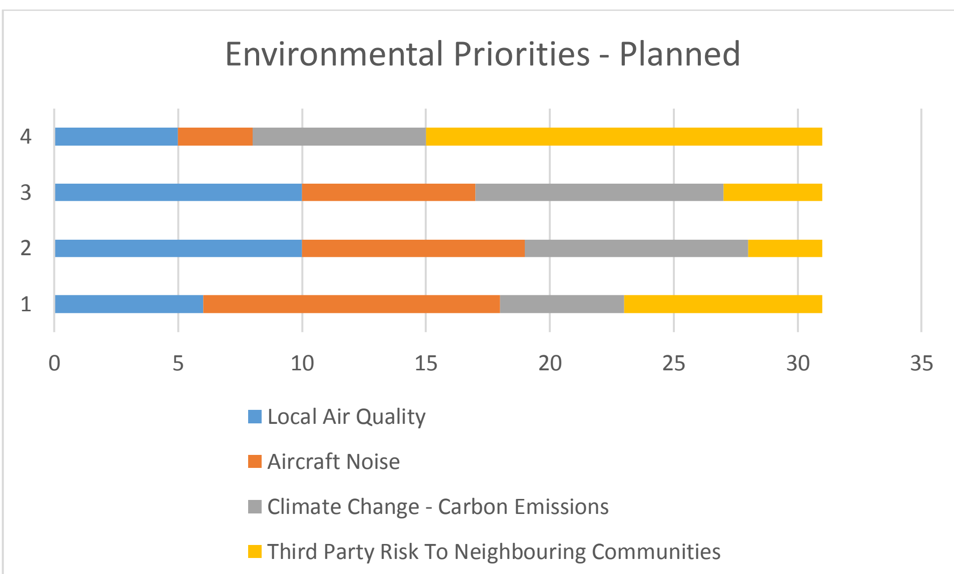

Figure 8 - Frequency of planned environmental issues per rank

The higher frequency of aircraft noise and LAQ in the first and the second place respectively for both current and planned policies, reinforces the findings presented in table 6 in regards to perceived environmental priorities. It is also noticeable that in current policies the issue of carbon emissions was more frequent as a 3rd and 4th priority, rather than in planned policies, where the issue was more frequent as a 3rd and 2nd priority.

Since respondents were asked to rank priorities regarding both current and future policies, we could use the statistical Kappa test to evaluate the level of internal agreement (consistency) between the ranks, the way past studies used to evaluate the level of agreement between two raters (Viera & Garrett, 2005). We treat answers about current and future policies as two "observers" for our case. Table 7 shows the kappa values that each option received.

Environmental Issue	Kappa Value
Aircraft Noise	0.493
Local Air Quality	0.504
Carbon Emissions	0.428
3rd Party Risk	0.668

Table 7 - Kappa Values showing agreement between current and future ranks of policy categories

The common interpretation of the kappa value sees values between 0.41 and 0.6 as a moderate agreement (Viera & Garrett, 2005). Aircraft noise, LAQ, and carbon emissions all received values in that range, with carbon emissions being the option with the lowest agreement, since several airports gave it a higher priority in their future policies. Values between 0.61 and 0.8 reflect a substantial agreement according to the literature (Viera & Garrett, 2005). The only option that got a value in that range is 3rd party risk, possibly since in North American airports, this issue is not considered purely "environmental" and is dealt in other departments, even though the level of agreement was high in both US and non-US airports (J. Bogusz, personal communication, May 29, 2015).

3.4.2 Perceived Barriers for Carbon Management

Carbon management in airports involves different parties, and in order to understand what the perceived barriers on collaborative carbon management are, respondents were asked the following open ended question: "What is the major barrier for working with tenants on GHG reduction policies?" regarding both their present and future policies. The question's purpose was to understand what airports perceived as the primary barrier for carbon management. The free-form answers were classified into categories and coded into eight response modes, whose frequencies were compared. Table 8 summarizes the findings.

Type of Barrier	Frequency – Current	Frequency - Future
Lack of carbon policy that engages tenants	10	5
Costs of implementation	5	9
Lack of financial incentives for tenants	3	2
Educating tenants - communication	2	2
Lack of designated staff	5	1
Monitoring Issues	3	3
Lack of time/technical solutions	3	3
Reaching consensus with tenants	Not mentioned	3
No answer	0	3
Total	31	31

Table 8 - Major barriers for carbon management in airports

The barriers mentioned by airports include technical, financial, and organizational constraints. When respondents were asked about their current policies, the barrier most frequently mentioned was "lack of carbon policy that engages tenants". When the same question was asked about the future, airports listed “cost of implementation” of such policies the most frequent. In addition, possible barrier of “reaching consensus with tenants” (pure organizational constraint) was only mentioned by airports when asked about future policies.

3.4.2.1 Perceived barriers for the implementation of specific solutions

In order to gain a deeper understanding about the barriers for implementation of specific solutions for carbon reduction and management, respondents were asked to rank specific barriers for implementation (technical, financial, negotiation with tenants) on a ranking scale (1 to 3), with 1 as the hardest challenge to overcome. Respondents were asked to only rank solutions that they currently being implemented or under planning for implementation. The same question was asked about current and future policies in areas that might involve some of the tenants. The following solutions were chosen after reviewing airport environmental policies for chapter 1:

1. Certifying terminal buildings with green building standards (LEED, BREEAM, etc.)

2. Producing renewable energy onsite

3. Buying green electricity from a specialized provider

4. Replacing airport-owned GSE fleet with an electric fleet (EGSE)

5. Providing chargers for electric GSE fleets that are owned by tenants

6. Tracking GSE

7. Transportation demand management, such as providing more access to public transport, or reducing parking spots for private cars.

All the solutions mentioned, barring two (tracking GSE fleets and providing electric chargers for EGSE), received the same rank for both current and future policies. Financial barriers were ranked as the most challenging, technical barriers were in the second place, and negotiation with tenants was ranked as the least challenging barrier to overcome.

In current policies, tracking GSE received the same mean score for financial and negotiation barriers, with technical barriers being the least challenging. In planned policies, however, negotiation with tenants was mentioned as the most challenging barrier, followed by technical and financial barriers, probably because most GSE fleets can be owned by 3rd party service providers. Providing EGSE with electric chargers got a similar rank for both current and future policies – financial barriers as the most challenging issue, followed by negotiation with tenants, and technical barriers. GSE fleets can be owned by different parties, and it is likely that negotiation with tenants can affect it more than the other solutions mentioned.

3.4.2.2 Further solutions and barriers

In order to learn what other solutions can be found in airports, the survey included an open ended question for airports to mention further solutions they use to manage their carbon emissions, and the challenges they face in implementation. Proposed solutions for this question included:

1. Providing jet bridge power to reduce reliance on aircraft APUs
2. Central carbon auditing system, and extra personnel to help tenants using it
3. No-idling policy for GSE fleet

In addition, table 9 summarizes the challenges that were mentioned by airports, regarding all types of barriers (financial, technical, and organizational) in current and future policies.

	Tenants' Requirements	Costs	Technical
Current Policies	• Airport provides EGSE chargers while tenants' GSE fleet is not electric. • Airports do not own GSE fleet – all contracted out to 3rd parties, so airports has less control. • Cold Climate (Canada) – tenants' find it challenging to implement no-idling policies because customers want heated vehicles in the winter.	• Proof of ROI of proposed solutions. • Federal incentive (US) makes it difficult to produce green fuel in competitive prices others market get.	• Lack of green electricity providers in the area. • Multiple HVAC systems that do not "speak" to each other are used in terminal buildings.
Future Policies	• Reducing the number of passengers or private vehicles arriving at an airports will reduce airport and tenants' revenues from parking.	• Lower demand for flights while the costs of complying with the state and federal standards are very high, because consultants who can do this work costs a lot (The US).	• Bus Fleet can produce more GHG than airport-owned GSE, and operations costs are higher. • Other buildings, not just terminal buildings, need green solutions.

Table 9 - Further barriers (qualitative)

3.4.3 Monitoring Greenhouse Gas Emissions

In order to understand how airports monitor their GHG emissions respondents were asked if they conducted a carbon audit in the past two years. Of the 31 airports, 26 responded yes (84%) and 5 airports responded no (16%). Next, respondents were asked about the biggest incentive for them to monitor their GHG emissions. They could choose from one of the following options: 1. overall environmental strategy – for those who wanted to present a complete picture of their environmental strategy 2. Mandatory regulation 3. Energy efficiency – the willingness to find opportunities for improving energy efficiency 4. Government grants to conduct the audit. 26 airports responded to the question (N=26). 14 airports listed “overall environmental strategy”, 6 airports listed “mandatory regulation, 4 airports listed “energy efficiency”, and 2 airports listed “government grants”. The biggest incentive was willingness to develop an overall environmental strategy, rather than a mandatory requirement, perhaps because there are few mandated requirements.

Since airport authorities need to obtain emissions’ data from their tenants in order to develop a complete GHG emissions inventory (including scope 3 emissions), respondents were asked about their relationships with their tenants with regards to the sharing of emissions’ data. Table 10 summarizes the responses (N=29). The possible answers, on a scale of 1-5 reflected a range of answers between “1= not at all” and “5=very collaborative”. The cumulative percentage of the range 1-3 (the less responsive tenants) was 65.5, in comparison with the range 4-5 (the collaborative tenants) that only received 34.5 percent. That situation might reflect a disincentive for tenants to monitor and share this information with airport authorities.

How collaborative are your tenants?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	4	12.9	13.8	13.8
	To a small extent	6	19.4	20.7	34.5
	Neutral	9	29.0	31.0	65.5
	Pretty collabrative	7	22.6	24.1	89.7
	Very Collaborative	3	9.7	10.3	100.0
	Total	29	93.5	100.0	
Missing	System	2	6.5		
Total		31	100.0		

Table 10 - Tenants colloration level in sharing emissions' data

The next question addressed incentives for tenants to share data regarding their carbon emissions. The question was open ended: “What would make your tenants more collaborative sharing emissions’ data?”

The answers were classified into themes and coded. Table 11 summarizes the main findings.

What would make your tenants more collaborative - data

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Financial Incentives	9	29.0	29.0	29.0
	Government Regulation	7	22.6	22.6	51.6
	A requirement in the lease agreement	5	16.1	16.1	67.7
	Data confidentiality	2	6.5	6.5	74.2
	More streamlined reporting process	4	12.9	12.9	87.1
	No problems/ We don't ask our tenants for information at this point	4	12.9	12.9	100.0
	Total	31	100.0	100.0	

Table 11 - Incentives for sharing emissions' data

The most frequent two options that came up were financial incentives for tenants to conduct GHG audits, as well as government regulation that obliges tenants to report their carbon emissions. Other airports mentioned a requirement in the lease agreement to disclose the emissions' data, an option to keep the data confidential, and a streamlined reporting process that can facilitate data sharing among tenants.

3.4.4 Collaborative Carbon Management – Existing Features

The review of current practices presented in chapter 1 revealed that some airport authorities already work together with their tenants to manage their carbon emissions. Therefore, respondents were asked about three elements of collaborative carbon management that are already part of some airports' carbon policies based on the review conducted for chapter 1. These were: 1. providing financial incentives to modernize tenants' GSE fleets 2. providing designated personnel to review and enforce emission standards 3. providing integrative sessions with airport's tenants to support carbon policy design. Respondents were asked about how they incorporated these aspects into current and future policies. The options for rating each aspect included:

- Not a part at all
- Incorporated to a small extent temporarily
- Incorporated to a small extent permanently
- Almost fully incorporated in the airport's operations
- Fully incorporated in the airport's operations.

The option that achieved the highest mean in both current and planned policies was having a designated personnel to review and enforce emission standards, followed by integrative sessions with tenants, and incentives to modernize tenants' GSE fleets. It seems like ever since the airport professional community received its first guidance about carbon management the major step taken was assigning a designated person or personnel to deal with the issue.

Further analysis with paired sample T test (two-tailed test) revealed significant difference between the mean of current and future policies of both designated personnel and integrative sessions with tenants. Table 12 summarizes the values received in the paired sample T tests.

Value	Designated Personnel	Integrative Sessions
t	-3.324	-4.004
df	30	30
p value	0.002	0.000

Table 12 - Paired t test values for current and future policies (designated personnel and integrative sessions)

A possible explanation could be attributed to a growing willingness to expand the environmental personnel in airports, and to take a collaborative management approach to carbon management with all parties involved, as a result of voluntary and mandatory drivers. In addition, participatory planning approaches gain popularity in urban, regional, and even a single building planning (e.g. the LEED "Charrette" process) to make them more sustainable, and these processes are likely to be transferred to airport sustainability management too, including carbon management (Dodge & Bennett, 2011; USGBC, 2009).

3.5 DISCUSSION

The results of the survey and the analysis help us to better understand how airports currently manage carbon policies, and what visions they might have for the future as part of an overall approach to environmental management.

Perceived environmental priorities reflect a situation where the airport industry that deals with an established technology (jet airplanes that have been around since the 1960s) gives a higher rank to local adverse impacts caused by aircrafts, such as aircraft noise, and LAQ. The invention of the car fostered urban sprawl and the creation of more suburbs, and airports that have previously been located within a few kilometers of distance from inhabited areas, found themselves bordering and affecting residential communities (Gilbert & Perl, 2010; Tumlin, 2012). There have been several documented cases in the literature of citizens opposing airport authorities via local action groups due to noise complaints and resulting consequences on health and real-estate property values (Bronzaft, 2000; Espey & Lopez, 2000; Suau-sanchez, 2010; Vancouver Court, 2001a; YVR Airport Authority, 2014a).

Carbon emissions tend to affect globally, and since the issue is somewhat abstract and less tangible than noise. Public opposition to the expansion of airports due to the possible increase in carbon emissions is low, though there has been at least documented one case in the UK of a campaign that stopped Heathrow airport's expansion (Hayden, 2014). However, the awareness to the effects aviation as a whole has on the global carbon inventory is growing, especially due to the international talks in the ICAO headquarters in the past few years, trying to reach a global agreement to reduce GHG emissions from commercial flights (EuroActive, 2014; Keating, 2013). That might explain why "carbon emissions" was perceived as a higher environmental priority in future policies than in current policies, since airports see themselves part of the aviation sector.

Monitoring GHG emissions is the first step for shaping carbon policies. Findings on how airports monitor emissions reflect a possible barrier or disincentive for tenants to track and share their GHG emissions. 84% of the airports in this sample monitored their emissions in the past 2 years, and even so, 65.5% of the airports responded that their tenants were not collaborative in sharing data regarding their GHG emissions. Possible drivers for tenants to keep track of their GHG emissions can be: financial incentives of any kind, mandatory regulation, a term in the leasing agreement that requires them to do so, and also a streamlined process for tenants to track and share their emissions' data with airport authorities. In addition, some tenants might ask for data confidentiality in return for sharing their data. These findings support a claim from chapter 1 that it might be difficult to gain access to tenants' GHG emissions' data, especially in the early stages of the implementation of a new carbon policy. When airports join the ACA program, many airports start with the basic levels (1 and 2) that do not require gathering data from their tenants (Airport Council International, 2014b).

The most common barrier regarding the implementation of collaborative carbon management with tenants was a lack of carbon policies. At the same time, the collaborative management action that received the highest rank was having a designated staff to review and enforce emission standards. A possible explanation may be that airport authorities do not often see themselves as a coordinating unit or the leading organization when it comes to the implementation of inter-organizational carbon policies, letting each party monitor and manage its own impacts (Windischer et al., 2007). However, when it comes to noise complaints, another classic environmental issue related with airports, airport authorities do see themselves as a coordinating unit (Eurocontrol, 2015; GTAA, 2013; YVR Airport Authority, 2012). That situation is likely to change in the future, as airport authorities come to see an evolving future role as a coordinating entity for carbon reduction. In addition, both collaborative actions "having a designated personnel" and "integrative sessions" received a significantly higher score in future policies when compared to current policies. Hence, we predict that in the future airports will see themselves as the coordinating entity of the entire airport and its tenants. Collaborative decision making processes already exist in airports in the field of air traffic management and therefore, they are likely to be transferred to other instances, including environmental management and ground operation (Buuren et al., 2012; de Arruda et al., 2015).

After reviewing specific solutions to reduce GHG emissions, it was found that financial barriers were the most challenging, apart from GSE-related solutions where negotiating with tenants is perceived as the most challenging issue. When respondents were asked about major barriers for working with tenants, in future policies the cost of implementation came up as the most challenging one. It is interesting to see that one of the answers of the qualitative part reveal a situation where having absolute targets for GHG emissions may result in a decrease in airport's revenues due to reduced amounts of passengers or cars using the parking lots (ACI-North America, 2013). This situation may cause even more problems for small regional airports that rely mainly on aeronautical revenues and face a decreased number of flights, while at the same time, the costs of complying with the regulation are increasing due to the need to pay for specialists and consultants. In such cases, airports might choose intensity-based reduction goals (reduction in GHG emissions per unit of passenger or cargo load) over absolute reduction targets, in order to avoid a situation of an overall decrease in economic activity (GHG Managment Institute, 2008).

3.6 CONCLUSIONS

The results of the study serve as an evidence that shows how airport authorities develop and implement carbon and environmental policies together with their tenants. Amongst the environmental issues that still receive more attention from airport authorities are airport noise and local air quality, issues that tend to affect locally. However, the ongoing negotiations towards reaching a global solution to reduce global GHG emissions from aviation can influence airports to give the issue of carbon emissions a higher priority, since they share the responsibility for those emissions together with airlines due to technological interdependence (Airports Council International, 2010; Grübler, 1998).

Airports around the world are becoming bigger and their organizational structure is more complex due to the fact that many tenants can be involved in airports' operations. That situation put even more challenges in place for airports that need to plan for a collaborative environmental management strategies, allocate sufficient financial resources, while making sure that all the parties involved are on the same page. Airport authorities are still developing their capabilities of becoming a leading organization or a coordinating unit that can coordinate inter-organizational environmental management efforts together with airports' tenants. Environmental departments are already part of some major airports' organizational structure. However, smaller airports might lack this function, and even if the function exists, it might lack a designated person or personnel who can deal with carbon and GHG emissions specifically. Putting regulation in place that requires airports to work with tenants in order to solve the issue of GHG emissions can serve as a driver for airport authorities to come up with collaborative management policies, and can also serve as guidance about how to allocate the sufficient resources to manage and reduce those emissions in accordance with the airport's size, number of tenants, and capabilities, while avoiding a decrease in the economic activity.

4 – CONCLUSION

4.1 SUMMARY

The study conducted for this thesis contributes to the current understanding of GHG emissions generated by the global aviation sector as a whole, together with past studies that examined the issue from different angles, including environmental implications of airlines choice of aircrafts size, as well as possible reduction in carbon emissions from air-rail integration (Givoni & Rietveld, 2010; Givoni, 2007).

When discussing the global aviation system as a whole, current airport GHG emission reporting standards fail to recognize the technological interdependence between airplanes and airports. More than 50% of the carbon emissions generated by an airport are attributed to Landing and Take-off (LTO) cycles that are typically reported in scope 3 emissions of airport emission inventories, and thus seen as 'external' to airport responsibility. Consequently there is a need to develop new unified reporting standards that better reflect the inter-organizational structure of airports, and inter-organizational structures in general, emphasizing geographic boundaries, and accounting for some major reduction opportunities in scope 3. A good example of such standard is the one used by cities and includes residents' cars that are not owned by the city government who conducts the carbon audit (ICF International et al., 2007; Wyman et al., 2014). Such standards can facilitate the monitoring and reporting processes for airports, and if supported by government regulation that requires airports to involve tenants in carbon management, it might lead airports to put the issue of carbon emissions on a par with local issues such as noise and LAQ in terms of importance.

Regulation that requires airports to work together with tenants and airlines to improve carbon management is needed if carbon emissions from international flights are to be reduced (EuroActive, 2014; Stefan Gössling & Upham, 2009). Collaborative solutions that involve airports (especially large hubs that deal with high passenger volume) to a greater extent in the process of carbon management are needed in the aviation sector. Government funding to airport authorities and their tenants to manage carbon emissions in the form of a budget for training in-house personnel, as well as for modern equipment (e.g. EVs), can also contribute to the rise of airport authorities as leading organizations for carbon management within airports' geographic boundaries, a function that airport authorities have seldom taken responsibility for.

4.2 POTENTIAL APPLICATION OF THE RESEARCH FINDINGS

Beyond the need to develop new GHG reporting standards and the need to create government regulation that requires airport authorities and tenants to collaboratively manage carbon emissions in airports, the findings of this study can lead to a few potential applications of carbon management practices in airports. Airport authorities can create their own mechanism that ensures collaboration from their tenants on the issue of carbon management by using different tools altogether or separately to help getting access to tenants' data. The first tool is a regulatory measure in the form of a requirement in the lease agreement of tenants who operate in the geographic boundaries of the airport to report their GHG emissions periodically to the airport authority. In exchange, airport authorities can offer data confidentiality to the tenants by reporting those emissions in a general form without mentioning a name of a specific organization, in accordance with the current organizational GHG accounting methodology. The second tool is a technical measure in the form of a centralized GHG reporting system that is user-friendly and accessible to all the tenants operating in an airport in order to allow everyone to report their GHG emissions easily and quickly. In addition, airport authorities can provide tenants with guidance and support about how to use the system by hiring designated in-house personnel.

In addition to carbon emission mapping and reporting, airport authorities can also use different tools to reduce carbon emissions from ground sources and from LTO cycles. On the ground, airport authorities can create no-idling policies to reduce emissions caused by pieces of GSE (regulatory measure), and provide aircrafts with jet bridge power to reduce the usage of APU (technical measure). In regards to LTO cycles, airports can use single-engine taxiing procedures and runway pricing, encouraging the use of bigger fuel-efficient airplanes and reducing the number of flights per given route (Givoni & Rietveld, 2010). Long-run planning can also include intermodal travel options using air-rail integration, such as the ones used by some major airports in Europe and China in order to substitute some short-haul flights especially on routes between major hub airports and secondary airports (Air France, 2014; Costa, 2012; Givoni & Banister, 2006; Perl, 1998).

4.3 DIRECTIONS FOR FUTURE RESEARCH

Chapter three of this thesis used an internet-based survey in order to capture the big picture of carbon management in airports. A future study can go deeper by conducting a case study in one or two airports that made the issue of carbon management a top priority, in order to learn more about best practices. Moreover, a similar study to the one used in this thesis can be replicated a few years from now in order to learn about the progress in the field of carbon management in airports assuming technological and regulatory progress.

Another branch of possible research could be about the possibilities of using major airports as a leverage point for carbon management in the broader international aviation system. Since the hub-and-spoke model is the preferred mode of operation nowadays by most major airlines, a relatively small number of airports around the world serve as major hubs and receive significant passenger volume annually. For instance, in 2011, only 73 airports around the world surpassed a volume of 20 million passengers (Rogers, 2012). The purpose of a future study is to understand for how much of the world's traffic do these airports account, and to suggest scenarios for planning a cap-and-trade mechanism around the world's busiest airports.

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Appendix A – Airports that made their GHG inventories publicly available online

RANK	REG	CODE	Airport	Airport location	Passengers 2011
1	NAM	ATL	ATLANTA GA, US (ATL)	ATLANTA GA, US (ATL) Airport	92365860
3	EUR	LHR	LONDON, GB (LHR)	LONDON, GB (LHR) Airport	69,433,565
9	EUR	FRA	FRANKFURT, DE (FRA)	FRANKFURT, DE (FRA) Airport	56436255
10	ASP	HKG	HONG KONG, HK (HKG)	HONG KONG, HK (HKG) Airport	53314213
11	NAM	DEN	DENVER CO, US (DEN)	DENVER CO, US (DEN) Airport	52699298
14	EUR	AMS	AMSTERDAM, NL (AMS)	AMSTERDAM, NL (AMS) Airport	49754910
15	EUR	MAD	MADRID, ES (MAD)	MADRID, ES (MAD) Airport	49644302
16	ASP	BKK	BANGKOK, TH (BKK)	BANGKOK, TH (BKK) Airport	47910744
22	NAM	SFO	SAN FRANCISCO CA, US (SFO)	SAN FRANCISCO CA, US (SFO) Air	40907389
27	EUR	MUC	MUNICH, DE (MUC)	MUNICH, DE (MUC) Airport	37763701
30	EUR	IST	ISTANBUL, TR (IST)	ISTANBUL, TR (IST) Airport	37398221
31	ASP	SYD	SYDNEY, AU (SYD)	SYDNEY, AU (SYD) Airport	36022614
33	ASP	ICN	INCHEON, KR (ICN)	INCHEON, KR (ICN) Airport	35191825
35	EUR	BCN	BARCELONA, ES (BCN)	BARCELONA, ES (BCN) Airport	34387597
36	EUR	LGW	LONDON, GB (LGW)	LONDON, GB (LGW) Airport	33668048
37	NAM	EWR	NEWARK NJ, US (EWR)	NEWARK NJ, US (EWR) Airport	33577154
38	NAM	YYZ	TORONTO ON, CA (YYZ)	TORONTO ON, CA (YYZ) Airport	33434199
40	NAM	MSP	MINNEAPOLIS MN, US (MSP)	MINNEAPOLIS MN, US (MSP) Airp	33074443
41	NAM	SEA	SEATTLE WA, US (SEA)	SEATTLE WA, US (SEA) Airport	32820060
43	NAM	PHL	PHILADELPHIA PA, US (PHL)	PHILADELPHIA PA, US (PHL) Airpo	30839130
44	ASP	BOM	MUMBAI, IN (BOM)	MUMBAI, IN (BOM) Airport	30439122
48	NAM	BOS	BOSTON MA, US (BOS)	BOSTON MA, US (BOS) Airport	28866313
57	EUR	ZRH	ZURICH, CH (ZRH)	ZURICH, CH (ZRH) Airport	24283941
61	EUR	PMI	PALMA DE MALLORCA, ES (PMI)	PALMA DE MALLORCA, ES (PMI) A	22723837
62	EUR	CPH	COPENHAGEN, DK (CPH)	COPENHAGEN, DK (CPH) Airport	22673477
67	EUR	OSL	OSLO, NO (OSL)	OSLO, NO (OSL) Airport	21092873
73	EUR	MXP	MILAN, IT (MXP)	MILAN, IT (MXP) Airport	19291427
76	EUR	MAN	MANCHESTER, GB (MAN)	MANCHESTER, GB (MAN) Airport	18991503
79	EUR	BRU	BRUSSELS, BE (BRU)	BRUSSELS, BE (BRU) Airport	18756885
83	EUR	STN	LONDON, GB (STN)	LONDON, GB (STN) Airport	18046777
97	EUR	HEL	HELSINKI, FI (HEL)	HELSINKI, FI (HEL) Airport	14851675

Appendix B – Scope 1, 2, 3, and LTO emissions in CO_2e (tonnes, million)

Rank	Airport	Scope 1	Scope 2	Scope 3	Total CO2 emissions (tonnes, million)	Emissions LTO	% S1	% S2	% S1+2	% S3	%LTO
3	London -Heathrow	0.043	0.241	1.987	2.271	1.208	0.018934	0.106121	0.125055	0.874944958	0.531924
9	Frankfurt	0.037	0.206	1.845	2.088	0.919	0.01772	0.098659	0.116379	0.88362069	0.440134
27	Munich				0		0.14	0.1	0.24	0.76	0.62
37	Newark		0.058	1.632	1.69	0.533			0.03432	0.965680473	0.326593
40	Minneapolis	0.063	0.06	0.459	0.582	0.327	0.108247	0.103093	0.21134	0.788659794	0.561856
62	Copenhagen		0.03	0.306	0.336	0.23256			0.089286	0.910714286	0.692143
67	Oslo		0.04	0.265	0.305	0.204			0.131148	0.868852459	0.668852

Appendix C – Online Survey to Airports

Survey for environmental departments in airports

Current practices

1. From 1-4, please rank the importance of addressing these environmental issues in your specific airport in your current policies – 1 means the top priority, 4 means the least important priority:

Environmental Issue	Importance 1-4
Aircraft Noise	
Climate Change – Carbon Emissions	
Local Air Quality	
Third party risk (accidnets)	

2. For the practices your airport is currently using, rank the challenges for their implementation from 1-3 (1- the most challenging issue, 3- the least challenging one). Example - if your airport sees technical requirements as the most challenging barrier, rank it as "1" and so on)

Carbon Reduction Practice	Technical Requirements	Financial Cost	Negotiating with your tenants
Green building practices for terminal building (e.g. building new terminal building or major renovations according to LEED or BREEAM rating systems)			
Using an on-site renewable energy production facility			
Buying green electricity from specialized providers			

Carbon Reduction Practice	Technical Requirements	Financial Cost	Negotiating with your tenants
Replacing airport-owned GSE with electric fleet			
providing electricity chargers for tenants' GSE			
Tracking GSE to reduce idle time and maximize efficiency			
Transportation Demand Management (e.g. Consolidating public transport to nearby cities to reduce car usage, etc)			
Other:			

3. Collaboration with tenants – how are these aspects of collaborative work with your tenants being reflected in your airport's carbon policy:

Action	1- Not a part at all	2- Incorporated to a small extent temporarily	3- Incorporated to a small extent permanently	4 – almost fully incorporated in the airport's operations	5 – fully incorporated in the airport's operation
Providing financial incentive to modernize tenants' GSE fleet	1	2	3	4	5

Action	4- Not a part at all	5- Incorporated to a small extent temporarily	6- Incorporated to a small extent permanently	4 – almost fully incorporated in the airport's operations	5 – fully incorporated in the airport's operation
Having designated personnel to review and enforce emission standards	1	2	3	4	5
Having integrative sessions with your tenants on carbon reduction policy/ strategies	1	2	3	4	5

4. What is the major barrier for working with tenants on GHG reduction policies? ______________

Planned actions

5. From 1-4, please rank the importance of addressing these environmental issues in your specific airport in future policies – 1 means the top priority, 4 means the least important priority:

Environmental Issue	Importance 1-4
Aircraft Noise	
Climate Change – Carbon Emissions	
Local Air Quality	
Third party risk (accidnets)	

6. For the practices your airport is planning to use, rank the potential challenges for their implementation from 1-3 (1- the most challenging issue, 3- the least challenging one). Example - if your airport sees technical requirements as the most challenging barrier, rank it as "1" and so on).

Carbon Reduction Practice	Technical Requirements	Financial Cost	Negotiating with your tenants
Green building practices for terminal building (e.g. building new terminal building or major renovations according to LEED or BREEAM rating systems)			
Using an on-site renewable energy production facility			
Buying green electricity from specialized providers			
Replacing airport-owned GSE with electric fleet			
providing electricity chargers for tenants' GSE			
Tracking GSE to reduce idle time and maximize efficiency			
Transportation Demand Management (e.g. Consolidating public transport to nearby cities to reduce car usage, etc)			
Other:			

7. Collaboration with tenants – based on your planned policy , how will these aspects of collaborative work with your tenants be reflected in your future airport's carbon policy:

Collaborative action	1-Not a part at all	2 - Incorporated to a small extent temporarily	3 - Incorporated to a small extent permanently	4 – almost fully incorporated in the airport's operations	5 – fully incorporated in the airport's operation
Providing financial incentive to modernize tenants' GSE fleet	1	2	3	4	5
Having designated personnel to review and enforce emission standards	1	2	3	4	5
Having integrative sessions with your tenants on carbon policy design	1	2	3	4	5

8. What will be the major barrier for working with tenants on future GHG reduction policies? _______________

Monitoring

1. Have your airport conducted a GHG audit in the recent 2 years? Yes/no
2. If the answer was yes - What was the first incentive for your airport to conduct such audit? (select all reasons that apply) A. Identifying areas for energy efficiency improvements. B. It's mandatory by local regulation. C. It's part of an overall environmental strategy. D. Other: ____________
3. If the answer is no, what will provide the biggest incentive for your airport to conduct GHG audit? (select all reasons that apply) A. Identifying areas for energy efficiency improvements. B.

It’s mandatory by local regulation. C. part of an overall environmental strategy. D. Other:____________

4. How are GHG emissions currently monitored in your airport? A. by regular ongoing audit using GHG accounting methodologies based on tenants’ data in addition to airport authority data (ACERT, etc). B. Using GHG accounting methodologies to analyze data that comes from the airport authority, and approximation of the tenants’ emissions. C. By using similar airports data and approximation (for the entire airport GHG inventory).
5. How collaborative are your tenants in contributing necessary data for a planned or current GHG audit (fuel usage, etc): 1 – not collaborative at all 2-collaborative to a minor extent 3- neutral 4- pretty collaborative 5- very collaborative.
6. In your opinion, what would make your tenants more collaborative helping with the GHG monitoring process? _________________

General Information

9. Name of airport: ___________
10. Location: ___________
11. Type of airport authority: a. government owned/operated b. government owned/privately operated c. Independent not-for-profit d. Fully private-for profit
12. Size (passengers) in 2014: ___________
13. Number of major tenants involved in airport operations , including major airlines and third parties: ____________
14. Briefly describe the tenants proportions in the airport management in % - a. airport authority _______ b. airlines ________ c. other tenants (e.g. GSE providers): ______
15. If your airport is a major airline hub, which airline(s) use it as their hub? ____________
16. In which year did you start developing carbon reduction policies? _________

Appendix D – List of Airports that Responded to the Survey

Airport's name	Country	Number of passengers in 2014	Number of major tenants involved in airport operations, including major airlines, and third-party service providers
Sacramento International Airport	US	8,000,000	15
San Francisco International Airport	US	46,200,000	230
Denver International Airport	US	53,472,514	150
Aéroports de Montréal	Canada	14,840,067	100
Minneapolis St. Paul Airport	US	35,152,460	15
Dane County Regional Airport	US	1,600,000	10
Oakland International Airport	US	10,400,000	25
Airprot Authority Hong Kong	Hong Kong	63,000,000	100
Stockholm Arlanda Airport	Sweeden	22.400,000	
Greater Moncton International Airport	Canada	672,000	6
Brisbane International Airport	Australia	21,900,000	20
Calgary International Airport	Canada	15,260,000	
Los Angeles International, Ontario International, Van Nuys	US	71,000,000	100
San Jose International	US	9,400,000	15
Monterey Regional Airport	US	400,000	6
Victoria International Airport	Canada	1,650,000	80
Dallas/Fort Worth International Airport	US	63,000,000	25
Enfidha Hammamet International Airport	Tunisia	2,400,000	30
Salt Lake City International Airport	US	21,141,610	30
Dayton International Airport	US	1,200,000	20
Cleveland Hoplkins International Airport	US	7,700,000	15
Kelowna	Canada	1,600,000	10
Seattle-Tacoma International Airport	US	37,500,000	23
Las Vegas International Airport	US	42,800,000	30
Nantucket Memorial Airport	US	125,000	20
Toronto Pearson	Canada	38,600,000	30
Zurich Airport	Switzerland	25,480,000	5
Philadelphia International Airport	US	30,740,242	
Austin Bergstrom	US	10,000,000	100
Winnipeg Richardson International Airport	Canada	3,670,000	50
Prince George Airport	Canada	445,929	5