SMALL RINGS IN A LONG CHAIN

The Role of Air Traffic Controllers in Reducing The Environmental Impacts of Aviation

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ABSTRACT

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This thesis aims at determining the role and attitudes of air traffic controllers (ATCs) in reducing the environmental impacts of aviation, including emissions and noise. The study concentrated on environmental attitudes of the ATCs as well as the methods which can be used to reduce the environmental impacts of aviation.

An online survey was used to get answers from 193 air traffic controllers around the world. The survey measured the respondents' attitudes and views on environmental issues and the ATC work regarding the environmental impacts of aviation. The respondents were also encouraged to express the methods they considered useful and/or used themselves to reduce the environmental impact of air traffic.

The survey revealed that the opinions of the ATCs did not differ based on background factors such as gender, age, experience or geographical location, but rather the attitudes were distinctive to the individual respondent, as hardly any correlation occurred between the opinions and background variables. Only location was somewhat of an issue when discussing environmental methods and knowledge on the matter, which can refer to cultural and local differences. The overall results showed that the ATCs wish to aim at their ultimate goals of safety and efficiency but do not hesitate to act green simply by doing their job to the best of their abilities.

Key words: Air traffic controller, aviation, environmental impact, attitudes

TIIVISTELMÄ

Tampereen ammattikorkeakoulu TAMK
Ympäristötekniikan koulutusohjelma
O'NEILL, MIA: Pisarat meressä – lennonjohtajien rooli ilmailun ympäristövaikutusten vähentäjänä.
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Elokuu 2011

Tämä opinnäytetyö pyrkii määrittämään lennonjohtajien roolin ja asenteet ilmailun ympäristövaikutusten, kuten päästöjen ja melun, vähentämisessä. Tutkimus keskittyy lennonjohtajien ympäristöasenteisiin sekä menetelmiin, joiden avulla ilmailun ympäristövaikutuksia voidaan vähentää.

Tutkimusaineiston keräämiseen käytettyyn Internet-kyselyyn saatiin 193 vastausta lennonjohtajilta ympäri maailmaa. Kysely mittasi vastaajien asenteita ja näkemyksiä ympäristöasioita kohtaan sekä lennonjohtajien työtä ilmailun ympäristövaikutusten näkökulmasta. Vastaajia myös kehotettiin jakamaan menetelmiä, joita he käyttivät tai kokivat muuten hyödyllisiksi lentoliikenteen ympäristövaikutusten vähentämisessä.

Tutkimusaineiston mukaan lennonjohtajien mielipide-erot eivät selittyneet taustatekijöillä, kuten sukupuoli, ikä, työkokemus tai maantieteellinen sijainti, vaan asenteet olivat yksilökohtaisia eikä korrelaatiota mielipiteiden ja taustamuuttujien välillä juuri esiintynyt. Sijainnilla oli merkitystä keskusteltaessa menetelmistä ja ympäristötietämyksestä, mikä viittaa kulttuurieroihin eri maissa. Yleisesti ottaen tulokset osoittavat, että lennonjohtajien tavoitteena ovat pääasiallisesti turvallisuus ja tehokkuus, mutta he eivät epäröi ottaa myös ympäristönäkökulmaa huomioon tehdessään työnsä parhaan kykynsä mukaan.

Avainsanat: Lennonjohtaja, ilmailu, ympäristövaikutukset, asenteet

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1. Introduction

It is generally acknowledged that air traffic controllers (ATCs) are an important occupational group and their expertise is relevant to the safety of aviation. Several studies have been conducted on the effects that workload, automation, aviation policies and psychological factors have on ATCs. However, the effects that ATCs may have on the emissions produced by aviation have not been previously studied.

This study aims to find out how ATCs in general perceive that their actions and performance can affect the environmental impact created by aviation, if at all, and what methods they utilise in order to obtain this effect. It can be assumed that an ATC can have a significant effect on the rate and manner at which planes are landing and taking off, and thus, the amount of emissions and noise. The aim of the study is to learn whether the ATCs understand and appreciate the power they have, whether or not they use it, and what motivates them to do so.

The study aims to answer the following:

- How do ATCs see their own role in reducing environmental impact of aviation?
- What are the general attitudes of ATCs towards environmental actions, and do these attitudes affect their work?
- How can emissions of aviation be reduced and what are the methods?

As a result, the study is somewhat interdisciplinary, mixing both environmental and aviation technology but concentrating mainly on the sociological approach on environmental attitudes.

Firstly, the methodology of research will be described, after which the theoretical framework will be constructed in order to support the research questions. The technical aspects of aviation and air traffic control will be briefly described and the methods and tools used by the ATCs will be introduced. Finally, the results of the survey will be presented and eventually analysed along with the interviewees' views. As a conclusion, some of the most efficient and popular methods as well as potential future applications for reducing emissions will be discussed.

2. Methodology

As the purpose of the study was to reach as wide range of ATCs as possible, an electronic questionnaire was used for gathering the main data. The link to the questionnaire was sent to air traffic controllers via the International Federation of Air Traffic Controllers' Association (IFATCA) who distributed it to all of its member countries, after which it was up to the national organisations to forward the link to ATCs. Thus, responses were received unevenly from only 30 countries out of 137 member countries of IFACTA. The survey was available to be answered for nearly three months in October-December 2010, during which time 193 ATCs responded to it. The copy of the online survey can be found in appendix 1.

The general attitudes of the ATCs towards the environment were queried as well as the methods they use in their work to reduce pollution. The correlation between personal attitudes and work methods was studied, as was the knowledge the ATCs had on environmental issues and the effect they could have on emissions of aviation. The ATCs were also allowed to freely comment on the questionnaire as well as on the topic at hand.

After collecting the data, it was analysed with the program SPSS Statistics 19. The basic deviation of the respondents based on gender, age and experience is studied further in chapter 4. Also the free comments were studied and important points made by respondents were raised during analysis. Some expert interviews were used as supporting material when analysing the results.

3. Theoretical framework

This study aims to determine the attitudes of a certain professional group towards the environment. There is a difference between the so called green motives and green behaviour. People base their actions on various motives, and their reasons to make environmental choices may have nothing to do with environmental attitudes as such. They may even never have considered the environmental effects of their actions. In this study, it will be examined how environmental attitudes affect the behaviour of the

ATCs and what they see as the motivation of their own emission reducing actions. (Brand 1997; Massa & Ahonen 2006.)

Another perspective is the role of ATCs in aviation. The hypothesis of this study is that one group of people can make a considerable difference in the emissions of air traffic, but this resource may not have been used to its full potential. Effective training and management play a critical role in reducing emissions, and these methods ought to be utilised to a great extent. In fact, the role of ATC training in terms of environmental impact reduction is examined to determine whether or not the ATCs know how they can reduce the environmental impact. In short, the study concentrates on the work of ATCs, the environmental impacts of aviation and the ATC's attitudes towards environmental actions as well as how they are formed. Another aspect of the study is the technical methods of air traffic control and what the ATCs can do to reduce the environmental impact.

There have been several studies on air traffic controllers but none from the point of view of environmental attitudes. Clearly the psychological aspects of the work have been analysed by many (e.g. Palukka 2003; Garland and Endsley 1996), and another important perspective has been the more general human factors in aviation/air traffic control (e.g. Cardosi and Murphy 1995; Hopkin 1995 ; Wise et al. 1994). Another aspect of research has been the technological development of air traffic control, which is not included in this case. Wickens *et al.* (1997) have produced a clear complexion of the entire scope of the work of the ATC, but have also concentrated mainly on the human factors in the procedures.

3.1. Air traffic control

It is necessary to briefly explain the basics of air traffic control in order to understand what kind of roles the ATCs could have. There are three distinct tasks of air traffic control: ground and local control (i.e. tower controllers), approach control (approach and departure) and en-route control, who accordingly are in charge of "ground operations from the gate to the taxiway to the runway, takeoff and climb operations to reach a cruising altitude, cross-country flight to the destination, approach and landing operations at the destination, and finally, taxi back to the gate (or other point of unloading)". (Wickens *et al.* 1997, 19-21.) Figure 1 gives an overall view of the different phases of air traffic control.

This study will not make a distinction between different types of tasks done by the respondents. However, the tasks of the operators also shed light to the procedures of air traffic control, from take off to landing. This process will be described in the following chapters.

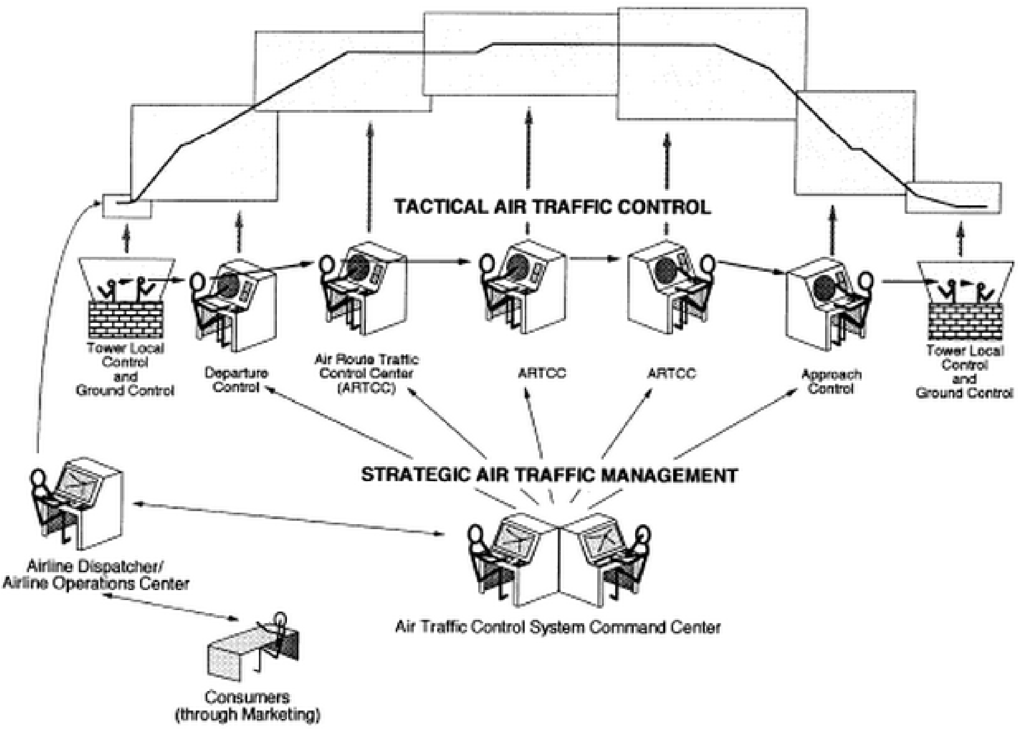

Figure 1: Phases in air traffic control operations. (Wickens 1997, 21.)

The ultimate goal of the air traffic control system is to ensure the safe and efficient flow of traffic from origin to destination. The goals of safety and efficiency, being the most important ones for the ATCs, are accomplished by a variety of procedures: communication and coordination between the pilot and the controller, as well as within the air traffic control facilities. Controllers hand off aircraft as they pass from one sector to the other. The hierarchical communications flow from the global and national perspectives to regional and local ones. (Wickens *et al.* 1997, 21-22.)

The goals of safety and efficiency can be considered somewhat contradictory; however, safety is always a priority. Safety is ensured by guaranteeing minimum separation between aircraft, defined by altitude and lateral dimensions; the dimensions varying in different regions of airspace. Efficiency, on the other hand, is met by maximising the capacity of the current airspace and optimising the flow of traffic by delivering aircraft to line up for the final approach. To accomplish both the goals of safety and efficiency creates strong pressure on the system – as well as on an individual ATC. (Wickens *et al.* 1997, 21-22.) Therefore, to ensure that the ATC can concentrate and cope under stressful situation, the training procedure is intensive including simulations and handling real life situations. As the goal of the training is to ensure safety and efficiency of air traffic control, environmental issues are not discussed as such. However, as mentioned before, environmental actions often go hand in hand with efficiency, assuming one sees the connection between the two.

3.1.1. Tower control

Tower control tasks are usually divided between the ground controller and the local area controller. The tower controller controls aircraft on the ground, just after takeoff and just before landing, from a glass structure "on top of the tower". The main responsibilities of a tower controller are giving issue clearances to push back from the gate and to leave the ground, taking into account the sufficient separation from other traffic as well as the confirmation of flight plans; managing ground traffic to and from the gate; and handing off the departing aircraft to and accepting the arriving aircraft from the radar controller. The most important task of the tower controller is to observe the movements of the aircraft at and around the airport. (Wickens *et al.* 1997, 34-35.)

The tower controllers do not rely on their vision only but also get some assistance from *airport surface detection equipment (ASDE),* a systems which provides radar identification of ground vehicles and aircraft. Another form of support is a radar display, *DBRITE (digital brite, radar indicator tower equipment)*, which provides the local controller with a radar presentation around the airport as well as alphanumeric information on the approaching aircraft not yet under tower controller's control. Tower control also uses paper flight strips, computer generated based on the flight plan, which are moved around the controller's workstation to help to maintain the big picture of the whereabouts of the aircrafts. (Wickens *et al.* 1997, 35-36.)

3.1.2. Approach control

The approach controller (APP), located in a windowless radar room, controls the aircraft in the wider region around the airport. The tasks of the approach controller are to manage the flow of departing aircrafts accepted from the tower to a handoff to the en route controller as well as the arriving aircraft accepted from the en route controller. The tasks can be divided between approach and departure controllers. Similarly to the tower control, the approach controller aims to sequence the line up of the aircraft at regular spacings in order to maintain both efficiency and safety. The task is made more challenging by the three dimensional separation as the aircraft are constantly climbing and descending as well as moving forwards; the separation must be maintained at 1000 feet (304,8 m) vertical and 3, 4 or 5 miles (4,8 km, 6,4 km or 8 km) lateral separation, depending on the size of the aircraft. The approach controller will juggle between the varying altitude, speed and heading of the aircraft, trying to fill any empty slots in the airspace as efficiently as possible. (Wickens *et al.* 1997, 37.)

The critical information available to the approach controller is collected by the *ARTS (automated radar terminal system)* computer system. The information is provided by primary airport surveillance radar, which receives returns from the aircraft in the air, and secondary radar, which receives digital signals from the aircrafts with a transponder. There is also the flight data input/output computer (FDIO), which hosts computer-based flight plans. The information received from these sources is contained in ARTS, including aircraft call sign, type of aircraft, route information, and other useful information. Another important system for the approach controller is the radar display, showing the big picture of the traffic in the sky. The aircrafts equipped with a transponder are displayed with a data tag containing some of the crucial information from ARTS. Similarly to tower control, flight strips assist the controller to form the view of the traffic situation, even if controllers are no longer as dependent on them as they were before radar data blocks. (Wickens *et al.* 1997, 38-41.)

3.1.3. En route control

Finally, the ACC, Area Traffic Control Centre, is responsible for the air traffic travelling from one region to the other, so there is an ATC in touch with an aircraft at all times. The primary objective is to maintain the expeditious but regular delivery of aircraft to the receiving AAPs, providing them as rapidly as possible but not too fast to avoid bottlenecks in the sky. (Wickens *et al.*1997, 47.)

Like the approach controller, the en route controller aims to expedite traffic flow while maintaining safety. However, the safety separation standards are greater en route: 5 miles (8 km) lateral or, depending on the aircraft's altitude, 1000 ft (304,8 m) or 2000 ft (609,6 m) vertical separation, rather than 3 miles (4,8 km) and 1000 ft – this is due to the more distant radar coverage which makes it challenging to establish precise location, as well as the faster speed. Each en route sector has usually two controllers, a radar position (R-side) responsible on monitoring the radar display and ensuring separation, and a data position (D-side), who primarily handles data and coordinate. (Wickens *et al.*1997, 45.)

The information for the en route controller is gathered from air route surveillance radar and integrated with information from the FDIO by the en route automated system (HOST), which provides flight data processing for developing flight plans, and radar data processing interfaced with towers, APPs and other en route centres so the flight plans can be automatically sent. Despite the automated process, it is eventually up to the individual controllers to monitor the air traffic, respond to pilot requests and adjust to weather conditions. The changes are made according to the ATC instructions to alter air speeds, flight levels, and (if necessary) headings, in order to maintain maximum but regular flow. (Wickens *et al.*1997, 46-47.)

3.1.4. Air traffic control in general

The ATCs are bound to the goals of safety and efficiency but they are free to manage the airspace according to their own skills. Any unpredictable or conflict situation must be dealt with swiftly and smoothly to maintain a well organised flow. Secondary adjustments, such as the granting of a pilot request, are considered only if it will not disturb the other traffic and the flow. (Wickens *et al.*1997, 46-47.) The systems are often highly automated but this varies from facility to facility, which is why the paper flight strips are still necessary, as all the ATCs must be prepared to deal with unanticipated events such as equipment failure (Wickens *et al.*1997, 52).

As the facilities around the world differ from one another in the level of technology, so do the three basic positions – tower, APP and ACC – have differences in their tasks in addition to the shared basic competencies. Furthermore, as the technologies, tasks as well as the organisational culture vary in different facilities, it has not been possible to create a common training programme due to the local variation in job requirements. (Wickens *et al.*1997, 52-53.)

3.2. Environmental policies and management in aviation

Aviation companies, airports, and various air traffic and environmental authorities have prepared several environmental policies to tackle the issues created by aviation. For the most part, these policies and regulations are being followed, but they can only count as part of the methods required to deal with aviation emissions and other forms of pollution. Another part is formed by the people whose everyday work can make a difference, here specifically the air traffic controllers. As Massa and Ahonen (2006, 13) point out, large lines of national environmental policy requires the support of small, everyday actions – and, in the case of professionals, management and training on environmental issues. The important aspects include the silent knowledge, way of life and cultural change of a single person – as the only way to achieve sustainable change is through attitudes, not only rules and sanctions. As policies can work only to certain extent in producing cleaner solutions, the bigger issue is the motivation of the people doing the work. (Brand 1997.) This study will examine the motives and the attitudes of the ATCs to understand the potential of their environmental actions.

There is a difference between acting environmentally friendly because of "green" views and doing so for other reasons. In fact, several actions pursuing economic sustainability or efficiency also benefit the environment, and it is not fruitful simply to examine actions based on their motives. (Brand 1997.) However, motives do count when considering the extra bit one can do to be more environmentally sustainable. This study will determine whether the environmental actions done by the ATCs are done mainly by those who are environmentally oriented in general, or whether it is something that the ATCs feel that they can contribute to simply based on their sense of responsibility and to achieve their goal of efficiency.

3.3. Environmental effects of aviation

Aviation in itself is a complex equation which causes a variety of environmental effects. The types of traffic included in air traffic are passenger and cargo transportation, while private and military aviation are also included. The environmental effects of aviation are here limited to direct effects excluding the health effects of the actual flying (e.g. jet lag, pressure differences etc.). The main effects of aviation can be divided into exhaust emissions, chemical use and noise.

3.3.1. Exhaust

Overall, the emissions of aviation amount to only a fraction of the entirety of emissions caused by human activity: in a global scale the carbon dioxide emissions of aviation are only approximately 2 % (Finavia 2009). Other emissions from exhaust are mainly nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds, known as NMVOC, which covers organic atmospheric compounds as well as materials found at airports such as benzene, polyaromatic hydrocarbons, fuels and de-icing chemicals such as kerosene and ethyl glycol.

In addition to the aviation itself, the airport support networks cause sulphur dioxide -(SO_2), ozone (O_3), and particulate matter (PM_{10}) emissions. In more concentrated targets, such as around airports, the amount of emissions is naturally greater and affects the air quality. (Hume & Watson 2003.) Also water vapour can be considered as emissions, even though its role in cloud formations and climate change remains unclear. (Lee & Raper2003).

The emissions per aircraft depend on the type of the aircraft and the motor, as well as the route, the speed and the altitude (Finavia 2009). The emissions of an aircraft are calculated based on the LTO-cycle (Landing and Take-Off), which includes the emissions of take-off, landing and taxing up to the altitude of 3000 feet (approx. 900 m). In practice, this includes all the emissions from 6 kilometre distance in the take-off direction as well as 18 kilometre distance in descent direction. (Finavia 2008; Finavia 2009.)

Take-off causes the biggest NO_x-emissions and the lowest NMVOC and carbon monoxide emissions. Other emissions of aviations are mainly caused by refuelling (evaporation and leaks) as well as the use of the backup systems (Hume & Watson 2003.) The exhaust of jet engines and turbo propeller engines contains the same compounds as other common engine types (Finavia 2009). The most commonly used fuel is jet fuel, which contains mainly kerosene and C9-C16 hydrocarbons. In addition to this, jet fuel contains aromatic compounds (max 25 %), toluene (<1 %) and benzene (<0,1 %). Jet fuel is also known as trade name Jet A-1. (St1 2008; Työterveyslaitos 2009.) Turbo propeller engines consume approximately 2,5 – 3 l/100 km /person, a jet engine (A320) approximately 3,7 l /100 km /person and transcontinental flight consumes approximately 3 l /100 km in full load (Finavia 2010).

One consumed kilo of kerosene produces in burning process 3,2 kg CO_2 and 1,3 kg water vapour, the latter being the reason for the warming effect of aviation. The water vapour affects the forming of clouds, which in turn act as buffer for sun light but also prevent heat from evaporating. Clouds created and affected by water vapour of aviation are mainly cirrus clouds. (Finavia 2009.)

Even though air traffic is not statistically significant producer of CO_2, aviation does have an effect on the climate. For instance, the warming effect of aviation has been estimated to be twice that of the CO_2 emissions. (Finavia 2009.) However, the main issues of aviation exhaust affect public health. NO_x, SO_2, O_3, NMVOC and PM_{10} -emissions have all been linked to respiratory problems but conclusive evidence supporting this have not been found. Furthermore, airport employees exposed to fuels and exhaust have been diagnosed with respiratory symptoms, such as asthma, even though this connection has not been proven. NMVOC -emissions have been assumed to cause cancer but no significant links to the health of the people living close to airports have been found. (Hume & Watson 2003.)

Jet fuel is harmful to environment not only as an exhaust gas but also as a chemical. It does not dissolve into water but is fat-soluble, which is why it can cause long term adverse effects in aquatic ecosystems as well as pollute soil and ground water. (St1 2008.) Like other light fossil fuels, jet fuel soaks through the soil and eventually breaks down or evaporates on the surface but in large amounts it can find its way to groundwater. In anaerobic conditions, the fuel can remain in soil for long periods of time, penetrating further into the soil and potentially reaching groundwater. Thus, it is necessary to avoid any large spills of jet fuel. (Gråsten & Kiukas 2004, 11-12.) According to the international classification CONCAWE, jet fuel has been classified as dangerous for the environment (Työterveyslaitos 2009). In soil, jet fuel may evaporate or bind to the soil. The long carbon chains bind well to soil, which can prevent or slow the evaporation process and degradation, as chemical may find its way to groundwater through the soil. The adsorbed hydrocarbons may cause adverse effects to organisms in sediment. Jet fuel degrades biologically in aerobic conditions. (St1 2008.)

Apart from being harmful for the environment, jet fuel has been also classified as harmful to health. Skin contact causes irritation and the chemical may be absorbed through the skin. (Työterveyslaitos 2009.) Inhaling the fumes irritates eyes and respiratory track (St1 2008). However, evaporation in room temperature is minimal and the greatest risk is thus caused by maintenance procedures (Työterveyslaitos 2005). When inhaled, the substance is mildly toxic (LC50 > 5000 mg/m^3, rat) (St1 2008). When digested, jet fuel may cause even paralysis of the central nervous system as well as nausea, vomiting and diarrhoea. Digestion causes also a risk for aspiration, which may lead to a lethal lung infection – this is why vomiting is not recommended after swallowing jet fuel. There is no certain evidence on the carcinogenic effects of jet fuel in humans but already skin exposure has lead to cancer in animal tests. Threshold limit value (TLV) is 200 mg/m3 / 8 h (skin, rabbit). (Työterveyslaitos 2009.)

3.3.2. Noise

The highest points for air traffic noise are in approach and landing stages of flight, when the altitude is at its lowest. The flight routes are planned so that they avoid the biggest residential areas, and the areas surrounding the airport are taken into account by using a runway direction which does not direct low altitude planes above residential areas. However, it is to be noted that flight security goes above noise abatement. Flight noise is measured with the unit L_{den}, which describes the average level of noise energy annually and which takes into account the disturbance variations in different times of the day. (Finavia 2009.)

Traffic noise can cause considerable problems for both health and the environment. Noise disturbs sleep, and chronic exposure can lead to heart and vascular problems such as high blood pressure and heart disease. Continuous noise may cause stress, which affects on nervous system and hormonal balance, in addition to which noise exposure may cause irritation and sleep disorder. High level of noise in close distance can affect hearing, although only little evidence is presented of this. (Babisch 2005; Passchier-Vermeer & Passchier 2005; Hume & Watson 2003.)

3.3.3. Chemicals

Even though air traffic controllers have little or no say in where and how the aircraft are treated with chemicals, it is necessary to discuss the environmental impact of chemicals in aviation with a few words. A part of environmental effects of aviation is caused by chemicals such as de-icing and anti-skid chemicals. Even though the ATCs have no role in reduction of these chemicals, their environmental effects will be described here briefly. The chemicals used for these purposes vary from country to country; in Finland, the allowed substances for anti-skid runway treatment are sodium acetate, potassium acetate, sodium formate and potassium formate in both grainy and liquid form. In de-icing process the chemicals mainly contain proplylene glycol, which is also used as an additive in food products. All these chemicals are biodegradable but cause biological oxygen demand in water bodies and in certain conditions unpleasant odour. (Finavia 2009.)

Anti-skid and de-icing chemicals cause biological oxygen demand in catchments up to several tons. However, the chemicals have been classified as only moderately harmful, in addition to which their use has been reduced. The chemical amounts are mainly dependant on weather conditions. (Finavia 2009.) The colourings used in de-icing chemicals cause mainly aesthetic problems as the active ingredient propylene glycol is relatively harmless for both humans and other organisms (Jarmat Oy 2001). Out of all anti-skid chemicals the least harmful is potassium formate because it does not contain chloride, it dissolves less heavy metals and it breaks down to carbon dioxide and oxygen relatively quickly. The oxygen demand of formates is also smaller to that of acetate salts. (Salminen & Tuominen 2010.)

The spread of chemicals to the environment is carefully monitored at modern airports. Wastewater is collected and directed to treatment facilities. The most sophisticated runoff systems have also oil separation systems which reduce oil spills in the case of accidents. In addition the nearby catchments and groundwater are being monitored for chemical and biological oxygen demand. (Finavia 2009.)

3.4. Minimising the environmental effects

Environmental impacts of aviation are taken seriously and methods are implemented in order to reduce the impact. The methods which take place in the air or while the aircraft is on the move, are the ones that ATCs have the chance to affect. Here, some of the most common methods are described.

3.4.1. Continuous Descent Approach (CDA)

The actual emissions of air traffic are being reduced by using several methods, including the so called continuous descent approach (CDA). In this method, the aircraft maintains the cruising altitude as long as possible and slides engines idle to the location, powering them up only at the final stage of approach (see figure 1). Generally, the altitude of 27 000 ft is maintained until the distance is approximately 10 miles and the speed is 280 knots. This means that the traditional horizontal approach can be turned to slide within 10-30 km from the airport, which reduces the engine power demand and thus also CO_2-emissions up to 320 kg per one 150-seat aircraft, leading to over 100 000 kg fuel savings in a year. In Helsinki-Vantaa airport, for instance, CD-approaches amount up to 60 % of all approaches. Also in take-off the airways used are separate than the ones used in landing, which enables energy efficient take off in congestion free airspace. (Finavia 2009.) Another method is continuous climb, where the aircraft is allowed to climb straight up to its cruising altitude without unnecessary delays.

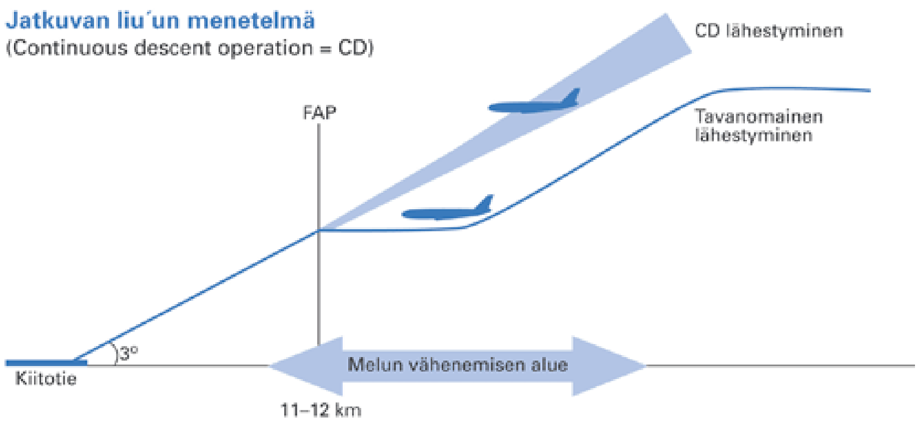

Figure 2: Continuous Descent Approach.

3.4.2. Flight planning

It is necessary to plan the flight path of every aircraft in order to anticipate the upcoming congestion and other possible issues that may affect the safety or efficiency of the air traffic. The dispatch unit formulates a flight plan for the aircraft, which is then distributed both to the ATC as well as the pilot. When the ATC knows the destination of the aircraft, it is possible to take into account the amount of traffic at the destination as well as en route.

In order to make flying as efficient as possible, the goal is to allow the aircraft fly as directly as possible to its destination without having to avoid other traffic by unnecessary turns. ATCs manage the flow of air traffic making sure that the aircraft come in regularly and no rush hour forms around the airport while the airplanes are waiting for landing clearance. It is beneficial also for the aviation companies as well as the entirety of stakeholders, including the passengers, to avoid delays before and during the flight, which is also why flight planning is a vital part of air traffic control.

3.4.3. Noise control measures

Noise control is part of the regulations set for each airport individually depending on their environment and need to avoid unnecessary noise pollution. Especially at airports with surrounding settlement, noise is being controlled especially at night time. The loudest noise is heard when the aircraft is flying low, landing or taking off. Thus, noise is avoided by favouring runways which have the least amount of settlement in their immediate noise area. Primary departure track is being used as air traffic safety allows and especially in night time. (Finavia 2009.)

3.4.4. Further methods

Other ways to reduce emissions of aviation, although independent from ATCs, include emissions trade and development bio fuels. However, these procedures are not likely to reduce the aviation itself but merely provide an option for reducing emissions. The emissions of infrastructure, the warming effect through water vapour, and the use of chemicals are still correlating with the amount flights, even though these methods would reduce the amount of exhaust emissions to some extent.

Several environmental policies have been put in place to reduce the emissions of aviation and various methods have been suggested. However, apart from emission trade and restrictions on the most toxic substances, no effective policies have been introduced as of yet. Rather, the policy making is concentrated on reducing aviation altogether even though the environmental effects of aviation (at this rate) are less than those of other modes of transport. (Dobbie 2003.) It is also noted, that more efficient air traffic operation could be part of the solution, together with the application of the latest technology (Pastowski 2003). It could be argued that more environmentally conscious training for the ATCs could, indeed, play an important role in reducing the environmental impact of aviation. As shown by the results of the survey discussed in the next chapter, not all ATCs are aware of how they could participate in the process.

4. Results of the survey

The ATCs are often seen as a small occupational group which has a demanding job and who are often on strike (Palukka 2003), and they have rarely been connected with environmental issues. In this chapter, the environmental attitudes and opinions of the ATCs will be presented based on the results of the online survey.

There were 193 respondents to the survey from 28 different countries worldwide (see appendix 2 for the background information of the respondents). Most of the continents were represented, with the largest representation revolving in Europe, namely respondents from Finland and Italy being extremely active. The featuring countries can be seen below in figure 3 and in more detail in table 1.

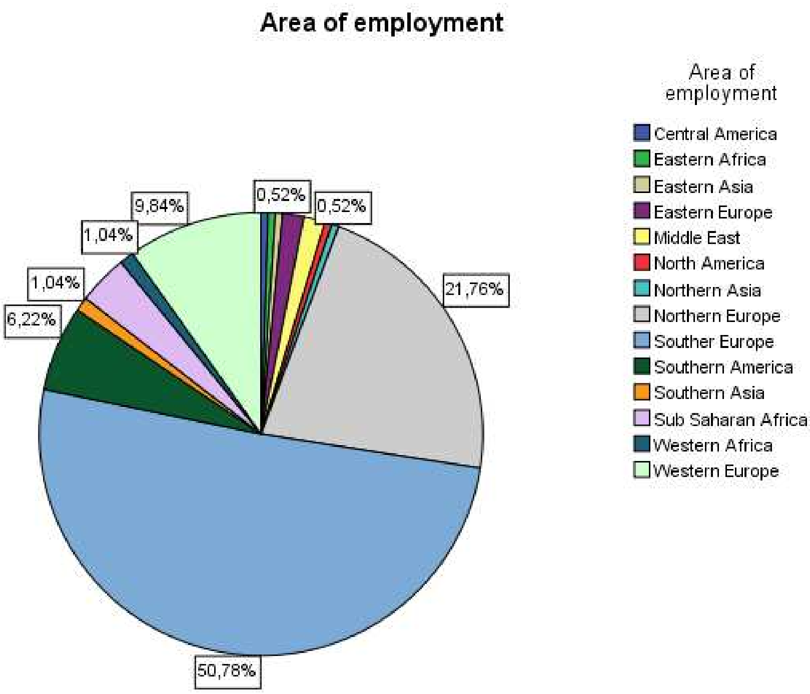

Figure 3: Area of employment (as defined by the respondents).

Table 1: Countries represented (as defined by the respondents).

Central Europe	**Western Europe**	**Southern Europe**	**Northern Europe**	**Eastern Europe**
Austria (1) Germany (1) The Netherlands (1)	The United Kingdom (1)	Italy (108) Undefined (4)	Finland (29) Iceland (1) Latvia (1) Sweden (11)	Bulgaria (1) Lithuania (1) Ukraine (1) Undefined (1)
East Africa	**West Africa**	**Sub Saharan Africa**	**Middle East**	**South Asia**
Madagascar (1)	Gabon (1) Sierra Leone (1)	South Africa (5) Swaziland (1) The Republic of Congo (1)	Jordan (2) Iran (1)	India (2)
South America	**Central America**	**North America**	**Northern Asia**	**East Asia**
Brazil (1) Columbia (10) Uruguay (1)	Jamaica (1)	Mexico (1)	Mongolia (1)	South Korea (1)

The age difference was not great: while there were respondents from each age category, no single category was clearly a dominant one, with 36-40 year olds representing the largest group by 26,9 % and 31-35 year olds following closely at 21,8 % (figure 4).

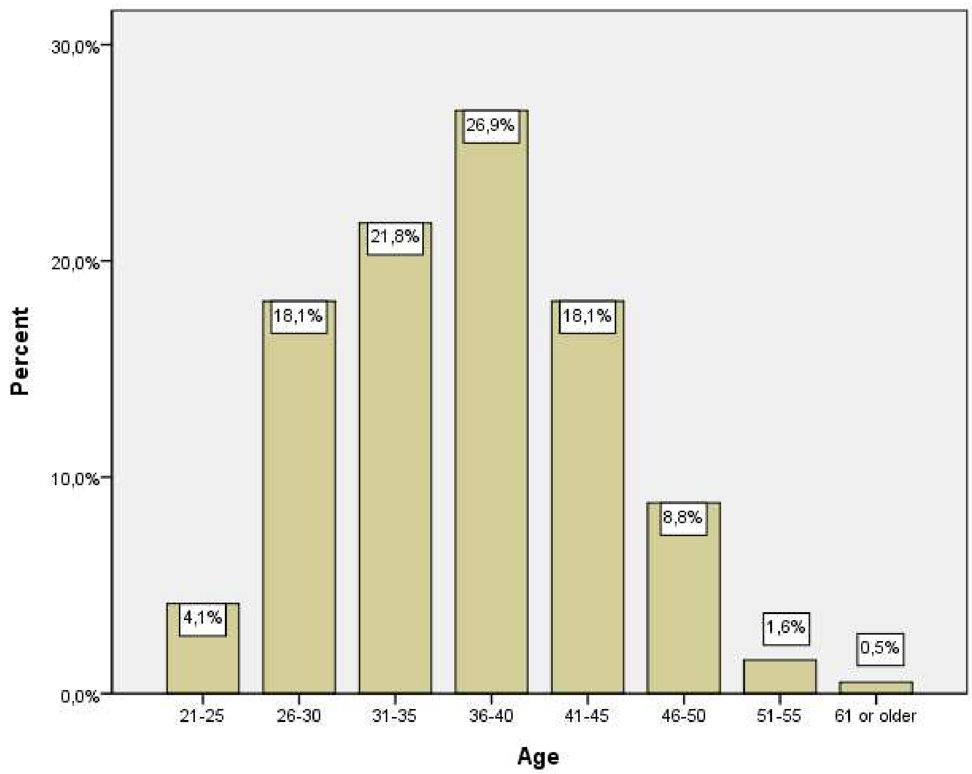

Figure 4: Age deviation of the respondents.

There were considerably more male than female respondents (85,5 % vs. 14,5 %) (figure 5), which can be explained by the nature of the occupation. In many countries ATCs are dominantly or even solely male.

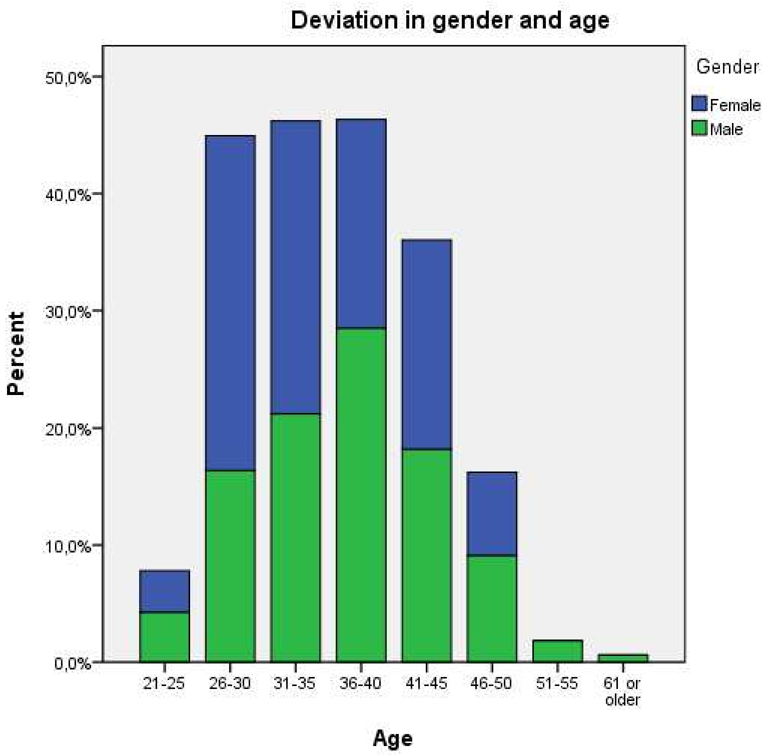

Figure 5: Deviation of age and gender of the respondents.

The majority of the respondents were highly experienced, with 42,0 % having more than 13 years of work experience (figure 6). Yet, all the categories were somewhat evenly represented.

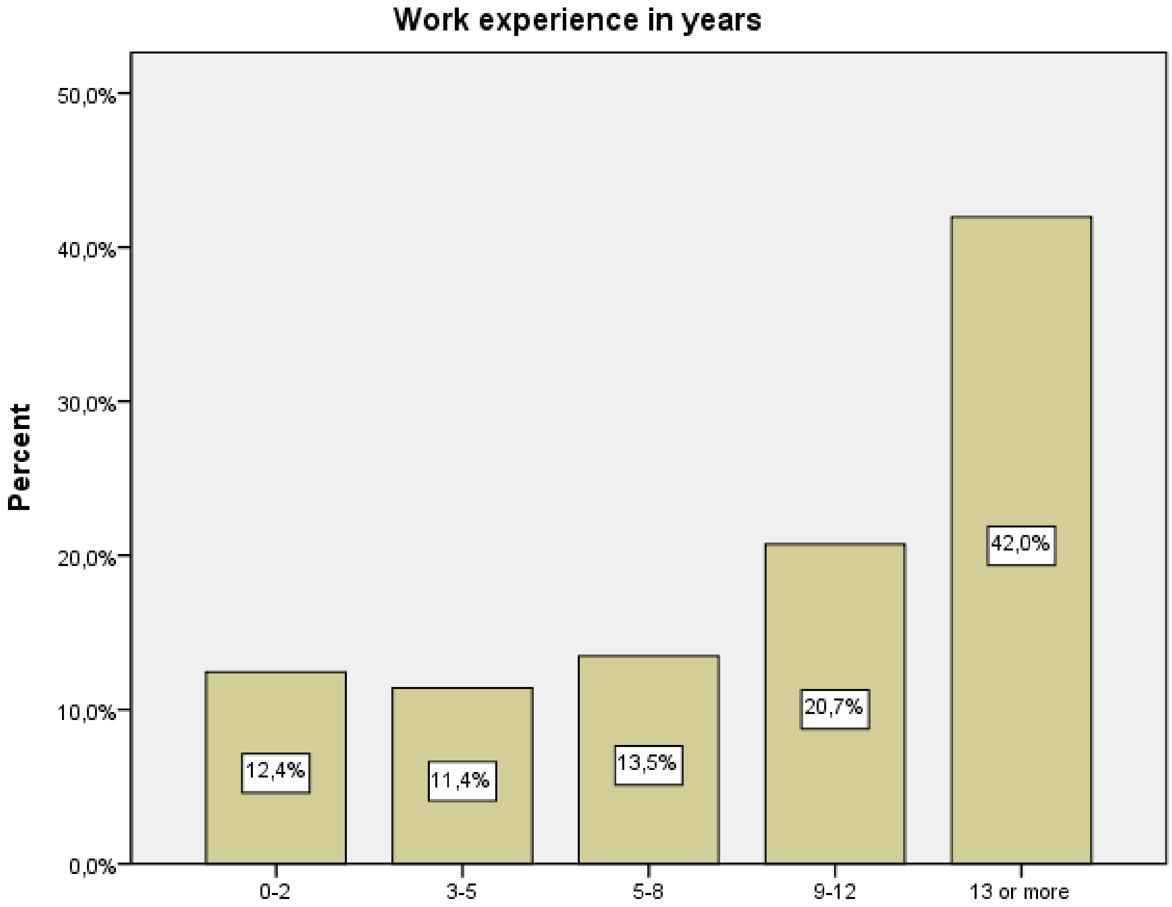

Figure 6: Work experience deviation of the respondents.

4.1. Environmental attitudes

Firstly, it was important to determine the overall environmental attitudes of the respondents. A clear majority (67,8 %) considered aviation causing a great deal of pollution (see figure 7). Still, there was more than 20 percent of respondents who did not agree with the statement that aviation is causing a lot of pollution. This, however, can be explained by the differences in definition: it is true aviation causes pollution in various ways, as explained before, but compared to other methods of transportation, for instance road traffic, the effect is not considerable.

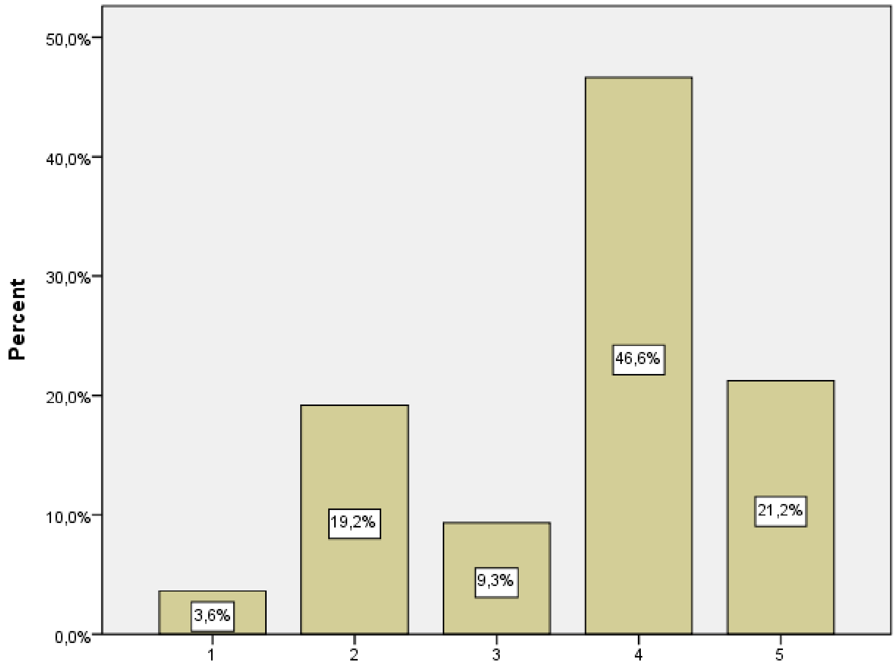

Figure 7: The frequency of ATC's opinions to the statement: In my opinion, aviation causes a great deal of pollution. 1=completely disagree, 5=completely agree.

Interestingly, no correlation could be detected between environmental views and gender – in other words, men are just as concerned over environmental issues as women, and vice versa. Women were slightly more sceptical towards the ATCs' role and ability in reducing emissions than men were, but it is also to be remembered that the number of female respondents was considerable lower (see cross tabulation, table 2).

Table 2: Cross tabulation between ATC's opinion of Gender and Environmental views: In my opinion, the ATCs have the ability to reduce aviation emissions if they want to do so. $\chi2(6, N = 193) = 27.48, p < .001$. 2= totally disagree, 5= completely agree.

% of Total

		Environmental views: In my opinion, the ATCs have the ability to reduce aviation emissions if they want to do so.					
		1	2	3	4	5	Total
Gender	Female	2,6%	2,1%	1,0%	7,8%	1,0%	14,5%
	Male	,5%	14,0%	11,4%	38,3%	21,2%	85,5%
Total		3,1%	16,1%	12,4%	46,1%	22,3%	100,0%

Some correlation could be found in terms of geographical location towards environmental attitudes, but factors such as age and work experience had no dependency to them. In general, the respondents in Western countries shared more concern about environmental issues as well as had more faith in the role of ATCs; however, again the number of respondents was considerably smaller in continents other than Europe.

It was also positive to see that the great majority considered environmental issues important in their everyday life (figure 8).

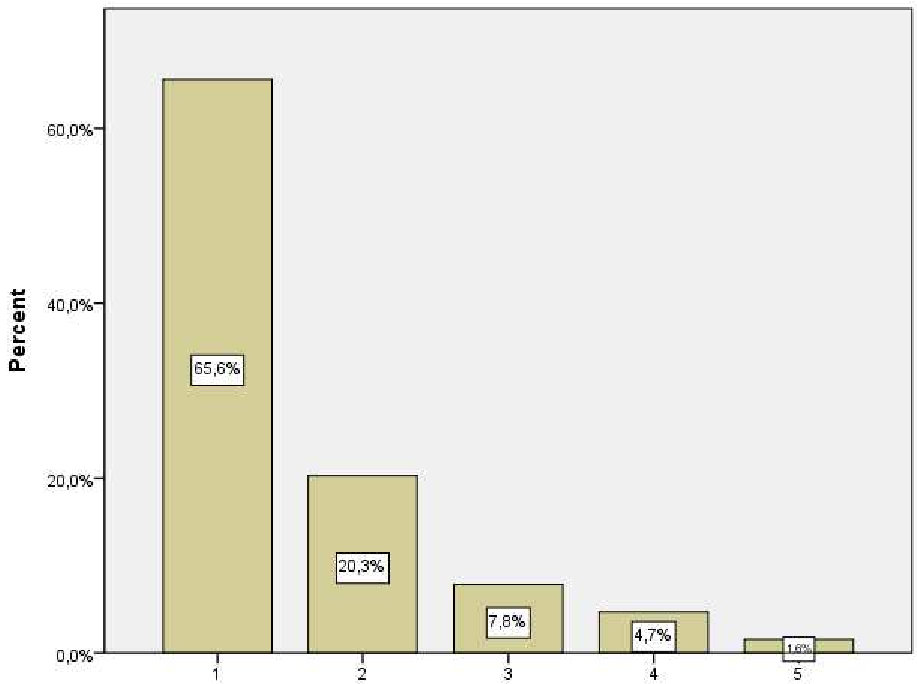

Figure 8: The frequency of ATC's opinions to the statement: In my personal life, I do not worry about environmental issues. 1=completely disagree, 5=completely agree.

Only 14,1 % found environmental issues in their personal life in significant or not so important. This correlated with age to a certain extent (see boxplot graph, figure 9); perhaps the younger respondents were slightly more aware or interested in environmental issues but this had very little to none statistical significance.

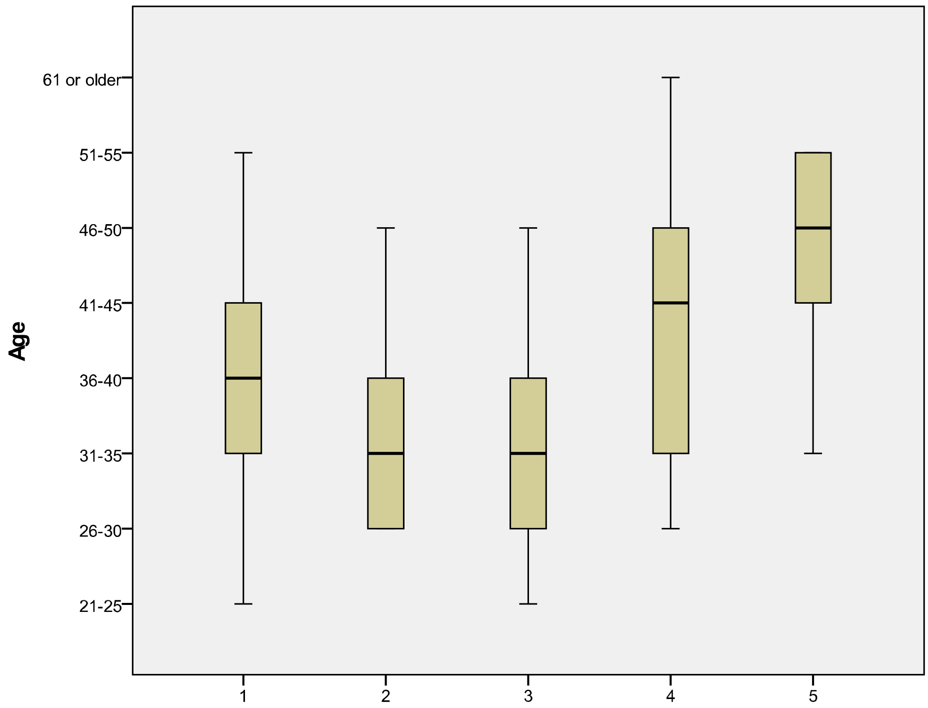

Figure 9: The frequency of ATCs opinions to the statement: Environmental views: In my personal life, I do not worry about environmental issues in relation to variable Age. $\chi2(6, N = 192) = 68.64, p < .001$. 1=completely disagree, 5=completely agree.

When considering the environmental issues in the ATC work, 66,5 % of the respondents found it important to take environmental issues into account in their work (figure 10).

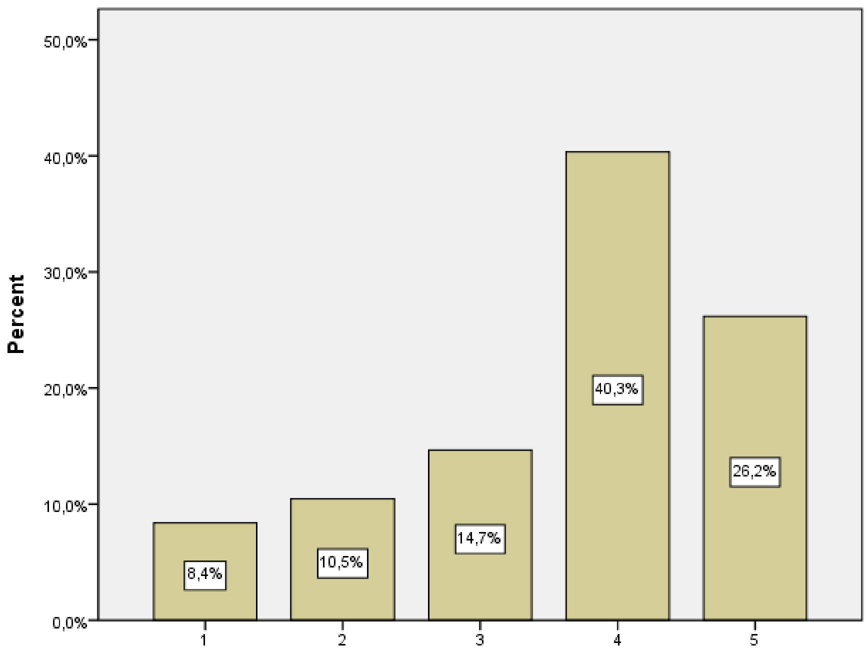

Figure 10: The frequency of ATC's opinions to the statement: Environmental issues are necessary to take into account in my line of work. 1=completely disagree, 5=completely agree.

Approximately the same amount of respondents (65,7 %) had considered environmental issues in their work prior to the survey (figure 11).

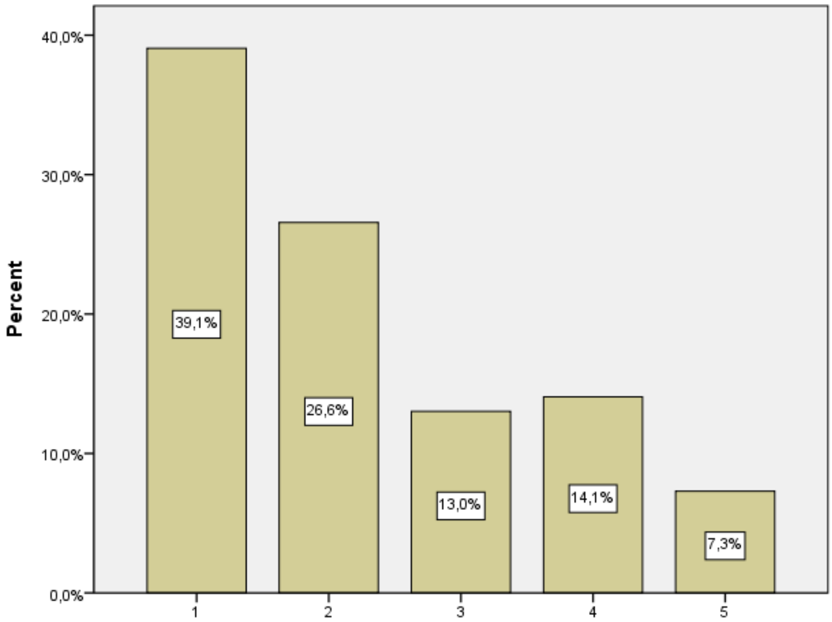

Figure 11: The frequency of ATC's opinions to the statement: I have not considered environmental issues in my line of work before. 1=completely disagree, 5=completely agree.

4.2. The role of ATCs

The ATCs do consider their role as very important in emission reduction. The great majority (62 %) finds that the ATCs have an important role in reducing emission of aviation – whether they find the pollution an issue or not (figure 12). Even a greater number (68,4 %) of respondents felt that the ATCs have the ability to reduce emissions if they wish to do so (figure 13). Furthermore, scatter plot graphs in figures 14 and 15 indicate the correlation between the ATC ability, personal effort made to reduce emissions and the necessity to reduce the environmental impact.

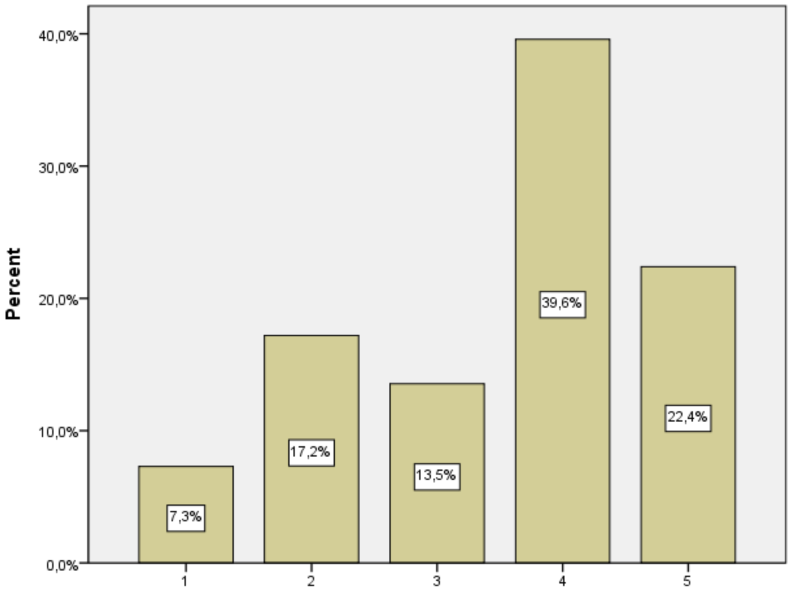

Figure 12: The frequency of ATC's opinions to the statement: In my opinion, the ATCs have an important role in reducing emissions of aviation. 1=completely disagree, 5=completely agree.

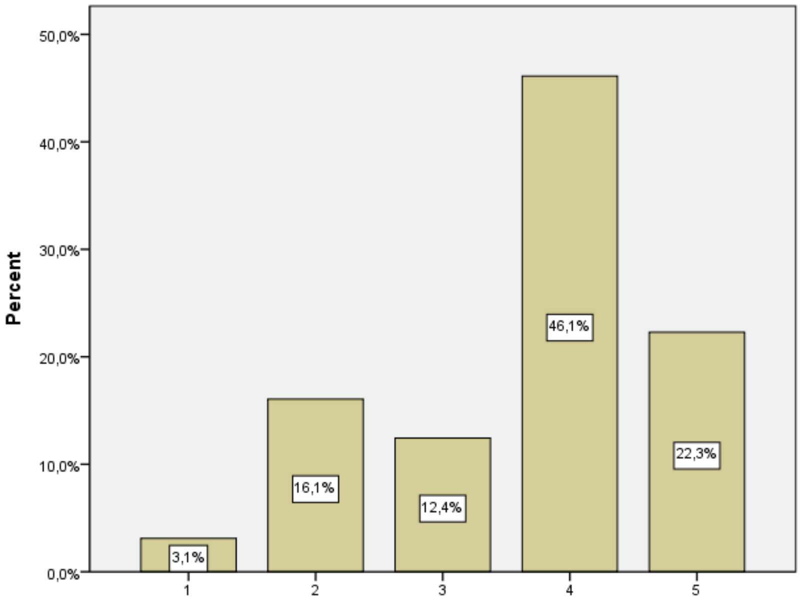

Figure 13: The frequency of ATC's opinions to the statement: In my opinion, the ATCs have the ability to reduce aviation emissions if they want to do so. 1=completely disagree, 5=completely agree.

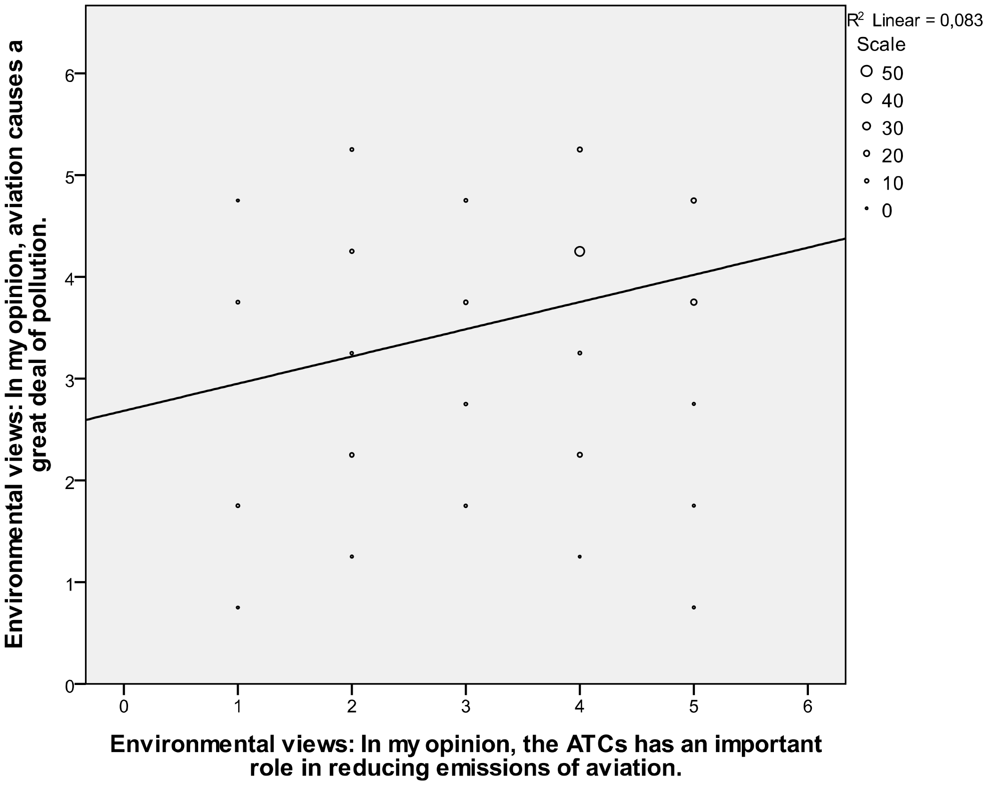

Figure 14: Correlation between the respondents' views on the ATC role and the polluting effect of aviation. N = 193, $p < .001$.

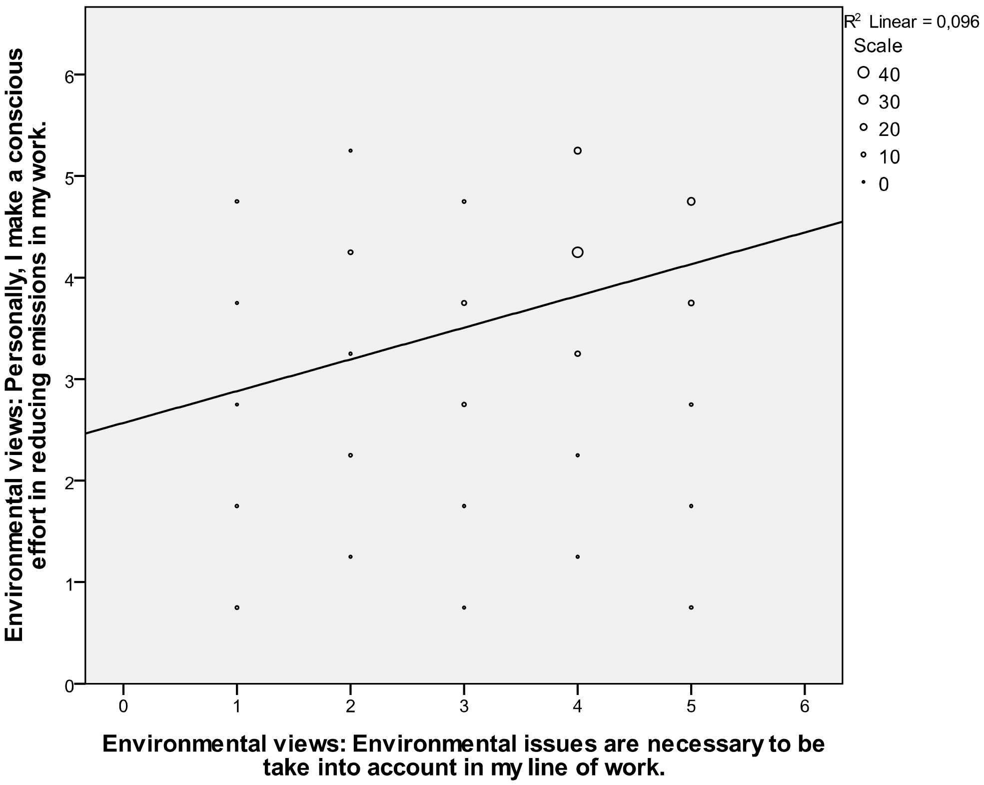

Figure 15: Correlation between the respondents' personal effort and their views on the importance of environmental issues in ATC work. N = 191, $p < .001$.

Further, in figure 16, as many as 68,2 % of the respondents indicated that they make a conscious effort in reducing emissions in their work.

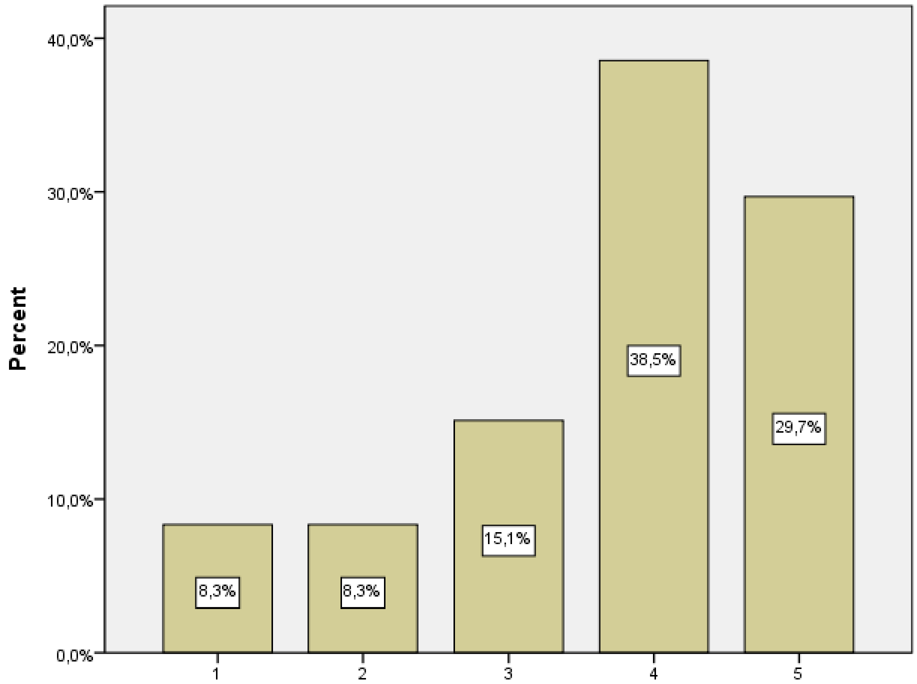

Figure 16: The frequency of ATC's opinions to the statement: Personally, I make a conscious effort in reducing emissions in my work. 1=completely disagree, 5=completely agree.

The ATCs' attitudes towards the environment vary, as stated above, based on their experience, but there was also correlation between the everyday attitudes and professional actions. People who were environmentally conscious tended to consider their professional role further than those who had not considered the environment before. As it can be seen from the figures presented above, nearly all of the participants have considered environmental aspects of their work. This comes apparent further in the analysis (see previous figures 14-15), where distinctive correlation can be spotted between the respondents' personal efforts and the way they see the role of ATCs in emission reduction.

Even though green behaviour and environmental actions are not consciously striven for, the actions are still taken due to alternative reasons (Ahonen 2006, 78). For instance, aircraft approach can be optimised for several reasons other than emission control, such as conserving fuel or simply doing a good job for its sake (Palukka 2003, 120-122). It is also important to highlight that as shown in figure 13, the majority of the respondents feel that ATCs can reduce emissions if they want to do so. Further, figure 16 indicates that the majority of the respondents consciously try to reduce emissions in their work.

4.3. Training

When asked about the training they received, the ATCs' answers vary greatly. Nearly 60 % had not received any training on environmental issues (figure 17). Here it comes down to the definition on training and how the respondents viewed it. It is likely that few have had training especially on environmental issues, but many aspects within training could be seen as environmental advice if one chooses to look at the matter from that perspective, for instance in terms of efficiency.

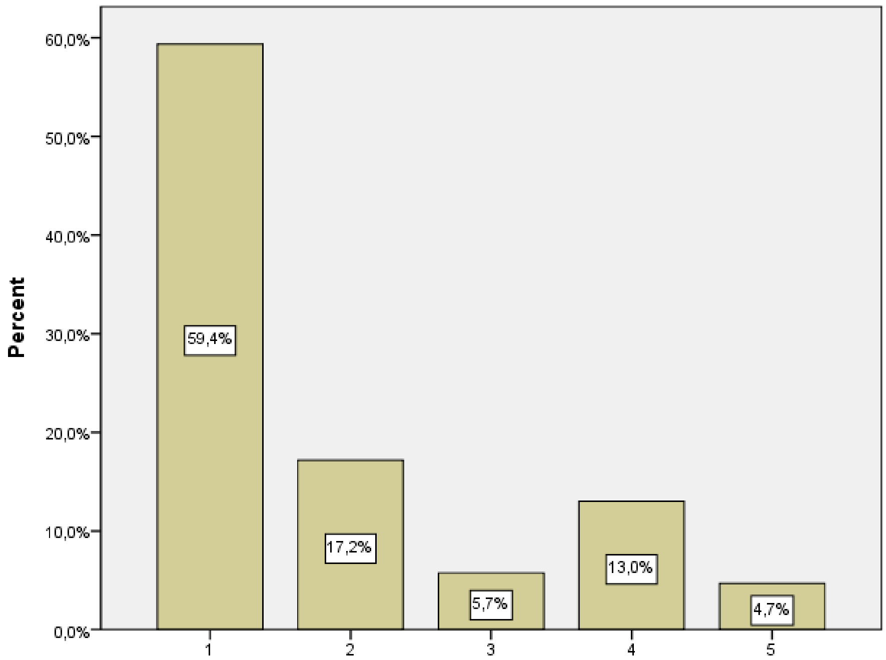

Figure 17: The frequency of ATC's opinions to the statement: I have received training on environmental issues related to my work. 1=completely disagree, 5=completely agree.

Yet, as many as nearly 80 % believe that ATCs should receive training on environmental issues (figure 18), which would indicate that environmental issues are considered important, if somewhat overlooked. Correlation can be found between the importance of training and the personal effort, the ATC role as well as the belief in the abilities of the ATCs – indicating that the respondents felt training would make a difference in environmental efforts (figures 19 and 20).

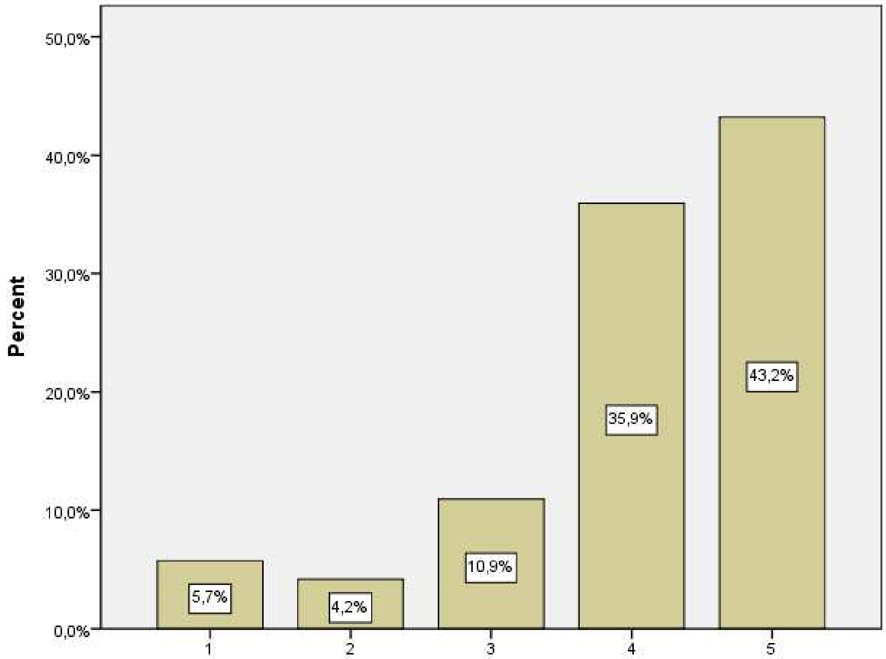

Figure 18: The frequency of ATC's opinions to the statement: I feel that ATCs should receive training on environmental issues. 1=completely disagree, 5=completely agree.

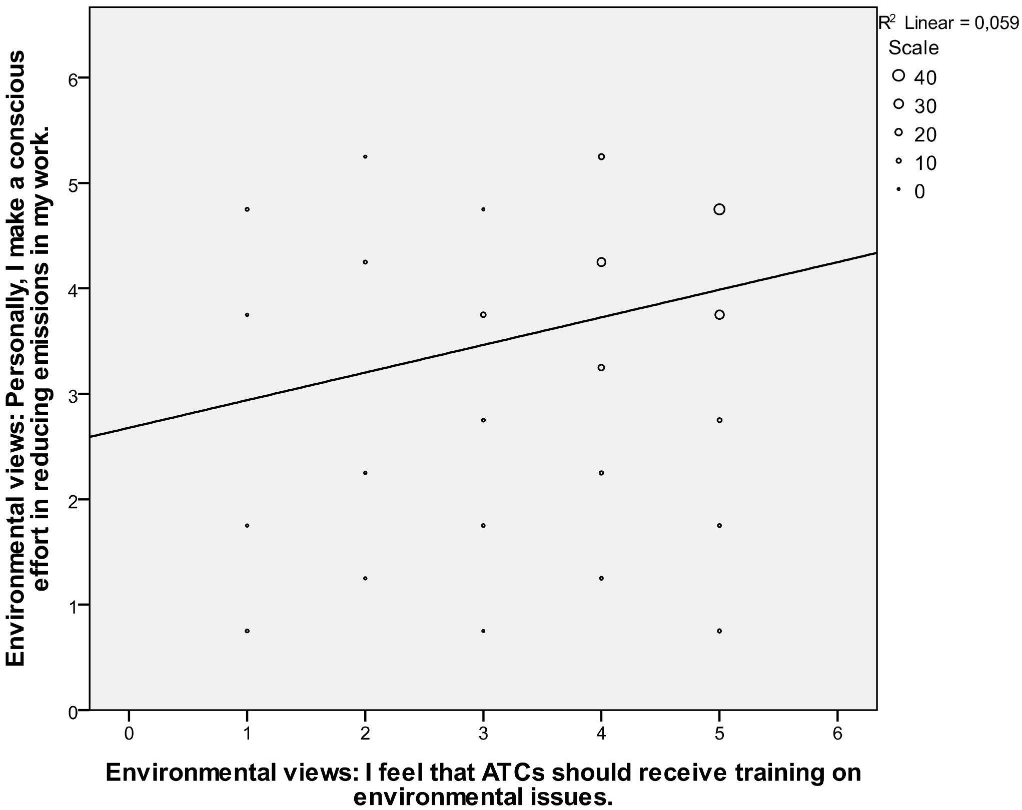

Figure 19: Correlation between the respondents' personal effort and their views on the importance of training on environmental issues. N = 192, p < .001.

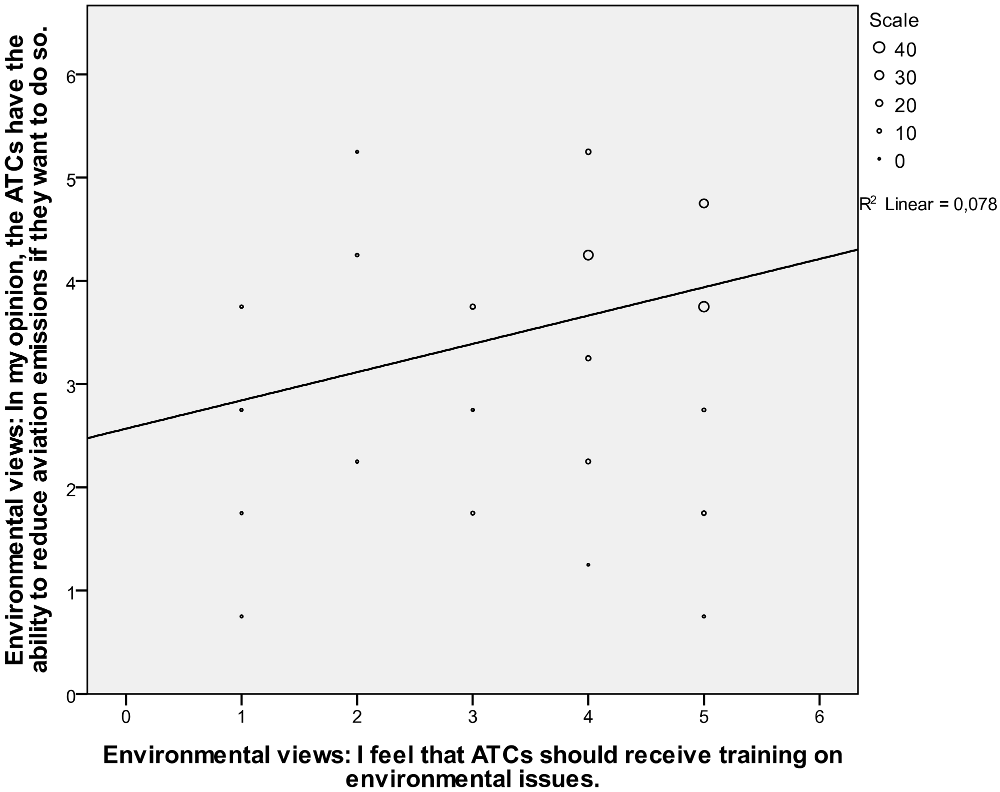

Figure 20: Correlation between the respondents' views on the importance of training on environmental issues and the ATC ability to have an environmental impact. N = 193, p < .001.

However, as far as the outcome of training is concerned, the skills of the ATCs regarding environmental issues varied greatly. Figure 21 shows significant variation in terms of the ATCs' confidence over how well they can reduce emission in their work. Further, figure 22 indicates correlation between the amount of personal effort regarding the training received: those who are trained, also do more.

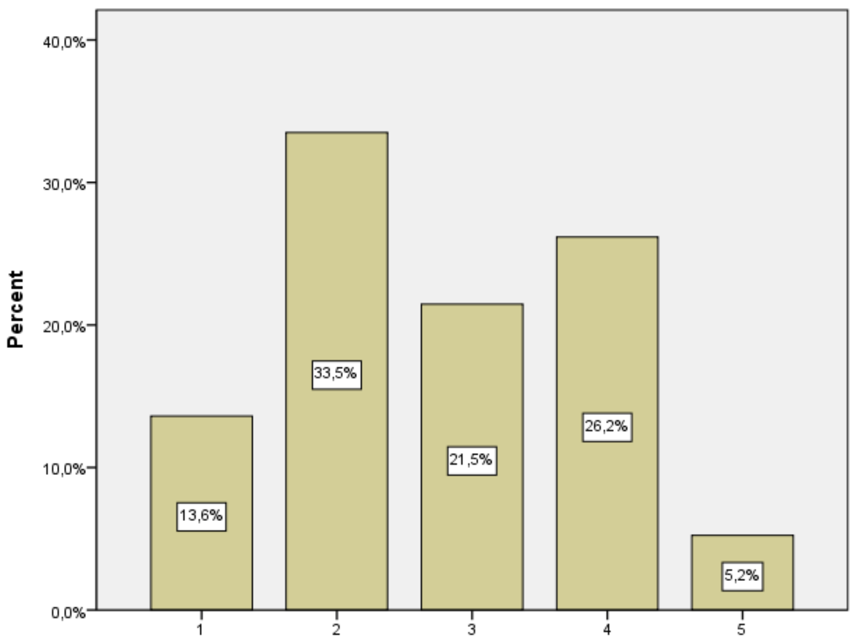

Figure 21: The frequency of ATC's opinions to the statement: I feel it is easy to reduce emissions as an ATC. 1=completely disagree, 5=completely agree.

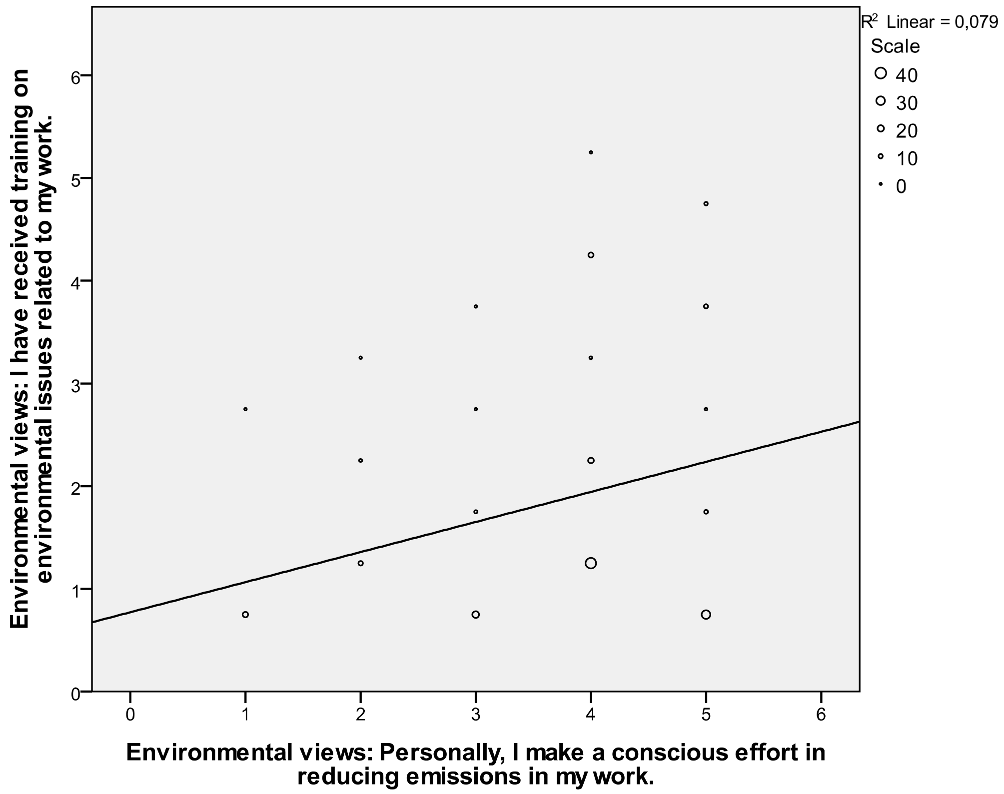

Figure 22: Correlation between the training received and the environmental effort made by the respondents. N = 192, p < .001.

5. Discussion

In this chapter, the results of the survey will be discussed in the light of the attitudes towards greener aviation and its impacts. The answers to the open questions in the survey will be studied to compliment the tools with which the ATCs tackle the environmental impacts of aviation.

5.1. Greener aviation

It is hardly fair to blame only flying for the emissions of aviation; after all, it is also the logistics, infrastructure at the airports as well as the research and development on greener fuel and technology which have their role in making aviation greener. Nevertheless, it is still possible for the ATCs to act ecologically – even if it is only for the economic savings. It may be challenging for the commercial airlines to find motivation to reduce their environmental impact, but financial savings can always count as one good reason. (Rhoades 2008.) Efficient flight patterns and lower fuel consumption are beneficial both for business as well as the environment, and these two issues lay strongly in the hands of the ATCs. (Hooper, Heath & Maughan 2003.) As shown by the results, the respondents felt that flight planning and direct routings were among the most used and most efficient methods for achieving greener aviation.

As the world is becoming an increasingly smaller place, the aviation industry continues to grow. Therefore, it is necessary to meet the demand with proper measures in order to mitigate the impacts on the environment. There are several methods that can be concentrated on, but the ATCs' responsibility is to reduce the impact of noise and emissions. It all starts from flight route planning, in which the ATCs play their part as well. It can be argued that the existing route structure today does not necessarily provide the most economic routes; in route planning issues such as wind, temperature, aircraft weight and safety must be taken into account. The current system with the fixed-route networks can result in concentration of air traffic flows, reducing the number of available routes and flight levels. Thus, international coordination is required in order to achieve the greatest efficiency. While a uniform system with consistent and high quality management, collaboration and transparent decision making is still lacking, it is the responsibility of the ATCs to direct the traffic to the most efficient route – whenever the situation allows. (Lieuwen & Elliff 2003.) The results of this research show clearly that the ATCs are indeed aware of their responsibility and their role as air travel facilitators, with their main goals being safety and efficiency. However, it was indicated frequently that one air traffic controller cannot do much as the methods used are dependent on the conditions as well as other airspace users. It also depends on the position of the ATC; a tower controller has different responsibilities and tasks, as well as limited room to maneuver compared to e.g. an en route controller.

5.2. Attitudes

As the survey results point out, the ATCs are aware of their role in the emission reduction process and to some extent they also feel that they can make a difference. More important, many of them feel they *want* to act as environmentally conscious as possible, whether it makes a difference in the long run or not. These attitudes are affected by several factors, from routine behaviour to traditionally thrifty ideology with no environmental motives whatsoever. (Ahonen 2006; Brand 1997.) It is still clear that environment is considered important by the respondents as training on environmental issues is desired by many and the information could be used to reduce the environmental impact of aviation.

However, it is clear based on the survey results that the ATCs do acknowledge their role in reducing emissions – no matter how they personally feel about environmental issues. Some are more concerned than others but many do see environmental aspects as a part of their work. It is also an ATC trait to do their work up to the highest of standards (Palukka 2003), so it is not necessarily surprising that also environmental issues are taken into account by the ATCs.

5.3. Concrete actions

The survey allowed the ATCs to share the methods they themselves use or consider possible in reducing emissions. The most common methods included using direct routings and Continuous Descent Approach (CDA). Several pointed out also that CDA as well as continuous climb are not only environmental but also fuel efficient and therefore economic solutions. The second biggest category of responses included avoiding delay, flow management and minimising holdings. To maintain well flowing traffic is also one of the goals for the ATCs professionally, and the environmental benefit comes as a bonus. Consistent planning of traffic falls under the category of frequently mentioned methods, too.

As most of the responses included methods already in use in air traffic control and serve the purpose of the safety and efficiency – the goals of the ATCs, it is not surprising to find the methods commonly in use by the controllers. Overall, it was considered that the cooperation between air traffic control and pilot was crucial, ATC being prone to grant pilots their requests in order to take shortcuts and save fuel – whenever situation allowed. In fact, shortcuts, timely start ups and direct clearances for short taxiing were listed as most important issues in terms of pilot-ATC communication.

However, some respondents had their own ideas of methods that they would like to improve or implement regarding both the ultimate goals as well as the environmental benefit. Training was considered necessary by many as knowledge on environmentally efficient air traffic control measures was not familiar to all respondents.

Yet, a more or less common consensus was the fact that one air traffic controller can only do so much. As Brand (1997) points out, it is often the sense of duty and saving costs which affect the behaviour in professional work, not ecological or other interests. Instead of personal values, it is the situational contexts, infrastructural deficits and financial incentives which play even a greater role and knowledge and environmental attitudes (Brand 1997). Training can help the ATCs to achieve their goals of safety and efficiency, but environmental attitudes do not change easily by training. Instead, environmental aspects can be linked to the actions of efficiency, as the goals are often the same.

5.4. Air traffic control in the future

The future brings increasing challenges to aviation industry. More efficient engines and aircraft designs, bio fuel and alternative energy sources are being developed and tested frantically by the aviation companies (see e.g. Finnair 2011). Still, the role of the ATCs has barely been discussed as most of the research concentrates on the technological aspects of aviation.

However, as research has shown, the ATCs are interested in improving their knowledge on environmental issues and doing their bit for greener aviation. Methods such as continuous descent approach (CDA) and other matters related to flight planning are efficient and simple means to reduce the environmental impact of aviation. It is a matter of training to spread the information on the environmental effects of air traffic control procedures. If environmental effects of aviation and the role of the ATCs were to be taken more closely as part of the ATC training, it could potentially create more significant results on the reduction of emissions, both gases and noise. Even though it is the aviation companies who want to emphasise the use of CDA, for instance, efficient take-offs and landings are not possible if the ATC does not approve of it.

Even if the ATCs were more aware of their own role and had the training required to concentrate also on environmental factors in addition to the safety and efficiency aspects, the role of the ATCs is changing. Automation has become more and more crucial part of the ATC work, as well as the work of the pilots. Autopilots, radars, signals indicating distance and location of the runway and so on – they all take some workload off from the ATCs and put more faith on technology. As technology develops, it can be assumed that human participation to air traffic planning and flying are diminishing. Already now, the flight paths are calculated by a computer program and the ideal speed and altitude are given by an automated system. Air traffic control observes and analyses these readings but only rarely rely on their own skills in the actual calculations.

The increase in technology is done in order to limit the chance of a human error but it is naturally relevant to ask, whether it is recommended to increase the role of the automated systems above human control. When asked from pilots and ATCs, the answer is nearly unanimous: a machine can never replace a human being but some amount of automation does help as it does bring some security to flying. Yet, it is still required that the ATCs are familiar also with the old techniques as technology can suddenly fail.

Another future aspect of environmentally conscious ATC work is related to the role of air travel. Today, air travel is the fastest means to get from one place to the other and the world has become a small place. But what if an alternative method of travel is to be invented? Or if the harm for the environment and potential lack of safety will reduce the amount of air travel in the future? It is relatively safe to say that air travel will remain as the main mode of transport for many years to come, as no astounding new technologies are even close to being developed. Further, the emissions from air travel are, as mentioned in the beginning of this thesis, small compared to other traffic and industries. Safety has always been the main issue in air travel, and it is the main goal of the air traffic control as well. Thus, it is unlikely that air travel will cease any time soon.

The most crucial changes that the ATCs will face in the future are the increasing congestion in the air as flying becomes more and more frequent as well as the automation that is bound to reduce the basic operational knowledge of the ATCs. Yet, as mentioned, it is impossible to completely surpass the human being in the air traffic control process. As the human knowledge, judgement and reactions will remain crucial to the system, it is only sensible to keep on training these individuals to achieve higher standards – not only in safety and efficiency but also in environmental terms. A challenge would be to determine the role of the ATC so that their responsibility is to reduce emission whenever possible and to train them in methods which could have such outcomes.

6. Conclusions

This research has discussed the role and the attitudes of air traffic controllers in terms of environmental impacts of aviation. The issues are tackled from the ATC point of view rather than examining the technical details, which have been done in several other studies on aviation technology. This study aimed at defining the ATC role in aviation as well as their attitudes towards the environment.

The ATCs are not often considered to have an environmental role, similarly like aviation is not considered to be particularly environmentally friendly. Even the results showed no particular interest towards the environment but the work of emission reduction was still considered to be important as a part of the ATC work ethics. In addition, it added to the study by Palukka (2003) on the ATC characteristics, that the results did not seem to differ a great deal between genders, or even age, but the answers were rather distinguished by only individual traits. The biggest differences could be seen from the geographic location of the respondents, which can be interpreted as differences in cultural and local practices.

This study is by no means definite but the scale has been somewhat narrow and the representation of the locations, age, gender and experience has been uneven. Yet, the study does give some type of general view of the ATC attitudes and the concrete work they do to ensure safety, efficiency, as well as environmental benefits of aviation. Environmental aspects are an important part of every sector of society, and aviation is no exception. The role of the ATCs ought to be included to the range of R&D in greener aviation, as more technical knowledge on the potential solutions to low emission aviation is required. Environmental issues include other factors than just emissions, as pointed out, and also noise and security factors could be studied in more detail.

Environmental aspects of aviation are often seen in a very narrow light, at least as far as the general public is concerned. Shorter flight routes, continuous climbs and descents and other methods are hardly known to the majority of the air travel passengers. Yet, the aviation companies are aware of these factors and do their best to achieve more efficient results in terms of fuel consumption – which of course is an environmental act in itself. Airports must take into account noise restrictions and the effects caused by flight noise, and also here the direction of take-off and landing are crucial. There are guidelines and regulations to be followed and goals to be met, but it is sometimes overlooked that these issues are monitored and managed by the air traffic controllers.

It is up to the ATCs to manage the air traffic so that environmentally efficient flight routines are possible – after safety has been taken into account. Thus, it is necessary to allow the ATCs have the information required in order to meet these goals, to understand the connection between efficient flight planning and the environmental impact.

In the future, as environmental issues such as climate change are global problems, aviation must, along with other industries, reduce its environmental impact. Developing new engines and aircraft is a consuming process, so it is worthwhile to make also the current models' flights more environmentally friendly. These methods, as has been repeatedly stated, are up to the air traffic controllers. The role of the ATCs ought to be included to the range of R&D in greener aviation, as more technical knowledge on the potential solutions to low emission aviation is required. It might be interesting to include a more technical study on the effect the ATCs have on the environmental impact of aviation, by studying their concrete actions and the amount of CDA approaches, for instance, as well as other methods used. The study also pointed out that ATCs are keen on learning more about how they can contribute to the environment, so further training on emission reduction would be recommended to all ATCs. A further study on the impacts of this training might also prove to be useful. Environmental aspects are an important part of every sector of society, and aviation is no exception. Thus, every method counts.

7. References

Ahonen S. (2006), Vihreän kuluttajan monet kasvot. Published in Massa & Ahonen (2006), Arkielämän ympäristöpolitiikka, pp. 72-86. Gaudeamus Helsinki.

Babisch W. (2005), Traffic, noise and health. Published in Nicolopoulou-Stamati P., Hens L. & Howard C.V. (eds.) (2005), Environmental Health Impacts of Transport and Mobility. Springer, Dordrecht.

Ballester F. (2005), Air pollution and health. Published in Nicolopoulou-Stamati P., Hens L. & Howard C.V. (eds.) (2005), Environmental Health Impacts of Transport and Mobility. Springer, Dordrecht.

Brand K-W. (1997), Environmental Consciousness and Behaviour: The greening of life-styles. Published in Redclift M. &Woodgate G. (1997), The International handbook of environmental sociology. Edward Elgar Publishing Ltd. Cheltenham.

Cardosi K.M & Murphy E. D, (eds.) (1995), Human Factors in the Design and Evaluation of Air Traffic Control Systems. Office of Aviation Research, Federal Aviation Administration. Washington, DC: U.S. Department of Transportation.

Dobbie L. (2003), Key Issues in Aviation Environmental Policy-making. Published in Upham et al. (eds.) (2003), Towards Sustainable Aviation, pp. 204-210. Earthscan, London.

Finavia (2010), Lentoliikennetilasto 2010. Available at: [http://www.finavia.fi/files/finavia2/liikennetilastot_pdf/Lentoliikennetilasto_2010.pdf].

Finavia (2009), Ympäristöraportti 2009. Available at: [http://www.finavia.fi/files/finavia2/ymparistoraportit_pdf/Finavia_ymparistoraportti_2009.pdf].

Finavia (2008), Helsinki-Vantaan lentoasema. Ympäristöraportti 2008. Available at: [http://www.finavia.fi/files/finavia2/ymparistoraportit_pdf/EFHK_ymparistoraportti_2008.pdf].

Finnair (2011), Corporate responsibility. Referred to on 22nd July 2011. Available at [http://www.finnair.fi/finnaircom/wps/portal/finnair/corporate-responsibility/flying-and-the-environment/fi_FI].

Garland D. & Endsley M. (1996), Experimental analysis and measurement of situation awareness. Daytona Beach, FL, Embry-Riddle Aeronautical University Press.

Gråsten J. & Kiukas I. (2004), Öljyvahingot Etelä-Savon, Kaakkois-Suomen ja Keski-Suomen alueilla. Rekisteri, tutkimussuunnitelma ja toimintamalli. Etelä-Savon ympäristökeskus, Mikkeli. Referred to on 25th August 2011. Available at: [http://www.ymparisto.fi/download.asp?contentid=21820].

Hooper, Heath & Maughan (2003), Environmental management and the aviation industry. Published in Upham et al. (eds.) (2003), Towards Sustainable Aviation, pp. 115-130. Earthscan, London.

Hopkin V.D. (1995), Human Factors in Air Traffic Control. London: Taylor and Francis.

Hume K. & Watson A (2003), The human health impacts of aviation. Published in Upham P., Maughan J., Raper D. & Thomas C. (2003), Towards Sustainable Aviation, pp. 48-76. Earthscan Publications Ltd, London.

Jarmat Oy (2001), Propyleeniglykolin käyttöturvallisuustiedote. Updated on 13th November 2002. Referred to on 2nd February 2011. Available at: [http://www.jarmat.fi/ktt/motovaripgktt.htm].

Lee D. & Raper D. (2003), The global atmospheric impacts of aviation. Published in Upham P., Maughan J., Raper D. & Thomas C. (2003), Towards Sustainable Aviation, pp. 77-96. Earthscan Publications Ltd, London.

Lentoliikenne ja ilmasto (2011), Päästöjen vähentäminen. Available at: [http://www.lentoliikennejailmasto.fi/vahentaminen].

Lieuwen A. & Elliff T. (2003), Potential Improvements to Air Traffic Management. Published in Upham et al. (eds.) (2003), Towards Sustainable Aviation, pp. 220-223. Earthscan, London.

Massa & Ahonen (2006), Arkielämän ympäristöpolitiikka. Gaudeamus Helsinki.

Nicolopoulou-Stamati P., Hens L. & Howard C.V. (eds.) (2005), Environmental Health Impacts of Transport and Mobility. Springer, Dordrecht.

Palukka (2003), Johtotähdet: lennonjohtajien ammatti-identiteetin rakentuminen ryhmähaastatteluissa. Doctoral thesis, University of Tampere.

Passchier-Vermeer W. & Passchier W.F. (2005), Environmental noise, annoyance and sleep disturbance. Published in Nicolopoulou-Stamati P., Hens L. & Howard C.V. (eds.) (2005), Environmental Health Impacts of Transport and Mobility. Springer, Dordrecht.

Pastowski A. (2003), Climate policy for civil aviation: actors, policy instruments and the potential for emissions reductions. Published in Upham et al. (eds.) (2003), Towards Sustainable Aviation, pp. 179-198. Earthscan, London.

Redclift M. &Woodgate G. (1997), The International handbook of environmental sociology. Edward Elgar Publishing Ltd., Cheltenham.

Rhoades D. (2008), Evolution of International Aviation. Phoenix Rising. Ashgate Publishing Limited, Hampshire.

Salminen J. & Tuominen S. (2010), Vaihtoehtoisten liukkaudentorjunta-aineiden kulkeutuminen pohjavedessä (MIDAS). Suomen Ympäristökeskus. Available at: [www.ymparisto.fi/syke/midas].

St1 (2008), Käyttöturvallisuustiedote. Lentopetroli JET A-1. Updated on 1st July 2008. Referred to on 28th December 2010. Available at: [http://www.st1.fi/ci/St1%20Jet-A%20lentopetroli.pdf].

Työterveyslaitos (2009), OVA-ohjeet. Lentopetroli. Updated on 17th December 2009. Referred to 28th December 2010. Available at: [http://www.ttl.fi/ova/lentopetroli.html].

Upham P., Maughan J., Raper D. & Thomas C. (2003), Towards Sustainable Aviation. Earthscan Publications Ltd, London.

Wickens C.D., McGee, J.P., Mavor, A.S. (eds.) (1997), Flight to the Future: Human Factors in Air Traffic Control. National Academy Press, Washington D.C.

Wise J.A., Hopkin V.D. & Garland D.J. (eds.) (1994), Human Factors Certification of Advanced Aviation Technologies. Daytona Beach, FL: Embry-Riddle Aeronautical University Press.

8. Appendix 1 - Questionnaire

Background

Area of employment	Northern Europe Western Europe Eastern Europe Southern Europe Northern Africa Sub Saharan Africa Western Africa Eastern Africa East Asia South Asia Northern Asia Middle East Far East North America Central America South America Australia and Oceania
Country of employment	[optional]
Work experience in years	0-2 3-5 6-8 9-12 13 or more
Age	Under 20 21-25 26-30 31-35 36-40 41-45 46-50 51-55 56-60 61 or older Do not want to say
Gender	Female Male

Environmental views

	Completely disagree	Somewhat disagree	Do not agree or disagree	Somewhat agree	Completely agree
In my opinion, aviation causes a great deal of pollution.	☐	☐	☐	☐	☐
In my opinion, the ATCs have the ability to reduce aviation emissions if they want to do so.	☐	☐	☐	☐	☐
Personally, I make a conscious effort in reducing emissions in my work.	☐	☐	☐	☐	☐
In my opinion, the ATCs has an important role in reducing emissions of aviation.	☐	☐	☐	☐	☐
I feel that ATCs should receive training on environmental issues.	☐	☐	☐	☐	☐
I have received training on environmental issues related to my work.	☐	☐	☐	☐	☐
Environmental issues are necessary to be take into account in my line of work.	☐	☐	☐	☐	☐
In my personal life, I do not worry about environmental issues.	☐	☐	☐	☐	☐
I feel it is easy to reduce emissions as an ATC.	☐	☐	☐	☐	☐
I have not considered environmental issues in my line of work before.	☐	☐	☐	☐	☐

What kind of methods could ATCs use to reduce emissions?

What kind of methods do YOU as an ATC use to reduce emissions?

Comments?