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A Sustainable Approach to Airport Design and Operations: Case Study of Munich Airport

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Abstract

The aim of this research is to empirically examine the sustainable aspects of airport design and operations, in the context of Munich Airport, one of the world's major airports. The primary research question addressed by this work is: What aspects of airport design and operation in a major airport are critical to its sustainability and mitigating its contributions to climate change? An exploratory single site case study methodology was utilised and the research concentrated on Munich Airport, Germany's second busiest airport, located in Bavaria, in south east Germany. The primary business of the airport is commercial and general aviation services. Air cargo, catering and retail, and real estate are other important strategic market segments. Data was gathered from the Flughafen München GmbH annual sustainability reports and company websites. Finally, the data was analysed using content analysis. All major aspects of airports infrastructure design and operations were explored, focussing on the environmental impacts. This included water usage and management, energy consumption, waste management, and other key aspects of pollution, including noise. In the case of Munich Airport, the most significant environmental impact factors identified were aircraft emissions and noise, waste, and water management. The significance of sustainable operations in the global aviation industry is, of course, relevant to airports. Since the commencement of operations in 1992, Munich Airport's strategic objectives have incorporated key sustainability focus areas. Indeed, the airport's strategy is essentially sustainability-driven. The airport has implemented systems and procedures to optimise its environmental footprint, and to ensure its compliance with all applicable statutory requirements.

Keywords

Airports, air pollution, aircraft emissions, aircraft noise, energy management, waste management

1. Introduction

The aim of this work is to examine how airports can have a sustainable approach to their design and operations. The first aim is to identify the variety of impacts that airports have on the natural environment and local communities. This will provide an understanding of how modern and large airports can manage both the design of their airport-related infrastructure and systems, whilst also facilitating sustainable operations. The second aim is to examine how the emergent technologies can improve sustainability of a modern, and large, airport's operation.

Air transport provides the only rapid global transportation network, which makes it critical for global business and tourism. The global air transport industry also facilitates economic growth, especially in developing countries. The air transport industry also facilitates global trade, enabling countries to participate in the global economy by increasing access to international markets, and enabling globalisation of production (Air Transport Action Group, 2014). Notwithstanding, the global community is currently paying greater attention to the impact that airports have on the environment. Consequently, many airports around the world are working to make themselves more environmentally friendly. The airport's location, current situation, and available opportunities also play a key role in this situation (Vanker et al. 2013).

The operations of airports have a variety of impacts on both local communities and the natural environment. These impacts include noise, local air quality, energy, water use, and airport waste (Graham, 2014; Thomas & Hooper, 2013).

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Noise is regarded as one of the most common adverse environmental factors (Vilutienė & Ignatavičius, 2011). In recent years, aircraft noise disturbance and its impact on communities surrounding airports is almost certainly the single most significant concern affecting airport operations and developments internationally (Vanker et al. 2009). The major source of noise at airports comes from aircraft, and occurs during take-off, landing, and also when taxiing to and from the terminal and apron area (de Neufville & Odoni, 2013).

Another environmental threat is that of aircraft emissions (Graham, 2014) which adversely impact human health through the degradation of air quality (Barrett et al. 2010). By consuming fuel, aircraft produce emissions of carbon dioxide (CO_2), nitrogen oxides (NOX), particles (principally soot) of sulphur oxides, carbon monoxide, as well as various hydrocarbons. CO_2 is regarded as the most important of all the greenhouse gases (Hossain, 2011).

In an airport's operational area, run-off waters represent a significant environmental threat (Sulej et al. 2012) and could have a negative impact on both soil and groundwater since it contains a relatively high concentration of contaminants (Vanker et al. 2013). Indeed, storm water runoff can be impacted by airport operations, for example, the use of chemicals for snow and ice removal, accidental fuel and oil spills on airport ramp areas, and the discharge of fire-fighting foam in the event of aircraft emergencies. Wastes associated with aircraft refuelling, operation and cleaning could potentially be carried to lakes and streams located nearby to the airport through the storm water drainage system. Other operational activities at the airport can influence water quality through contaminants in storm water runoff, for instance, major aircraft overhauls that utilise toxic chemicals to remove paint and clean and re-chrome engine parts as well as other light-industrial type activities (Culberson, 2011, p. 732). Similar with most other industrial activities, waste pollution is also an issue for airports (Pitt & Smith, 2003a). Energy management, which includes heating, ventilation, air conditioning, and lighting, is also extremely important (Graham, 2014).

The global air transport industry is growing rapidly. As Figure 1 shows, there is a forecasted exponential growth in world airline revenue passenger kilometres (RPKs) (the product of total passengers and the distance travelled), until 2030 (Schäfer & Waitz, 2014). The growth of the industry is driven by many factors, including economic growth, new flight routes, strategic airline alliances, and low-cost carriers (LCCs). As previously noted, the global air transport industry plays a critical role in facilitating both commerce, tourism, and trade (Air Transport Action Group, 2014). Accordingly, it is critical that sustainability in the industry is maximised, both economic sustainability and environmental sustainability.

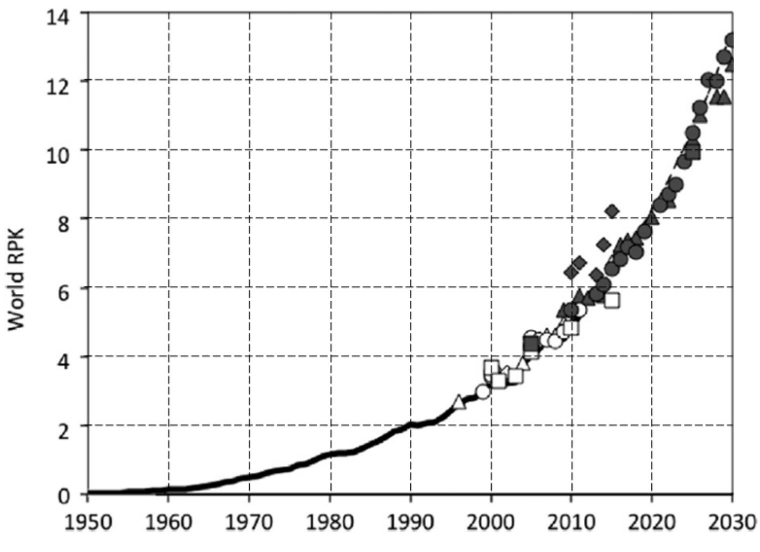

Figure 1: Historical and projected world airline revenue passenger kilometres (RPKs).

<u>Note</u>: RPKs in trillions are shown historically (solid line) from 1950 to 2011, and with various forecasts until 2030 overlayed.

Source: Adapted from Schäfer & Waitz (2014).

The increased projected demand for air travel in the upcoming years will, however, have a corresponding influence on emissions, air quality, and, potentially public health (Levy et al. 2012). Currently it is estimated that the contribution of the air transport industry to global warming is presently 2-3 per cent. The projected growth of the industry could see this rise to around 10-20 per cent by 2050. In order to accommodate the forecasted growth in air travel demand, whilst also mitigating its potential adverse environmental impacts, sustainability of airport design and operations is therefore essential.

The primary research question addressed by this work is: *What aspects of airport design and operation in a major airport are critical to its sustainability and mitigating its contributions to climate change*? To answer this primary research question several secondary research questions are also addressed: “What are the current trends in a major airport’s management of aircraft noise emissions?” Also, “Is it possible for a major airport to re-cycle waste in order to mitigate its environmental footprint?”

2. Research Methodology

With the aim of examining what aspects of airport design and operation in a major airport are critical to its sustainability and the mitigation of its contributions to climate change, a qualitative research approach was used. The study of airport sustainability and its contributions to climate change is an emergent area of study. Thus, the most appropriate research method for such an emerging area is a qualitative method (Edmondson & McManus, 2007). A case study approach was therefore used in this study as this research approach allows for the exploration of complex phenomena (Eisenhardt, 1989; Yin, 2014). Furthermore, case study research enables the collection of rich, explanatory information (Mentzer & Flint, 1997) and permits researchers to build theory and connect with practice (McCutchen & Meredith, 1993).

In order to alleviate potential biases and to support measurement validity careful attention has been paid to the selection of sources used in the study (Fasone & Maggiore, 2012). Accordingly, data for the study was obtained from a range of documents, company materials available on the internet and records as sources of case evidence. Documents included Munich Airport annual sustainability reports, corporate brochures, and the airport’s websites. The study therefore used secondary data (Rahim & Baksh, 2003). The three principles of data collection as suggested by Yin (2014) were followed: the use of multiple sources of case evidence, creation of a database on the subject and the establishment of a chain of evidence.

The data collected in the study was analysed using content analysis (Schreier, 2012). Content analysis is a research tool that can be utilised to determine the presence of certain concepts within texts. Texts can be broadly defined as books, articles, newspaper articles, historical documents as well as non-text based materials, such as television segments (Klenke, 2008). Content analysis procedures are used by researchers to describe, analyse and summarise trends and observations from field trips or the data that have been gathered (Green, 2011).

3. Case study of Munich Airport

Munich Airport, commenced operations in 1992, and is now Germany’s second busiest airport, as measured by passenger traffic, after Frankfurt Airport. The airport has two identical runways 08R/26L and 08L/26R, both concrete paved and 13,123ft (4,000m) long, which are capable of handling 90 aircraft movements an hour between them. Munich Airport expanded rapidly following its opening; this was primarily due to the major German airline Lufthansa decision to base more of its operations in Munich (Airport Technology, 2014).

Munich Airport places a very high focus on environmental sustainability and one of its key corporate strategies is to operate and develop the airport in such a way that is compatible with and effectively limits any harmful effects on the environment (Flughafen München GmbH, 2014b). Figure 2 shows the total aircraft movements and passenger (PAX) movements at Munich Airport from 2008 to 2012.

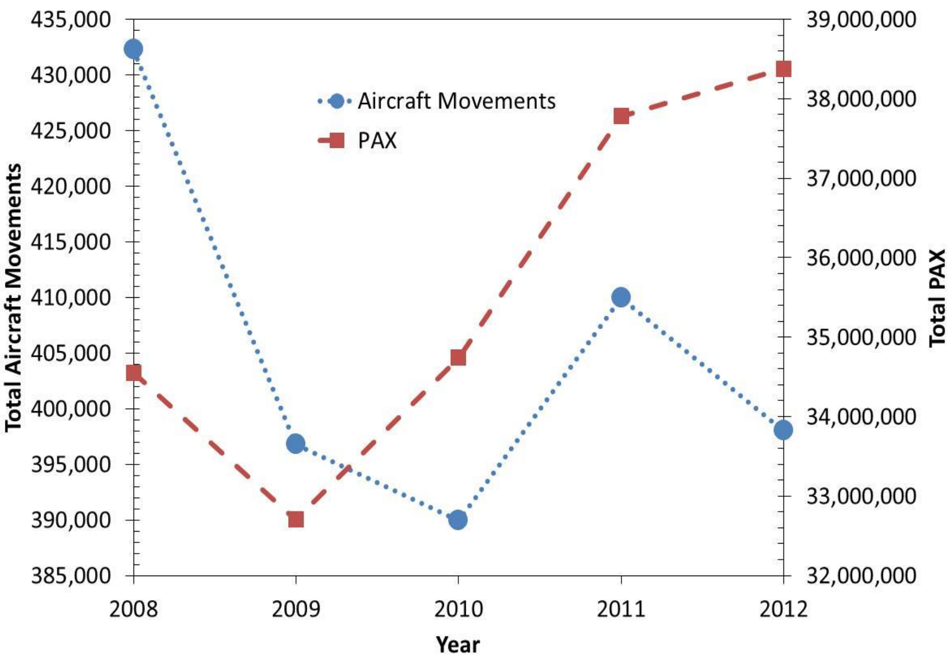

Figure 2: Munich Airport total annual passengers and aircraft movements.

Source: Flughafen München GmbH (Various).

3.1. Energy Consumption and Management

Airports require a guaranteed, appropriately priced, and secure energy supply in order to meet peak demand from their service partners and passengers and therefore optimise their operational capacity. The maintenance of an ambient temperature and air quality within airport passenger terminals so as to ensure passenger comfort typically represents the single most significant contribution to energy usage and management at most airports. In order to reduce their long-term operating costs and to ensure that energy demand can be satisfied when it arises, airports are placing a higher focus on energy-conservation measures in the design (and operations) of terminal buildings. Some airports have also developed and operate their own power-generation systems. Furthermore, airports often work closely with tenants, concessionaires, and service partners to reduce energy consumption through the introduction of low-energy equipment and systems (Thomas & Hooper, 2013).

In recent years, Munich Airport has placed a high focus on sustainable energy management. Some of the key initiatives that the airport has introduced include the gradual replacement of its conventional apron and exterior lighting using sodium-vapour bulbs containing with modern light-emitting diode (LED) technology. Areas of the airport aprons, several streets, and parking areas have already been retrofitted with LED technology lighting. The LED lamps require around 50 percent less energy than the previously used conventional and, at around 17 years, have a service life one and a half times greater. The airport estimates that the first phase of the conversion will make it possible to save around 122,000 kilowatt hours of electricity annually, and hence, eliminate around 70 tons of CO_2. Over the longer-term, the retrofitting of all 3,000 lights on the airport apron and 10,200 lights used for exterior lighting will generate annual savings of more than 5,000 tons of CO_2 (Flughafen München GmbH, 2013).

In terms of energy generation, the airport has placed a high focus from its beginning on both sustainability and economic efficiency. Hence, for instance, the airport's combined heat and power plant (CHP) is operated with natural gas. The use of natural gas not only reduces the airport's CO_2 emissions, but with an estimated total service life of more than a million operating hours, is also among the most economical and efficient systems available. The reduction of CO_2 emissions as compared with conventional energy generation is estimated to be around 30,000 tons a year. This high degree of efficiency in the generation of energy is made possible through the coupling of power and heat: The heat generated from the production of electricity is not lost but instead is used for providing heating and for air conditioning. Munich Airport presently satisfies around 75 percent of its annual heating energy requirements through its own combined heat and power plant. Except for a small amount of energy supplied by peak boilers, the airport satisfies the remainder of its heating requirements by purchasing district heat, supplied by a local utility company based in Freising via a pipeline. Since early 2011, 50 percent of our district heat – approximately 15 gigawatt hours (GWh) – is generated by a biomass-fired thermal power plant located in the town of Zolling. Importantly, the heat generated from biomass is renewable and climate-neutral. With this energy policy, CO_2 emissions are sustainably reduced by 3,500 tons a year (Flughafen München GmbH, 2013).

In August 2002, the photovoltaic facility (or solar energy facility) installed on the roof of Terminal 2 was connected to the airport power grid (Airport Technology, 2014). The airport's solar power facility, with modules covering a total area of 3,600 square metres, has an annual power output of 445,000 kWh. This system accounts for 0.2 per cent of the airport's total power requirements, and also represents a reduction in CO_2 emissions of approximately 400 tonnes per annum (Flughafen München GmbH, 2014a). The high production of energy is guaranteed even during winter months through the use of the latest polycrystalline silicon cells and the optimal alignment of the solar modules at a 20° angle facing south. The investment cost in this project was around €2.7m. Lufthansa also participated in this project as a sponsor (Airport Technology, 2014). Figure 3 shows Munich Airport's total energy consumption and the corresponding CO_2 emissions from 2007 to 2012.

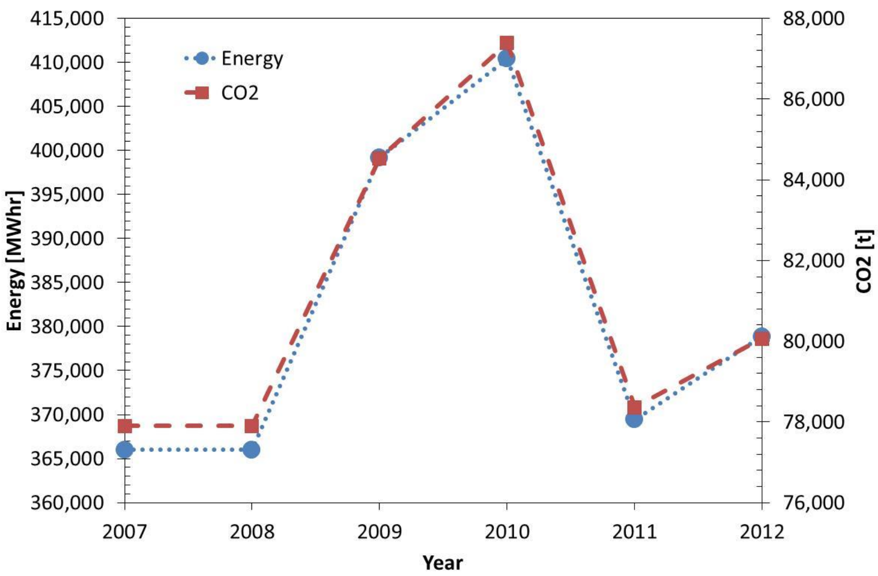

Figure 3: Airport total energy consumption (given in mega Watt hours) and the corresponding carbon dioxide emissions (given in tons).

Source: Flughafen München GmbH (Various).

3.2. Water Management

Airports consume significant amounts of water to maintain both their infrastructure and operations (de Castro Carvalho et al. 2013). Airport operators, ground service providers, and passengers and staff require water for drinking, catering, retail, cleaning, flushing toilets, system maintenance, as well as for airport grounds maintenance and landscaping. The operational capacity of an airport and the level of service quality delivered to its customers and service partners can be severely constrained if it is unable to guarantee and deliver a secure, adequate, and low-cost supply of water to satisfy peak demand (Thomas & Hooper, 2013, p. 563).

Munich Airport sources its potable water from the Moosrain water utility company. This company extracts its water from the tertiary strata via six bore holes at depths of between 94 and 160 meters.

During the airport's construction phase – hence prior to commissioning of the airport in 1992 – and currently, Munich Airport has participated in the infrastructure costs of this utility organization with capital investment subsidies of approximately €20 million. The water is subject to strict monitoring and controls and is of the highest quality (Flughafen München GmbH, 2013).

Water distribution at the airport is via two separate pipe systems. The drinking water network is comprised of small-diameter pipes in order to avoid stagnation for hygienic reasons, that is, the water remains in the pipe for too long a period. In contrast, the pipes for the firefighting water are of a larger diameter so as to be able to carry sufficient quantities of firefighting water for use in the event of a fire. Figure 4 shows the airport's total water usage from 2008 to 2012. The principal factor for the airport's increased water consumption is the increase in passengers (see Figure 1 above). Clearly, greater volumes of passengers results in higher consumption quantities in catering operations and the airport terminals. Another cause of increased water consumption are the new airport structures and expansion projects for the existing buildings. As a result of technical optimization measures, however, it has been possible for the water consumption in the buildings to be significantly reduced. For instance, through the installation of water-saving fixtures and the utilization of service water in the central energy centre (Flughafen München GmbH, 2013).

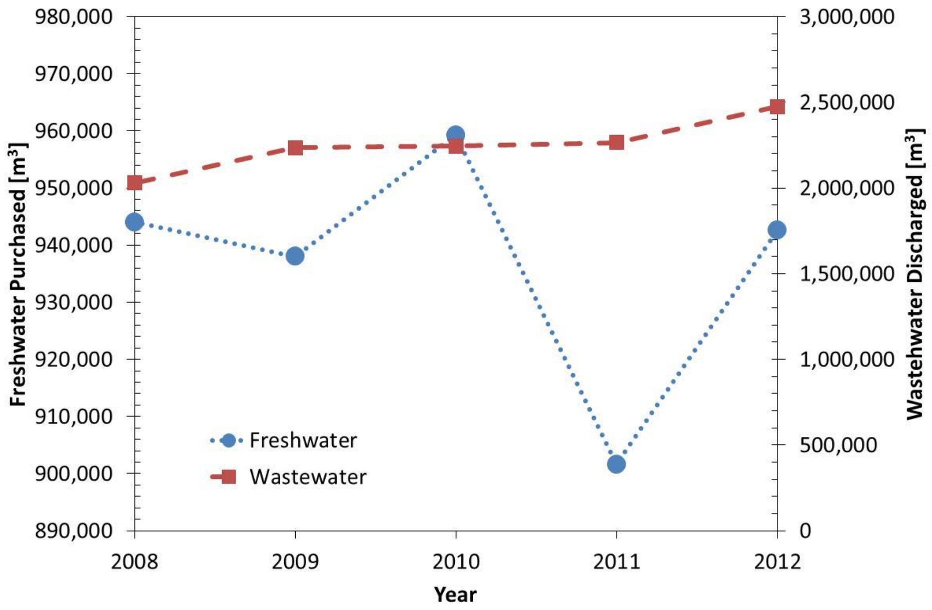

Figure 4: Total water purchased and discharged at Munich Airport.

Source: Flughafen München GmbH (Various).

Airports also generate large volumes of waste water (Pitt et al. 2002). An airport can be a significant contributor to water pollution if suitable facilities to treat airport wastes are not provided. Sources of water pollution from an airport include sewage from airport facilities, industrial wastes such as fuel spills, and high temperature water degradation from the various power plants located at the airport. Furthermore, runoff chemicals used in winter de-icing operations contributes to the collection of pollutants in the airport's surrounding water table (Young & Wells, 2011). Major airports could also have a number of hydrocarbon-based contaminants that may appear in storm-water runoff (Fisher et. al. 1995). Therefore, prior to entering the sewer the airport's waste waters must be properly treated (Kazda et al. 2007). Hence, managing storm water is critical for an airport's operations (Pazwash 2011).

Storm water occurring on paved areas of Munich Airport, depending on the area of origin (for instance, flight operation areas such as taxi runways or apron, parking areas or buildings) and the differing pollutants associated with them, are collected, treated, and managed by the airport in a variety of ways. In some cases the drainage is still mixed, but is primarily carried out in a modified separation system. Storm water from the mixed system is brought together with the wastewater and is sent to the treatment plant for further treatment. The storm water occurring in the separating system is collected separately, fed into treatment, and subsequently trickles away or is fed into surface bodies of airport's water. During the winter period, storm water that is mixed in winter with the agents used for de-icing aircraft and surfaces, enters into a de-icing wastewater pond system and from there is dosed into the central treatment plant. Only in the area of the taxiways does storm water containing de-icing agents trickle following pre-treatment in a filter system (underground degrading system) directly in the green area adjacent to the runways. In addition, during winter operations, small quantities of de-icing agents may be carried by wind to the green areas bordering on the airport's air-side areas and from there enter along with storm water into the groundwater. Since 2012, in order to prevent this occurring, the airport has installed ground filters in the green areas around the runway heads. These consist of underground storage areas filled with gravel and are sealed at the base (Flughafen München GmbH, 2013). Figure 4 shows the total volume of discharged water from 2008 to 2012. Following measurement of its quality (TOC or total organic carbon content), the water flowing out of the storage spaces is channelled either into the de-icing wastewater system or alternatively into a surface body of water, depending on its content (Flughafen München GmbH, 2013).

3.3. Waste Management

Waste management at airports compromises both solid and hazardous waste. To minimise the negative impact on the environment from the disposal of waste, it is necessary for airports to identify ways to decrease the quantity of waste particularly through recycling, composting, reuse and introduction of wasteless technologies (Kazda et al. 2007). The objective of waste management is therefore to reduce the volume of waste produced, thereby reducing disposal costs and, hence, the environmental impact of the airport (Pitt et. al. 2002). In addition, social costs will be decreased in terms of residential communities near waste landfill sites and incinerators (Pitt & Smith, 2003b).

In June 2012, the new *German Waste Management and Product Recycling Act* (KrWG) replaced the act that had previously applied since 1994. Thus the EU Waste Framework Directive (Directive 2008/98/EC) was enacted in German law. In accordance with the Munich Airport's in-house procurement guidelines, products that the airport purchases must satisfy environmental as well as economic requirements, and should also be as eco-friendly as possible, whilst also having a long service life. Two other important pillars are waste reduction and recycling at the airport. Only waste that cannot be recycled or processed for energy recovery is sent for permanent, environmentally compatible disposal. A basic requirement in recycling is the strict separation of recoverable fractions from waste generated at the airport. On the airport campus, this function is performed by specially trained staff located at six recycling stations. Certified transport or disposal operations then transport the materials separately for subsequent processing (Flughafen München GmbH, 2013).

The greater volume of all recyclable material (Figure 5) and waste are generated by the firms located at the airport. Specific advisement and appropriate disposal concepts are used to instruct these firms when collecting recyclables and wastes separately. Furthermore, continual waste logistics optimization, for example through maximizing container loads and short transport paths, helps reduce harmful emissions such as CO_2. Waste substances generated from the cleaning of aircraft cabins are removed in accordance with EC Regulation 069/2009 "Disposal of animal byproducts of October 21, 2009", as published in the Official Journal of the European Union L 300, by a disposal operator based at the waste incineration plant/thermal power plant at Munich North.

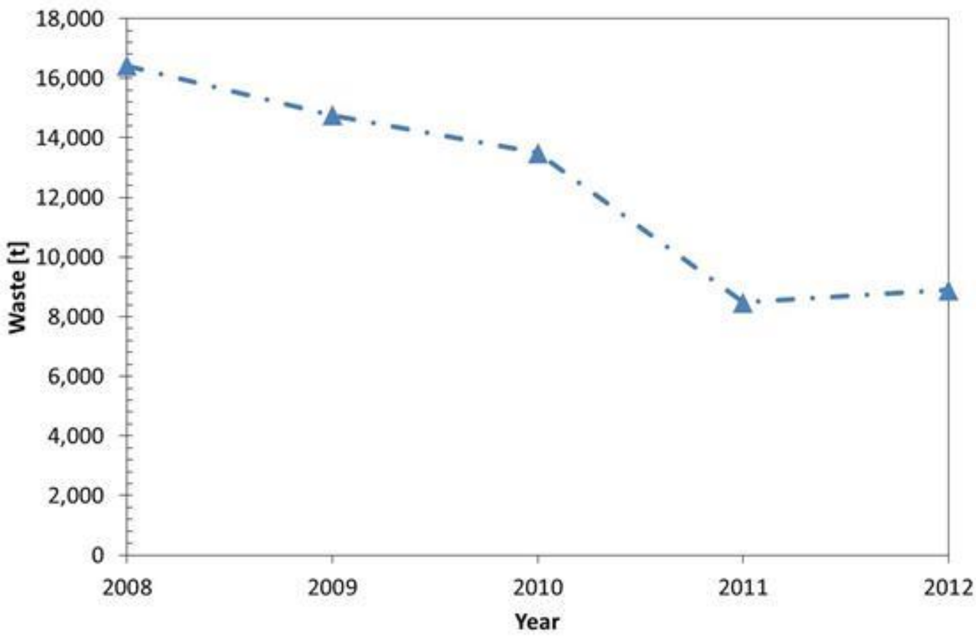

Figure 5: Total reclaimed materials/waste at Munich Airport.

Source: Flughafen München GmbH (Various).

3.5. Air Pollution

Gaseous emissions produced as a result of airport operations (aircraft operations, passenger and employee trips, apron activities such as aircraft refuelling, and other onsite activities such as power production), when taken together with those of other nearby polluting sources, such as major roads, can have a detrimental impact on local air quality. Airports may possibly be the major source of some pollutants in a particular locality and that while on the airport itself, aircraft emissions are the predominant source, and in the areas adjacent to the airport, road traffic can be the principal source (Thomas & Hooper, 2013).

Aircraft emissions produce air contaminants such as NOx, HC and fine particulate matter (PM). These can involve broader environmental issues related to ground level ozone (O_3), acid rain and climate change, and present potential risks relating to public health and the environment (International Civil Aviation Organization, 2011). At Munich Airport, the impact of pollution arising from airport operations and air traffic in the area around Munich Airport is measured at two measuring stations – one located to the west and one to the east of the airport campus (Flughafen München GmbH, 2013, p. 101).

In 2012, as in the preceding years, nitrogen dioxide (NO_2) and particulate matter were largely in the low to moderate range. The mean level of nitrogen dioxide recorded in 2012 was around 24 micrograms per cubic metre of air. This was below the values recorded from 2008 through 2011, with values of 29 to 31 micrograms per cubic metre of air (Figure 6). Based on the applicable emissions protection directive, the legally prescribed limit value for NO_2 (nitrogen dioxide) since 2010 has been approximately 40 micrograms per cubic metre of air (mean for the year) (Flughafen München GmbH, 2013, p. 101).

Nitrogen dioxide levels at the airport are similar to those measured in German towns such as Ingolstadt, Bamberg, or Würzburg. Levels in rural towns are normally lower, whereas levels in downtown Munich are significantly higher than at the airport. The mean annual level of particulate matter (PM10) measured during 2012 was 16 micrograms per cubic metre (continuous measurement at the main measuring station in the east). Mean levels between 2008 and 2011 were in the range from 18 to 21 micrograms per cubic metre of air. In addition to particulate matter PM10 and nitrogen dioxide, ozone, nitrogen monoxide, sulphur dioxide, carbon monoxide, benzene, toluene, and dust fall are also measured at Munich Airport. The airport complies with the applicable statutory limit values for all of these pollutants (Flughafen München GmbH, 2013, p. 102).

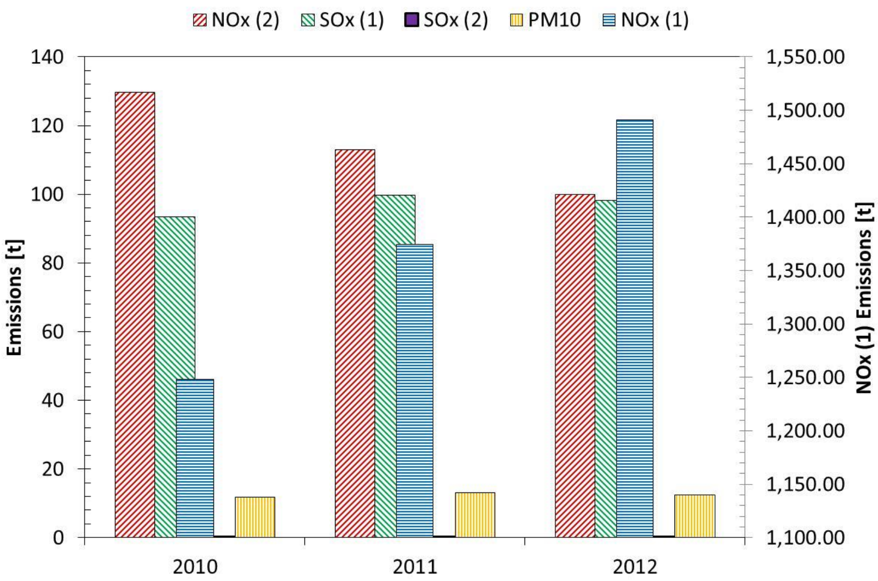

Figure 6: Air pollutants (other than CO_2) at Munich Airport.

<u>Note</u>: NOx (1) is from flight operations (landing and take-off), NOx (2) is from feeder traffic, SOx (1) is from flight operations (landing and take-off), SOx (2) is from feeder traffic (note that this is a constant 0.2t each year), PM10 is particulate matters

Source: Flughafen München GmbH (Various).

3.6. Aircraft Noise

Noise is a negative aspect arising from airport operations (Gorji-Bandpy & Azimi, 2012). Noise caused by aircraft is strictly monitored at Munich Airport. The International Civil Aviation Organization (ICAO), for example, requires a substantiated noise certificate for the type and airworthiness approval of new aircraft. All provisions, instructions, and procedures with respect to noise certification are contained in Annex 16 to the 1944 Chicago *Convention on International Civil Aviation*. This requirement has been implemented into German law in the form of “Noise Regulations for Aircraft (LVL)” (Flughafen München GmbH, 2013).

Munich Airport influences the aircraft operated to the airport through noise-based landing charges[1]. Airlines that use quiet aircraft benefit from a graduated widely spread system of charges at the airport. The noise-based aircraft take-off and landing fees can be as much as eight times as expensive for a loud aircraft type as compared to quieter aircraft types (Flughafen München GmbH, 2013).

To reduce the impact of aviation noise on the airport’s neighbouring communities, the airport is committed to doing more to improve the noise situation rather than just meeting its statutory regulations. In 2012, the airport was discussing and reviewing a number of active anti-noise measures that could reduce or avoid the noise at its source or could, for instance, redistribute the impact of noise. Such measures included the introduction of steeper aircraft descents, more frequent use of the continuous descent approach, which is quieter than conventional landings, and changing the approach slope angle so that aircraft are at higher altitudes when they fly over the airport’s wider surrounding area. Other measures included the optimization of flight routes to relieve individual town locations, the best possible utilization of the take-off and landing runways with respect to noise (in particular during night hours), and new developments in engine technology and retrofitting of aircraft fleets (Flughafen München GmbH, 2013).

Aircraft noise is continuously monitored at Munich Airport, using 16 fixed measurement points, which are positioned at a radius of about 20 kilometres around the airport, and three mobile measurement

[1] These noise-related charges are determined on the basis of fixed noise classes, which are based on the measured, average aircraft take-off and landing noise levels (Flughafen München GmbH, 2013).

stations for individual application. The measured values are published monthly. In 2012, all measurement sites – fixed and mobile –were equipped with new measuring devices. With sound level meters and microphones of precision class 1, they satisfy the highest electro-acoustic performance requirements. Each measuring site is checked on a daily basis and is acoustically calibrated annually during an interim test (Flughafen München GmbH, 2013). Figures 7a and 7b depict the nightly and day noise levels at Munich Airport from 2008 to 2012, respectively.

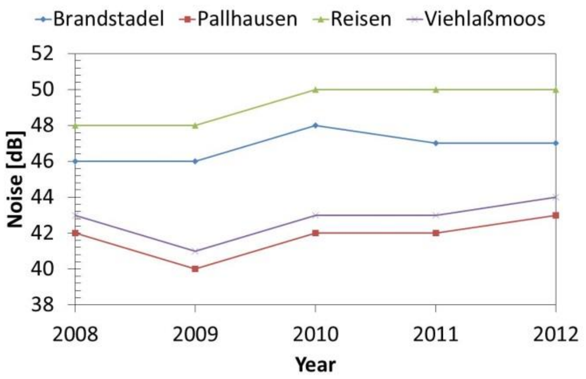

Figure 7a: Night noise levels at Munich Airport.

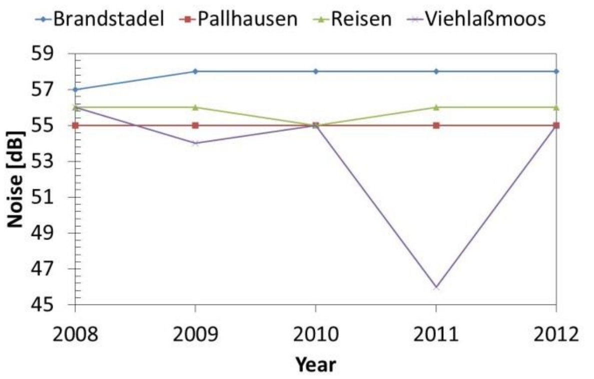

Figure 7b: Day noise levels at Munich Airport.

Source: Flughafen München GmbH (Various).

Munich Airport also has a night time curfew from 10:00 p.m. and 6:00 a.m. During this curfew period, only a limited of flights are permitted, and these are confined to particularly quiet aircraft. In addition to the curfew a noise quota also applies. Similar to 2011, in 2012 only 69 per cent of the allotted quota was used (Flughafen München GmbH, 2013).

4. Conclusion

In conclusion, this study has investigated the sustainable aspects of airport design and operations, in the context of Munich Airport, a major global airport. To do this, an explanatory case study methodology was utilised. The case study data was analysed using content analysis. We identified that the core strategies of Munich Airport are environmentally sustainable-based. Accordingly, throughout its history, the airport has focussed on mitigating its environmental footprint. The most significant environmental impact factors identified were aircraft noise, waste, and water management. The airport not only satisfies its statutory environmental obligations but seeks ways and measures to surpass these as part of its commitment to environmentally sustainable airport operations.

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