Environmental Impact Assessment Review 31 (2011) 240–252

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

Comparison of methodologies estimating emissions of aircraft pollutants, environmental impact assessment around airports

Jermanto S. Kurniawan *, S. Khardi [1]

INRETS-LTE, 25, avenue François Mitterrand, 69675 Bron cedex, France, Kampus Baru UI Depok - Indonesia

A R T I C L E I N F O

Article history:
Received 18 March 2010
Received in revised form 21 September 2010
Accepted 23 September 2010
Available online 16 October 2010

Keywords:
Aircraft
Pollutant emissions
Emission factors
Methods
Assessment

A B S T R A C T

Air transportation growth has increased continuously over the years. The rise in air transport activity has been accompanied by an increase in the amount of energy used to provide air transportation services. It is also assumed to increase environmental impacts, in particular pollutant emissions. Traditionally, the environmental impacts of atmospheric emissions from aircraft have been addressed in two separate ways; aircraft pollutant emissions occurring during the landing and take-off (LTO) phase (local pollutant emissions) which is the focus of this study, and the non-LTO phase (global/regional pollutant emissions). Aircraft pollutant emissions are an important source of pollution and directly or indirectly harmfully affect human health, ecosystems and cultural heritage. There are many methods to asses pollutant emissions used by various countries. However, using different and separate methodology will cause a variation in results, some lack of information and the use of certain methods will require justification and reliability that must be demonstrated and proven. In relation to this issue, this paper presents identification, comparison and reviews of some of the methodologies of aircraft pollutant assessment from the past, present and future expectations of some studies and projects focusing on emissions factors, fuel consumption, and uncertainty. This paper also provides reliable information on the impacts of aircraft pollutant emissions in short term and long term predictions.

Contents

Abbreviations: ALAQS, Airport Local Air Quality Study; APU, Auxiliary Power Unit; CAEP, Committee on Aviation Environmental Protection; CH_4, Methane; CO, Carbon monoxide; CO_2, Carbon dioxide; EEA, European Environment Agency; EI, Emission indices; EIS, Emission Indices Sheets; EMEP, European Monitoring and Evaluation Programme; EPA, Environmental Protection Agency; FAA, Federal Aviation Administration; GIS, Geographic Information System; H_2O, Water vapor; HAPs, Hazardous air pollutants; HC, Hydrocarbon; ICAO, International Civil Aviation Organization; IFR, Instrument Flight Rules; IPCC, International Panel of Climate Change; ISA, International Standard Atmosphere; LAQ, Local air quality; LTO, Landing and take-off; MEET, Methodologies for Estimating air pollutant Emissions from Transport; NMVOC, Non-Methane Volatile Organic Compounds; NO_x, Nitrogen oxides; OD, Origin and destination; PM, Particulate matter; SO_x, Sulphur oxides; TBEC, Thrust Based Emission Calculator; TIM, Time in Modes; VFR, Visual Flight Rules; VOC, Volatile Organic Compounds.

* Corresponding author. Tel.: +33 4 72 14 26 13; fax: +33 4 72 14 25 20.
E-mail addresses: Jermanto.kurniawan@inrets.fr (J.S. Kurniawan), Salah.khardi@inrets.fr (S. Khardi).
[1] Tel.: +33 4 72 14 24 79; fax: +33 4 72 14 25 20.

0195-9255/$ – see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.eiar.2010.09.001

1. Introduction

Air transportation growth has increased continuously over the years. However, the growth has not been uniform and varies from country to country. The general increase in air transport activity has been accompanied by a rise in the amount of energy used to provide air transportation services. Along with the increase in air transport activity and energy consumption increased environmental impacts are assumed.

Traditionally, the environmental impact of atmospheric emissions from aircraft has been addressed in two separate ways. On the one hand, air quality impacts from aviation have been considered by regulators, airports and aircraft manufacturers, focusing mainly on the emissions from aircraft occurring during the landing and take-off phases (LTO cycle) of aircraft operations (local pollutant emissions). On the other hand, studies on the environmental impact of aircraft emissions occurring in other flight phases such as climb and cruise (non-LTO cycle) have focused mainly on their influence on climate change, stratospheric ozone and UV-radiation (global/regional pollutant emissions).

The environmental impact of air traffic is often mainly associated with noise nuisance, smoke and gaseous emissions of carbon monoxide, unburned hydrocarbons, including methane and nitrogen oxides (NO_x — include nitrogen oxide and nitrogen dioxide), sulphur oxides in the vicinity of airports. Particles (such as particulate matter $PM_{2.5}$ and PM_{10}) present the most serious adverse health impacts from aircraft pollutant emissions. These have been controlled by implementation of standards and certification of aircraft engines. For this purpose the ICAO has defined reference emissions LTO cycle, with specific thrust settings and so-called Time in Modes for each operating mode, which reflects all aircraft operations in the boundary layer below the so-called inversion height (usually at about 1 km) (Olivier, 1991; ICAO, 2007a,b).

Aircraft pollutant emissions have been of concern since the beginning of commercial aviation. The continuing growth in air traffic and increasing public awareness have made environmental considerations one of the most critical aspects of commercial aviation. This means that pollutant emissions from aviation activity are expected to grow and increase by factors 1.6 to 10, depending on the fuel use scenario (IPCC, 1999; Antoine, 2004; FAA, 2005).

Conscious of this problem, engine manufacturers have developed low-emission combustors, and made them available as options. These combustors have been adopted by airlines operating in European airports with strict pollutant emissions controls, in Sweden and Switzerland, for example (Antoine, 2004; Celikel et al., 2005a,b).

Over the past several years, the pollutant emission indices have declined steadily as shown Fig. 1. However, considerably more progress has been made with HC and CO than NO_x (FAA, 2005).

Current emission regulations have focused on local air quality in the vicinity of airports. ICAO has set an environmental goal to limit and reduce the effects of aircraft pollutant emissions on local air quality from aircraft operations (ICAO, 2007a,b).

Operations of aircraft are usually divided into two main parts (EEA/EMEP, 2009):

- The LTO cycle defined by ICAO (1993) includes all activities near the airport that take place below the altitude of 3000 ft (914 m). This therefore includes taxi-in and out, take-off, climb-out and approach-landing.
- Cruise is defined as all activities that take place at altitude above 3000 ft (914 m). No upper limit altitude is given. Cruise includes climb from the end of climb-out in the LTO cycle to the cruise altitude, cruise, and descent from cruise altitudes to the start of LTO operations of landing.

Method for measurement, prediction and assessment of environmental problems such as aircraft pollutant emissions have been carried out. The use of certain methods will require justification and reliability that must be demonstrated and proven. Various methods have been adopted for the assessment of aircraft pollutant emissions. The use of different and separate methodologies causes a variation in results and there is some lack of information as shown in Table 1. This is because the gaps or differences in data availability, accuracy data input, and in-certainties in knowledge on the influence of engine ageing, the operational aircraft configuration, and atmospheric conditions on the pollutant emissions and their dispersions (Kalivoda and Kudrna, 1997; IPCC, 1999; Sourdine_II, 2005).

In order to provide reliable information on the impacts of aircraft pollutant emissions, this paper identifies, reviews and compares various methods of pollutant emissions assessment and evaluates the reliable methods to use in terms of accuracy, application, capability and problem of the uncertainty data and model.

2. Objectives

The objectives of this paper are: identification, review and comparison of various methods assessing aircraft pollutant emissions and evaluation of the reliable methods to use in terms of accuracy, application, and capability.

3. The literature review

3.1. Pollutant emissions source

Emissions from aircraft originate from fuel burned in aircraft engines. Aircraft jet engines produce CO_2, H_2O, NO_x, CO, SO_x, unburned or partially combusted hydrocarbons also known as VOC, particulates and other trace compounds (FAA, 2005; ICAO, 2007a,b).

A small subset of the VOCs and particulates are considered hazardous air pollutants (HAPs). Aircraft engine emissions are roughly composed of about 70% CO_2, a little less than 30% H_2O, and less than 1% each of NO_x, CO, SO_x, VOC, particulates, and other trace components including HAPs. About 10% of aircraft emissions of all types, except HC and CO, are produced during airport ground level operations and during landing and take-off. The bulk of aircraft emissions (90%) occur at higher altitudes. For HC and CO, the split is closer to 30% ground level emissions and 70% at higher altitudes (FAA, 2005).

Emission from combustion processes CO_2 is the product of complete combustion of hydrocarbon fuels like gasoline, jet fuel, and diesel. Carbon in fuel combines with oxygen in the air to produce CO_2. Water vapor is the other product of complete combustion as hydrogen in the fuel combines with oxygen in the air to produce H_2O. Nitrogen oxides are produced when air passes through high temperature/high pressure combustion and nitrogen and oxygen present in the air combine to form NO_x (FAA, 2005).

Hydrocarbons are emitted due to incomplete fuel combustion by an engine. Carbon monoxide is formed due to the incomplete combustion of the carbon in the fuel. Sulphur oxides are produced when small quantities of sulphur, present in essentially all hydrocarbon fuels, combine with oxygen from the air during combustion.

Particulates — small particles that form as a result of incomplete combustion, and are small enough to be inhaled. Particulates can be solid or liquid. Ozone (O_3) is not emitted directly into the air but is formed by the reaction of VOCs and NO_x in the presence of heat and sunlight. Ozone forms readily in the atmosphere and is the primary constituent of smog. For this reason it is an important consideration in the environmental impact of aviation (FAA, 2005; ICAO, 2007a,b).

Compared to other sources, aviation emissions are a relatively small contributor to air quality concerns both with regard to local air quality and greenhouse gas emissions. While small, however, aviation emissions cannot be ignored (FAA, 2005).