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**Combined effect of Aircraft Noise and Pollutant Emissions in the Intermediate Atmospheric Layers. International joint research project 2010 – 2012, Universitas Indonesia, Indonesia, INRETS, France**

Salah Khardi, J. Kurniawan

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*Salah KHARDI and Jermanto KURNIAWAN*

# **Combined effect of Aircraft Noise and Pollutant Emissions in the Intermediate Atmospheric Layers**

**INTERNATIONAL JOINT RESEARCH PROJECT**

**UNIVERSITAS INDONESIA – INDONESIA  
INRETS - FRANCE  
2010 – 2012**

**INRETS-LTE Report n° 1010**



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13 Summary: Air Transportation growth increased continuously over the years. The increase in transport activity has been accompanied by an increase in the amount of energy used to provide transportation services and it is assumed to increase environmental impacts. The role of Air Transportation Research is to maintain and increase the efficiency of different transport modes as well as to ensure their interaction and to stimulate progress in order to improve environmental quality. ICAO Balanced Approach to aircraft noise and emissions control consists of several instructions: reduction of noise and emissions at the source and certification; phase-out of non-certificated airplanes; land-use planning and management; new procedures and restriction of aircraft operations... There are many methods to assess pollutant emissions used by various country but using different and separately methodology will causes a wide 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 of this issue, this project presents identification and reviews some of the methodologies of pollutant emissions from the past, present and future expectation and projects focusing on emission factors, fuel consumption and uncertainty (impacts of aircraft pollutant emissions in short and long terms).					
This project identifies, develops, and validates methods on the following directions: noise control and its reduction, air quality analysis at a local level, environmental benefits of air transport and methodological bases. Four main stages of the research are concerned:					
1. Analysis methods to reduce commercial aircraft noise and emissions					
2. In flight integrated approach					
3. Development of joint estimation criteria of aviation noise and emissions					
4. Benefits of transport systems combination at a local level improving environmental quality around airports.					
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## AGREEMENT FOR RESEARCH COLLABORATION

**RESEARCH PROPOSAL  
INTERNATIONAL JOINT RESEARCH  
AND  
INTERNATIONAL PUBLICATION**



***Combined effect of Aircraft Noise and Pollutant Emissions in the  
Intermediate Atmospheric Layers***

Dr. Salah Khardi (INRETS-France)

Dr. Ir. Setyo Sarwanto Moersidik (UI-Indonesia)

**Accepted project version**

UNIVERSITAS INDONESIA – INDONESIA  
INRETS - FRANCE  
2010 – 2012





Institut national de recherche  
sur les transports et leur sécurité

## LETTER OF AGREEMENT for RESEARCH COLLABORATION

The purpose of this Letter of Agreement of Research Collaboration is to prepare a legal basis for research team and operations to be lead by Dr. Ir. Setyo Sarwanto, DEA at Civil Engineering Department of the Universitas Indonesia and by Dr. Salah Khardi at INRETS (Institut National de Recherche sur les Transports et leur Sécurité) at Bron (France). Both parties agree to conduct a Joint Research in Title:

### **Combined effect of Aircraft Noise and Pollutant Emissions in the Intermediate Atmospheric Layers.**

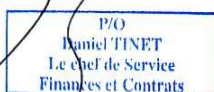
1. To implement the aims and purposes, the following is mutually understood and agreed.
2. Proposals for collaborative research work under this agreement will be submitted through French Embassy and DIKTI to assure financing support and conformity with the aims and purposes.
3. Individual programs of research work under this agreement will be jointly planned and conducted by both parties.
4. All research derived from the collaborative efforts of the two parties will be the property of party submitting the proposal.
5. In every year the joint research team will product at least one Publication in an International Journal.

This Agreement of Research Collaboration is effective within the three year period (2010-2012) and is written in English in 2 (two) copies, all are authentic.

Executed for  
INRETS

Executed for  
Universitas Indonesia

On behalf Mr. Guy Bourgeois  
INRETS Managing Director



Dr. Salah Khardi  
INRETS,  
Transport & environment Laboratory  
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Date : May, 17<sup>th</sup> 2010

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Place : Depok - Indonesia  
Date : May, 17<sup>th</sup> 2010



1. **Research Title** : *Combined effect of Aircraft Noise and Pollutant Emissions in the Intermediate Atmospheric Layers.*

2. **Head of Researcher**

- a. Full Name : Dr.Ir. Setyo Sarwanto Moersidik, DEA
- b. Sex : Male
- c. NIP :
- d. Structural Position : -
- e. Functional Position : Senior Lecturer
- f. Faculty/Department : Engineering / Civil Engineering Department
- g. Research Center : Universitas Indonesia
- h. Address : Kampus UI, Depok, 16424
- i. Telephone/Fax : (021) 7270029 / (021) 7270028
- j. Home address :
- k. Mob. Phone/E-mail : 0811861716 / smoersidik@yahoo.com

3. **International Cooperation Partner**

Name : Dr. Salah Khardi and Dr. Michel André  
Institution : INRETS (Institut National de Recherche sur les Transports et leur Sécurité), Bron Cedex 69675, Lyon-France.

4. **Research Term: 3 years**

5. **Financing for first year ;**

Total Financing : Rp 261.975.000,-  
Co-financing from French Embassy (5000 Euro) : Rp 64.500.000,-  
Total financing submitted to DIKTI : Rp 197.475.000,-

Depok, 15 May 2010

Approved,  
Dean of Engineering Faculty

Head of Researcher

Prof.Dr.Ir. Bambang Sugiarto, M.Eng  
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Dr.Ir. Setyo Sarwanto Moersidik  
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Approved,  
Head of DRPM-UI

Bachtiar Alam, Ph.D  
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## Research Identity

1. *Research Title* : *Combined effect of Aircraft Noise and Pollutant Emissions in the Intermediate Atmospheric Layers.*

2. *Head of Researcher* :

- a. Full Name : Dr.Ir. Setyo Sarwanto Moersidik, DEA
- b. Field of expertise : Environment
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- d. Functional Position : Senior Lecturer
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3. *Member of Research Team*

### *Indonesia*

No	Name and Academic Title	Field Expertise	of Institution	Allocated Time (hours/week)
1.	Ir, Gabriel Andari Kristanto, Ph.D	Environment	UI	10

### *France*

No.	Name and Academic Title	Field of Expertise	Institution
1.	Dr. HDR Salah Khardi	Environment (noise and pollutant emissions of aircraft)	INRETS
2.	Dr. Michel André	Environment – Emission factors and air quality	INRETS

4. *Research Plan in Year*

a. 1<sup>st</sup> year:

- Aircraft emissions inventory and comparison with already implemented solutions showing the interest and the stakes of this research.
- State of the art: aviation and the environment / the balance approach of ICAO
- Identification of methods assessing and measuring noise and pollutant emissions. Have to be analyzed the benefits of the incoming aeronautical fuels combined with the new aircraft design and engines. What are the impacts compared to the previous aircraft fleet?
- Development of new method based on fuzzy network combining noise and pollutant emission factors calculation. Theoretical tools have to be finalized



this year.

- b. 2<sup>nd</sup> year :
- Algorithm and method have to be developed to solve the fuzzy network problem with the answer to the following question: how to obtain an accuracy solution that should be implemented in-flight to manage noise and pollutant emissions
  - The new model has to be achieved taking into account air traffic
  - Dispersion modeling calculation development on the basis of EDMS or other available software has to be used to validate the developed method
- c. 3<sup>rd</sup> year:
- Experimental data collection
  - Comparison results
5. *Research Term:*
- Start : June 2010.
  - Finish : November 2012.
6. *Research Budget Proposed in first year: SUBMIT*
- |  |                       |
|--|-----------------------|
| Total Finance required:                    | Rp 261.975.000,-      |
| Co-Financed by French Embassy (5000 Euro): | <u>Rp 64.500.000,</u> |
| Finance proposed to DIKTI:                 | Rp 197.475.000        |
7. *Location of Research:* University of Indonesia and INRETS
8. *International Journal Intended:* International Journal for Environmental Impact Assessment such as: Atmospheric Environment (*areas covered include air pollution research and its applications, air quality and its effects, dispersion and transport, deposition, biosphere- atmospheric exchange, atmospheric chemistry and induced changes in radiation and climate*), Environmental Impact Assessment Review (this journal focus on theory and practice means focused on concepts, methods, techniques, approaches and systems), Environmental Pollution (focuses on papers that report results from original research on the distribution and ecological effects of pollutants in air, water and soil environments and new techniques for their study and measurement), Environmental Modeling & Software (focuses on issues and methods related to the integrated modeling, assessment and management of environmental systems - including relevant policy and institutional analysis, public participation principles and methods, decision making methods, model integration, quality assurance and evaluation of models, data and procedures), Environment International (covers all disciplines engaged in the field of environmental research), Transportation Research Part D: Transport and Environment (publishes original research on the environmental impacts of transportation, policy responses to those impacts, and their implications for the design, planning, and management of transportation systems). Other journals should be considered as: Journal of Intelligent & Fuzzy Systems. Applications in Engineering and Technology, International Journal of Fuzzy Systems, Journal of Fuzzy Optimization and Decision Making, Journal of Fuzzy Mathematics
9. *Target in first year:*
- Aircraft emissions inventory and comparison with already implemented

solutions showing the interest and the stakes of this research.

- State of the art: aviation and the environment / the balance approach of ICAO
- Identification of methods assessing and measuring noise and pollutant emissions. Have to be analyzed the benefits of the incoming aeronautical fuels combined with the new aircraft design and engines. What are the impacts compared to the previous aircraft fleet?
- Development of new method based on fuzzy network combining noise and pollutant emission factors calculation. Theoretical tools have to be finalized this year.

Two reports have to be provided this year describing the state of the art and theoretical concepts and method. Objectives and the future prospects have to be clearly carried out and presented.

10. *Other important details:* In this research, two Master students and one Doctoral student will be involved. Those students are registered in DDIP (Double Degree Indonesia Perancis) in the framework of. Memorandum of Understanding between Universitas Indonesia and INRETS.

### **Administrative issues**

This proposal is connected to Memorandum of Understanding signed between UNIVERSITAS INDONESIA University of Indonesia and INSTITUT NATIONAL DE RECHERCHE SUR LES TRANSPORTS ET LEUR SÉCURITÉ.

In this research activity, two Master students and one PhD student will be involved and registered at UI and at INRETS as students of Double Degree Indonesia Perancis (DDIP) program whose scholarships are be provided by DIKTI (Indonesian DGHE in Ministry of National Education) and French Embassy in Indonesia.

- Master (1<sup>st</sup> student): atmospheric chemistry and physics area – 1 year from autumn 2010
- Master (2<sup>nd</sup> student): numerical applications topic – 1 year from autumn 2010
- 1<sup>st</sup> Ph.D. Student (3<sup>rd</sup> student): Mathematical modelisation applied to environment (the combined effect of noise and pollutant emissions) – 4 years starting in autumn 2010

The distribution of the periods of stays of the students in INRETS (France) will be supervised by a project of research agreement including a study research convention signed by the three parties (UI-INRETS-student) which provided the work hours, the holidays to which have right the students, the obligations of the student stay in INRETS. Failing this, no reception will be possible in INRETS. The students will

continue, on the other hand, to be directed by their French person in charge.

It is designed that during the 3 years of the research, there will always be at least one student involved at UI and at INRETS in DDIP Master's and Doctorate program to guarantee a successful research. We believe that combining the DDIP Master's and Doctorate program with International Joint Research will become an effective and strong motivation for students and provide a big opportunity for UI-INRETS collaboration as well as ensure the continuity of international joint research in multi years.

## **RESEARCH SUBSTANCE**

### **Abstract**

Air Transportation growth increased continuously over the years. The increase in transport activity has been accompanied by an increase in the amount of energy used to provide transportation services and it is assumed to increase environmental impacts.

The role of Air Transportation Research is to maintain and increase the efficiency of different transport modes as well as to ensure their interaction and to stimulate progress in order to improve environmental quality. In particular, at different levels, commercial aircraft impacts on the environment in the following ways: (1) noise impact, (2) air and water quality impact, (3) global climate change. Moreover, the capacity of airports, particularly in Europe, could be limited by environmental impacts. ICAO Balanced Approach to aircraft noise and emissions control consists of several instructions: reduction of noise and emissions at the source and certification; phase-out of non-certificated airplanes; land-use planning and management; new procedures and restriction of aircraft operations...

Aircraft pollutant emissions are an important as a source of pollution and directly or indirectly will affect harmful to human health, ecosystems and cultural heritage. There are many methods to assess of pollutant emissions used by various country but using different and separately methodology will causes a wide 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 of this issue, this project presents identification and reviews some of the methodologies of pollutant emissions from the past, present and future expectation of some studies and projects focusing on emissions factor, fuel consumption and uncertainty and to get reliable information of the impacts of aircraft pollutant emissions in short term and long term prediction.

Existing research is directed towards examining environmental performance by a development of models, which integrate engine functionality and in flight performance, aircraft design and aircraft procedures and operations. Future research should address the strong relationship between aircraft noise and emissions with the aim to reduce their combined effects on environment. In this way, research actions

carried out in the two laboratories on aircraft noise and emission reductions contribute towards the achievement of the 2020 objectives recommended by the Advisory Council for Aeronautics Research in Europe (ACARE). Taking 2001 as the baseline, the ACARE objectives are:

- To reduce fuel consumption and hence CO<sub>2</sub> emissions by 50% per passenger-kilometer
- To reduce NO<sub>x</sub> emissions by 80% in landing and take-off according to ICAO standards and down to 5 g/kg of fuel burnt in cruise
- To reduce unburnt hydrocarbons and CO emissions by 50% according to ICAO standards
- To reduce external noise by 10 EPNdB per operation of fixed-wing aircraft, for rotorcraft the objective is to reduce noise foot-print area by 50% and external noise by 10EPNdB.

Objectives of this cooperative project are to respond to the following questions:

1. How to monitor and to control aircraft noise and emissions for the sustainable development of air traffic and for environment quality improvement.
2. Whether the benefits in terms of improvement of environmental quality, the joint analysis and assessment of the impact of air transport in combination with the other transport systems should be performed at a local level (in the vicinity of airports).

This cooperation should identify, develop, and validate methods on the following directions: noise control and its reduction, air quality analysis at a local level, environmental benefits of air transport in combination with other transport systems at a local level, methodological bases rest on the “balanced sheet” approach to a problem of abatement of aircraft noise and emissions.

Four main stages of the research are concerned:

1. Analysis methods to reduce commercial aircraft noise and emissions (optimization concept)
  1. In flight integrated approach
2. Development of joint estimation criteria of aviation noise and emissions
3. Benefits of transport systems combination at a local level improving

environmental quality around airports.

The synergies between the four tasks and their contribution to the common objectives of advancing competitiveness and responding to the environmental challenges of the air transport sustainable development will be exploited as appropriate.

This project aims to develop more extensively the scientific exchanges and excellence between the two research laboratories of the two countries. In particular, these works and exchanges should be developed through the organization of several internships for high-school students on the above topics, and which should be managed jointly by the French and Indonesian partners to favor the bilateral partnership. Ideally, a PhD thesis and two Master students should be proposed (at the issue of a first period).

### **Working plan**

**a. 1<sup>st</sup> year:**

- Aircraft emissions inventory and comparison with already implemented solutions showing the interest and the stakes of this research.
- State of the art: aviation and the environment / the balance approach of ICAO
- Identification of methods assessing and measuring noise and pollutant emissions. Have to be analyzed the benefits of the incoming aeronautical fuels combined with the new aircraft design and engines. What are the impacts compared to the previous aircraft fleet?
- Development of new method based on fuzzy network combining noise and pollutant emission factors calculation. Theoretical tools have to be finalized this year.

**b. 2<sup>nd</sup> year :**

- Algorithm and method have to be developed to solve the fuzzy network problem with the answer to the following question: how to obtain an accuracy solution that should be implemented in-flight to manage noise and pollutant emissions
- The new model has to be achieved taking into account air traffic
- Dispersion modeling calculation development on the basis of EDMS or

other available software has to be used to validate the developed method

**c. 3<sup>rd</sup> year:**

- Experimental data collection
- Comparison results and validation
- Demonstrator achievement that should be implemented in the aircraft FMS

## **INTRODUCTION**

Transportation growth increased continuously over the years. However, the growth has not uniform in the various transport modes and sectors, and varies from country to country. The general increase in transport activity has been accompanied by an increase in the amount of energy used to provide transportation services. Along with the increase in transport activity and energy consumption is assumed to increase environmental impacts that will happen.

The environmental impact of air traffic is often mainly associated with noise nuisance, smoke and gaseous emissions of carbon monoxide (CO), unburned hydrocarbons - also referred to as Volatile Organic Compounds (VOC), including methane (CH<sub>4</sub>) - and nitrogen oxides (NO<sub>x</sub>) in the vicinity of airports. These have been controlled by implementation of standards and certification of aircraft engines. For this purpose the International Civil Aviation Organization (ICAO) has defined reference emissions Landing and Take-Off (LTO) cycle, with specific thrust settings and so-called Time-In-Modes (TIMs) 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].

However, aircraft generally emit most of their exhaust gases and particles at higher altitudes, in particular during cruise flight. The emissions of supersonic transport (SST) in the stratosphere have been subject of study in the 1970s in relation with the issue of ozone depletion. However, when it became clear that only a small fleet of 14 SST - i.e. Concorde – it would come into operation, the interest of researchers and policy makers in their impact on the environment diminished. Recently however the emissions by aircraft of compounds attributing to acidification, ozone depletion, smog formation and climate change have attracted new attention from the research community as well as from policy makers [Olivier, 1991].

Aircraft 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 today.

It is generally accepted that significant improvements to the environmental



acceptability of aircraft will be needed if the long-term growth of air transport is to be sustained. The Intergovernmental Panel on Climate Change (IPCC) has projected that, under an expected 5% annual increase in passenger traffic, the growth in aviation-related nuisances will outpace improvements that can be expected through evolutionary changes in engine and airframe design [IPCC, 1999].

The release of exhaust gasses in the atmosphere is the second major environmental issue associated with commercial airliners. The world fleet releases approximately 13% of Carbon dioxide (CO<sub>2</sub>) emissions from all transportation sources, or 2% of all anthropogenic sources [IPCC, 1999]. The expected doubling of the fleet in the next twenty years will certainly exacerbate the issue: the contribution of aviation is expected to increase by factor of 1.6 to 10, depending on the fuel use scenario. 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 emissions controls, in Sweden and Switzerland, for example, [Celikal *et al.*, 2005].

Over the past several years, pollutant emissions Index have declined steadily. NO<sub>x</sub> has been the most challenging pollutant to constrain and progress has lagged that of other pollutants [FAA, 2005].

Current emissions regulations have focused on local air quality in the vicinity of airports. Emissions released during cruise in the upper atmosphere are recognized as an important issue with potentially severe long-term environmental consequences, and ICAO is actively seeking support for regulating them as well.

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

- The Landing Take-off (LTO) cycle which includes all activities near the airport that take place below the altitude of 3000 feet (914 m). This therefore includes taxi-in and out, take-off, climb-out and approach-landing. The LTO is defined by ICAO (1993).
- Cruise which is defined as all activities that take place at altitude above 3000 feet (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 has 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 methodology causes a wide variation in results and there are some lacks of information. In order to get reliable information of the impacts of aircraft pollutant emissions, it will identify, review and comparison of various methods of pollutant emissions assessment and evaluate the reliable methods to use in terms of accuracy, application, capability and problem of the uncertainty data and model.



## **LITERATURE STUDY**

### **Pollutant Emissions Source**

Emissions from aircraft originate from fuel burned in aircraft engines. Aircraft jet engines produce Carbon Dioxide (CO<sub>2</sub>), Water Vapor (H<sub>2</sub>O), Nitrogen Oxides (NO<sub>x</sub>), Carbon Monoxide (CO), Oxides of Sulphur (SO<sub>x</sub>), unburned or partially combusted hydrocarbons (also known as volatile organic compounds (VOC)), particulates and other trace compounds [FAA, 2005].

A small subset of the VOCs and particulates are considered hazardous air pollutants (HAPs). Aircraft engine emissions are roughly composed of about 70 percent CO<sub>2</sub>, a little less than 30 percent H<sub>2</sub>O, and less than 1 percent each of NO<sub>x</sub>, CO, SO<sub>x</sub>, VOC, particulates, and other trace components including HAPs. Aircraft emissions, depending on whether they occur near the ground or at altitude, are primarily considered local air quality pollutants or greenhouse gases [FAA, 2005].

Water in the aircraft exhaust at altitude may have a greenhouse effect, and occasionally this water produces contrails, which also may have a greenhouse effect. About 10 percent of aircraft emissions of all types, except hydrocarbons and CO, are produced during airport ground level operations and during landing and takeoff. The bulk of aircraft emissions (90 percent) occur at higher altitudes [FAA, 2005].

For hydrocarbons and CO, the split is closer to 30 percent ground level emissions and 70 percent at higher altitudes. Aircraft are not the only source of aviation emissions. Airport access and ground support vehicles produce similar emissions. Such vehicles include traffic to and from the airport, ground equipment that services aircraft, and shuttle buses and vans serving passengers. Other emissions sources at the airport include auxiliary power units providing electricity and air conditioning to aircraft parked at airport terminal gates, stationary airport power sources, and construction equipment operating on the airport [FAA, 2005].

Emission from Combustion Processes CO<sub>2</sub> – Carbon dioxide 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<sub>2</sub>. H<sub>2</sub>O – Water vapor is the other product of complete combustion as hydrogen in the fuel combines with oxygen in the air to produce H<sub>2</sub>O. NO<sub>x</sub> – 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<sub>x</sub> [FAA, 2005].

HC – Hydrocarbons are emitted due to incomplete fuel combustion. They are also referred to as volatile organic compounds (VOCs). Many VOCs are also hazardous air pollutants. CO – Carbon monoxide is formed due to the incomplete combustion of the carbon in the fuel. SO<sub>x</sub> – Sulfur oxides are produced when small quantities of sulfur, present in essentially all hydrocarbon fuels, combine with oxygen from the air during combustion [FAA, 2005].

Particulates – Small particles that form as a result of incomplete combustion, and are small enough to be inhaled, are referred to as particulates. Particulates can be solid or liquid. Ozone – O<sub>3</sub> is not emitted directly into the air but is formed by the reaction of VOCs and NO<sub>x</sub> 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].

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]. Emissions will be dependent on the fuel type, aircraft type, engine type, engine load and flying altitude. Two types fuel are used. Gasoline is used in small piston engines aircraft only. Most aircraft run on kerosene and the bulk of fuel used for aviation is kerosene [Rypdal, K.]. Table 1 is shown emission indices from exhaust engine.

In general, there exist two types of engines; reciprocating piston engines and gas turbines [Olivier, (1991) and EEA, (2009)]. Table 1 is shown an example exhaust emission indices from the engine and fuel flow.

Table 1. Exhaust Emission Indices and fuel flow for the Pratt & Whitney JT8D-15 Turbofan Engine [Landau, 1994]

Power Setting	Fuel Flow (kg/hr)	Emission Indices (g/kg)		
		NO <sub>x</sub>	CO	HC
Takeoff	4241	19.1	0.7	0.3
Climb Out	3402	15.0	1.0	0.3
Approach	1225	5.9	9.6	1.7
Idle	532	3.0	35.6	11.0

## Identification of Various Methods of Assessments and Measurements

**The International Civil Aviation Organization (ICAO)** is a United Nations intergovernmental body responsible for worldwide planning, implementation, and coordination of civil aviation. ICAO sets emission standards for jet engines. These are the basis of Federal Aviation Administration (FAA) aircraft engine performance certification standards, established through Environmental Protection Agency (EPA) regulations.

ICAO has covered three approaches to quantifying aircraft engine emissions: two in detail and one in overview: Simple Approach, Advanced Approach and Sophisticated Approach, [ICAO, 2007].

- a. Simple Approach is the least complicated approach, requires the minimum amount of data, and provides the highest level of uncertainty often resulting in an over estimate of aircraft emissions. This approach considers the emission pollutant of NO<sub>x</sub>, CO, HC, SO<sub>2</sub>, CO<sub>2</sub>. The equation used for calculating emission of species does not account for specific engine types, operational modes or Time in Modes (TIM) as it assumes that the conditions under study are the same or similar to the default data being used.
- b. Advanced Approach reflects an increased level of refinement regarding aircraft types, Emissions Index (EI) calculations and TIM. This approach considers the emission pollutant of NO<sub>x</sub>, CO, HC, SO<sub>x</sub>. ICAO does not have emissions certification standards for SO<sub>x</sub>. However, SO<sub>x</sub> emissions are described as a function of the quantity of sulphur in the fuel.
- c. Sophisticated Approach is provided in overview, will be further developed in an update of this guidance (e.g. Committee on Aviation Environmental Protection – CAEP/8) and is expected to best reflect actual aircraft emissions. This approach requires the use of propriety data or models that are not normally available in the public domain.

**Environmental Protection Agency (EPA)** recommended emissions calculation methodology for a given airport in any given year can be summarized in six steps:

- 1) Determine the mixing height to be used to define a landing and takeoff (LTO) cycle.
- 2) Determine airport activity in terms of the number of LTOs.
- 3) Define the fleet make-up at the airport.
- 4) Select emission factors.
- 5) Estimate time-in-mode (TIM).
- 6) Calculate emissions based on the airport activity, TIM, and aircraft emission factors.

Steps two through five are repeated for each type of aircraft using a given airport.

This methodology is essentially the same as that used in the FAA *Aircraft Engine Emissions Database* (FAEED) model, [EPA, 1999].

For Time in Mode Calculations, the duration of the approach and climb out modes depends largely on the mixing height selected. EPA guidance provides approach and climb out times for a default mixing height of 3000 feet, and a procedure for adjusting these times for different mixing heights. The adjustments are calculated using the equation below:

*Climb out:*

$$TIM_{adj} = TIM_{adj} \times \left[ \frac{MixingHeight - 500}{3000 - 500} \right]$$

*Approach:*

$$TIM_{adj} = TIM_{adj} \times \left[ \frac{MixingHeight}{3000} \right]$$

For Emissions Calculation (HC, VOC, CO, NO<sub>x</sub>, PM<sub>10</sub>, SO<sub>2</sub>), Total emissions for each aircraft type are summed to yield total commercial exhaust emissions for the facility as shown below:

$$ET_i = \sum_{j=1}^N (E_{ij} \times LTO_j)$$

Where  $ET_i$  = the total emissions for pollutant  $i$  from all aircraft types;  $E_{ij}$  = the emissions of pollutant  $i$  from aircraft type  $j$ ;  $LTO_j$  = the number of LTOs for aircraft type  $j$ ; and  $N$  = the total number of aircraft types.

**European Environment Agency / European Monitoring and Evaluation Programme (EEA/EMEP)** uses decision tree (Tier 1, Tier 2 and Tier 3) to select the methods for estimating the emissions from aviation that applicable to all nations. When estimating aviation emissions the following should be considered:

- use as detailed information as is available;
- if the source category is a key source, then a Tier 2 or Tier 3 method must be used for estimating the emissions.

The three Tiers are harmonized with those specified in the IPCC 2006 Guidelines. Table 2 summarizes the data required to use the three Tiers in terms of activity measure and the degree of technology stratification required for the category 1 (IFR) flights. It will often be the case that the overall emissions for category 2 and 3 flights

are sufficiently small and the statistics available so poor, that a Tier 1 approach for these portions of aviation is appropriate, [EEA, 2009].

The Tier 1 and Tier 2 methodologies are both based on LTO data and fuel used is assumed equal fuel sold. The emission estimation can be made following either the Tier 1 or Tier 2 methodology.

For estimating the total emissions of CO<sub>2</sub>, SO<sub>2</sub> and heavy metals the Tier methodology is sufficient, as the emissions of these pollutants are dependent of the fuel only and not technology, [EEA, 2009].

The emissions of PM<sub>10</sub> or PM<sub>2.5</sub> are aircraft and payload dependent. Therefore, when estimating the total emissions of these pollutants, it may be appropriate to consider the aircraft activity in more detail, using the Tier 2 methodology. The Tier 3 methodology may be used to get an independent estimate of fuel and CO<sub>2</sub> emissions from domestic air traffic.

### Tier 1

The Tier 1 approach for aviation is based on quantity of fuel consumption data for aviation split by LTO and cruise for domestic and international flights separately. The method uses a simple approach to estimate the split of fuel use between cruise and LTO. This approach was labeled the 'very simple methodology.

This approach considered emission pollutant SO<sub>2</sub>, CO<sub>2</sub>, CO, NO<sub>x</sub>, NMVOC, CH<sub>4</sub>, N<sub>2</sub>O, and PM<sub>2.5</sub>. Annual emission of pollutant for each of the LTO and cruise phases of domestic and international flights ( $E_{\text{pollutant}}$ ) is calculated as function of activity rate by fuel consumption for each of the flight phases and trip types ( $AR_{\text{fuel consumption}}$ ) multiply by emission factor of pollutant for the respective flight phase and trip type ( $EF_{\text{pollutant}}$ ).

Tier 1 emission factors ( $EF_{\text{Pollutant, Fuel type}}$ ) assume an averaged technology for the fleet, and knowledge of the number of domestic and international LTO cycles for the nation. Default emission factors and fuel use (jet kerosene and aviation gasoline) are available in EEA/EMEP Guidebook 2009, but need statistics to be split into cruise and LTO as well as domestic and international.

Where statistics are available for fuel use and the number of LTOs by domestic and international flights, the assumptions on LTO fuel consumption below can be used to split these data by LTO and cruise using the following equation.

$$\text{Total fuel} = \text{LTO fuel} + \text{cruise fuel}$$



where:

*LTO fuel = number of LTOs x fuel consumption per LTO.*

Sulphur content of the fuel (jet kerosene) is assumed to be 0.05% S (by mass) for both LTO and cruise activities. PM<sub>2.5</sub> data is equal PM<sub>10</sub> emissions. It is inferred from smoke data from ICAO database using the methodology described in ICAO.

### Tier 2

The Tier 2 approach applies if it is possible to obtain information on LTO per aircraft type but there is no information available on cruise distances. The level of detail necessary for this methodology is the aircraft types used for both domestic and international aviation, together with the number of LTO carried out by the various aircraft types.

This approach considered emission pollutant SO<sub>2</sub>, CO<sub>2</sub>, CO, NO<sub>x</sub>, NMVOC, CH<sub>4</sub>, N<sub>2</sub>O, and PM<sub>2.5</sub>. Annual emission of pollutant for each of the LTO and cruise phases of domestic and international flights ( $E_{\text{pollutant}}$ ) is calculated as function of activity rate by fuel consumption for each of the flight phases and trip types for each aircraft type ( $AR_{\text{fuel consumption, aircraft type}}$ ) multiply by emission factor of pollutant for the respective flight phase and trip type for each aircraft type ( $EF_{\text{pollutant, aircraft type}}$ ).

This methodology is not relevant for technology abatement approach.

### Tier 3

The Tier 3 methodologies are based on actual flight movement data, either for Tier 3A origin and destination (OD) data or for Tier 3B full flight trajectory information. These methodologies are bottom-up, flight-based, rather than top-down calculation-based on the fuel consumed.

Tier 3A takes into account cruise emissions for different flight distances. Hence details on the origin (departure) and destination (arrival) airports and aircraft type are needed to use this approach, for both domestic and international flights. In Tier 3A, inventories are modeled using average fuel consumption and emissions data for the LTO phase and various cruise phase lengths, for an array of representative aircraft categories.

The data used in Tier 3A methodology takes into account that the amount of emissions generated varies between phases of flight. The methodology also takes into account that fuel burn is related to flight distance, while recognizing that fuel burn can be comparably higher on relatively short distances than on longer routes. This is

because aircraft use a higher amount of fuel per distance for the LTO cycle compared to the cruise phase.

Tier 3B methodology is distinguished from Tier 3A by the calculation of fuel burnt and emissions throughout the full trajectory of each flight segment using aircraft and engine specific aerodynamic performance information. To use Tier 3B, sophisticated computer models are required to address all the equipment, performance and trajectory variables and calculations for all flights in a given year.

Models used for Tier 3B level can generally specify output in terms of aircraft, engine, airport, region, and global totals, as well as by latitude, longitude, altitude and time, for fuel burn and emissions of CO, hydrocarbons (HC), CO<sub>2</sub>, H<sub>2</sub>O, NO<sub>x</sub>, and SO<sub>x</sub>. To be used in preparing annual inventory submissions, Tier 3B model must calculate aircraft emissions from input data that take into account air-traffic changes, aircraft equipment changes, or any input-variable scenario.

The components of Tier 3B models ideally are incorporated that they can be readily updated, so that the models are dynamic and can remain current with evolving data and methodologies.

The emission factors for NO<sub>x</sub>, hydrocarbons, CO and the fuel used for all the components of a flight (LTO cycle) are available from the accompanying spreadsheet (EEA/EMEP Guidebook) for the representative jet and turboprop aircraft types.

There is little information available on emission factors for non-IFR flights and it is at present not possible to recommend default emission factors. Generally, the NO<sub>x</sub> emission factors will be lower and the CO and VOC factors substantially higher than for IFR flights.

Fuel consumption factors for non IFR flight are given for two categories of aircraft (Cessna and others) to be used if other information of fuel used is not available. It is only apply to single engine aircraft only. If the aircraft is fitted with two engines (e.g. Cessna 500), then double the fuel consumption. Ranges of emission factors are shown in MEET (1997), [EEA, 2009].

### **Methodologies for Estimating air pollutant Emissions from Transport (MEET)**

Project has the objectives which are to review the existing air traffic emission models and present an emission simulation model. The model uses artificial flight profiles and emission indices for the thirty most frequent used aircraft types in Europe and to estimate the air pollutant emissions for the flight of an aircraft based on the duration of specific operational states (engine start, taxi-out, take-off, climb, cruise, descent,

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landing, taxi-in and ground operations) and the corresponding specific emission factors.

Completed in 1997, MEET describes of three main classes of air transport that can be distinguished when analyzing its operational and emission related characteristics:

- flights performed under Instrument Flight Rules (IFR),
- military operational air traffic,
- flights performed under Visual Flight Rules (VFR).

There are some minor overlaps between the classes. However, each category has its own typical data set available for traffic characteristics and engine emissions.

Accuracy of data input is different for the three categories, but is their contribution to total air transport emissions. About sixty to eighty percent of emissions originate from IFR flights. Normally IFR flights are operated as flights controlled by Air Traffic Services (ATS) within controlled airspace only and generally flights with civil aircraft. Only those military flights which belong to general air traffic (GAT) are included in IFR data. Jets, turbofans and turboprops generally represent this sort of traffic, which typically involves big commercial aircraft flying long distances using fixed operational routines.

Flights performed under VFR generally are not operated as controlled flights so neither a Flight Plan nor detailed information on the route flown is available. However, VFR flights represent less than 5 % of fuel consumption and pollution caused by air traffic, [Kalivoda and Kudrna, 1997].

For IFR flights, emission indices (EI), i.e. the mass of pollutant produced per mass of fuel used, are provided for eight typical operational conditions, which combined to cover most of an aircraft's operation during a flight.

The fundamental methodology to estimate the air pollutant emissions for the flight of an aircraft is based on the duration of specific operational states/typical operational condition (engine start, taxi-out, take-off, climb, cruise, descent, landing, taxi-in and ground operations) and the corresponding specific emission factors. Using typical flight profiles (for each aircraft type separately), with the common cruising altitude of the aircraft and the flight distance being the basic parameters, the total fuel consumption can be estimated.

## Emission factor calculation

The methodology adopted for the calculation of air traffic emissions differs for IFR (instrument flight rules), VFR (visual flight rules) and military air traffic.

Generally, no detailed information on the flight route and height is stored in the air control centers for VFR flights, so that only a tentative estimation of the air pollutant emissions related to this category of flights is available. However, emissions from VFR flights generally are emitted at lower altitudes than IFR flights, often even within the planetary boundary layer.

The basic formula for one flight (for a specific aircraft/engine combination, i.e., different engine types for the same machine are treated as different aircrafts) is:

$$E = \sum_{j=1}^8 T_j FC_j EI_j$$

This formula is a compilation and reformulation of the basic approach from Kalivoda and Kudrna (1997) by Keller and Haan, [1998], where:

- $E$  [g] total emission of air pollutant
- $j$  [-] index running over the 8 operational stages, i. e., taxi out, take off, climbing, cruise, descent, landing, taxi in, ground operations.
- $T_j$  [s] duration of operational stage  $j$
- $FC_j$  [kgfuel/s] fuel consumption during operational stage  $j$
- $EI_j$  [gpoll./kgfuel] emission index of pollutant for operational stage  $j$

## Emissions Index

Emission index for IFR flight for each aircraft/engine are given in Emission Index sheet (EIS). Calculation has to be carrying out for 9 operational states (OS). Input for the calculation using the aircraft emission index sheet for a complete mission from airport to airport has to be:

- aircraft type,
- total distance between the two airports (e. g. distance as the crow flies, actual route, actual rout including holding patterns),
- cruise altitude.

Additional information:

- average duration of taxi out [s]

- average duration of taxi in [s].

Table 2. Emission Factor of MEET

Reference (g/kg)	CO <sub>2</sub>	H <sub>2</sub> O	SO <sub>2</sub>
EIs used in MEET (annex data sheets)	3150	1240	1.000

Emission Index Sheets (EIS) were produced by MEET covering all the information necessary for a calculation. NO<sub>x</sub>, HC, CO emission indexes and fuel consumption are available in EIS. There are some gaps and uncertainties in knowledge on the influence of real in flight ambient environment condition and maintenance and ageing of engines. On the emissions as well as on the actual amount of emissions from starting up aircraft engines, additional aircraft related ground operations like refueling and operating APU and turboprop, piston and military engines in general.

### **Airport Local Air Quality Study (ALAQS)**

It aims to promote best practice methods for airport Local Air Quality (LAQ) analysis concerning issues such as emissions inventory, dispersion, and the data required for the calculations, including emission factors, operational data, and aircraft landing and take-off profiles.

ALAQS methodology consists of developing Pan-European emission inventory methodology with spatial information and future application of dispersion modeling to this inventory with use of GIS technologies. The toolset and database to support ALAQS of European airports are:

- Pan-European ALAQS central databank for emission factors of different sources: All related emissions factors for different pollution sources are defined and aggregated from different sources and harmonized in Access database. This will provide the opportunity to change or compare different emissions factors used for the same type of sources.
- Scalable approach for developing emission inventory and dispersion modeling.
- ALAQS-AV GIS application.

Flight operations encompass the entire landing and take-off (LTO) cycle as defined by the ICAO. Emissions of each aircraft type are computed by knowing the emission factors for the aircraft's specific engines at each power setting or mode of operation

and the time spent in each mode.

The emission factors included in the ALAQS-AV emission inventory database are CO, HC, NO<sub>x</sub>, SO<sub>x</sub> and PM<sub>10</sub>. SO<sub>x</sub> and PM<sub>10</sub> emission factors are not included in the ICAO aircraft engine database, so substitute indicative figures were used instead.

In ALAQS-AV methodology for a specific scenario, aircraft movements table is prepared for this specific period. For each movement: date, time, aircraft type, arrival/departure flag, gate (stand) and runway are specified. ALAQS-AV toolset uses the movements table to calculate hourly emissions at gates, taxiways, queues and runways.

Aircraft exhaust emissions are calculated for the following operating modes:

- Engine Start
- Taxi in and taxi out (TX, 7% thrust)
- Queuing (TX, 7% thrust)
- Approach (AP, 30% thrust)
- Landing roll (AP, 30% thrust)
- Takeoff roll (TO, 100% thrust)
- Climb-out (CL, 85% thrust)

Except for engine start emissions - aircraft engine emissions during a particular operating mode of the Landing and Take-Off (LTO) cycle are given by the product of the time-in-mode, the fuel flow rate and the emission index for the appropriate engine thrust setting engaged. Data is extracted from the system database. (i.e. aircraft-engine combination, number of engines etc.). The equation is shown below:

$$ACe = FF_{mode} \times EF_{mode} \times T \times N$$

where ACe=Aircraft total engine emissions, per landing-takeoff (LTO) cycle; FF<sub>mode</sub>=Fuel flow rate (kg/s) per engine in mode; EF<sub>mode</sub>=Emission factor (kg/kg) per engine in mode; T=Time-in-mode (s); N=Number of engines.

The ALAQS project approach is based on delivering case study reports, guidance material, a database of default parameters for European LAQ, and the ALAQS-AV toolset. The case studies are used to raise awareness among the airport operators

and serve to study the merits and sensitivities of different inventory and dispersion methods. The studies may be based on actual or predicted traffic. Typical air quality assessment; consist of emission inventory and spatial allocation, dispersion modeling, determination of background concentration and, visualization of the results. ALAQS methodology consists of developing Pan-European emission inventory methodology with spatial information and future application of dispersion modeling with use of GIS technologies.

For ALAQS dispersion modeling studies it is initially focus on using the Lagrangian dispersion model that already exists in LASPORT (LASAT)<sup>1</sup>.

**Sourdine II project** objectives was to propose and evaluate new innovative procedures for reducing the impact of emission and aircraft noise on the ground.

For the emission assessments of the Sourdine II (SII) NAPs, a specific tool called Thrust Based Emission Calculator (TBEC) has been developed. This tool calculates aircraft emission levels associated to a given INM-like flight profile, on the basis of the ICAO Engine Exhaust Emissions Data Bank.

### Thrust-Based Emission Calculator

The Thrust-Based Emission Calculator (TBEC) is a Microsoft Access application which has been specially developed for Sourdine II in order to calculate aircraft emissions (HC, CO, NO<sub>x</sub>, SO<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>O, VOC, and Total Organic Gas (TOG) resulting from the different SII procedures. It uses the ICAO Engine Exhaust Emissions Data Bank, which provides, for a large series of engine types, fuel flow (kg/s) and emission indices (g/kg of fuel) at four specific engine power settings (from idle to full take-off power). The overall principle of TBEC consists of calculating (by interpolations) emission levels, based on the actual thrust along the vertical fixed-point profiles associated to the SII procedures.

The emission level of pollutant  $EL_{seg}$  is expressed as:

$$EL_{seg} = \Delta T_{seg} \times \left[ EF_{seg}(P_i) + \frac{P_{seg} - P_i}{P_{i+1} - P_i} (EF_{seg}(P_{i+1}) - EF_{seg}(P_i)) \right]$$

$$EF_{seg}(P_i) = EI(P_i) \times FF_{seg}$$

$$P_{seg} = \frac{CNT_{seg}}{Max\ StaticThrust} \times 100$$

Where:  $EF_{seg}(P_i)$ =the emission flow for the segment associated to power setting  $P_i$  (in

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<sup>1</sup> A program system for the calculation of airport – related pollutant emissions and concentrations in the lower atmosphere, was developed in 2002.

g/s);  $P_i$ =one of the tabulated engine power setting for which emission indices are provided in the data bank (7%, 30%, 85% or 100%);  $EI(P_i)$ =the emission indices associated to power setting  $P_i$  (in g/kg of fuel);  $P_{seg}$ =the segment-specific power setting (%);  $CNT_{seg}$ =the average corrected net thrust (lb) on the segment, calculated using the input CNT values at the two end-points of the segment;  $MaxStaticThrust$ =the engine-specific maximum sea level static thrust, available in the INM database (lb);  $EL_{seg}$ =the emission level of the pollutant produced on the segment (g);  $\Delta T_{seg}$ =the duration (in seconds) of the flight segment.  $\Delta T_{seg}$  is calculated using the distance between the two end-points of the segment, divided by the average speed of the aircraft on the segment;  $P_i$  and  $P_{i+1}$  are the two tabulated power setting values bounding  $P_{seg}$  (%), [Sourdine II, 2005].

To calculate emission levels of different pollutants, it is necessary to have fuel flow information along the flight profiles. It was originally planned to approximate these by interpolations on input thrust values, as the ICAO databank provides fuel flow data associated to specific power settings. However, the International Civil Aviation Organization Committee on Aviation Environmental Protection (CAEP)'s Modeling Working Group (WG2) considered that estimating fuel flow based on thrust was unsatisfactory without having a greater knowledge of individual aircraft/engine performance parameter.

The TBEC tool remains a prototype with several limitations. Further investigations need to be carried out in order to refine and validate its modeling principles. Emission results produced with such a tool should therefore be taken with caution and analyzed in a relative way (i.e. relative variations of emission levels between the SII procedures and a baseline/reference procedure).

The limitation of TBEC is that it does not take into account the variation of the emission indices with altitude due to temperature and pressure changes. Indeed, the ICAO databank provides emission indices for International Standard Atmosphere (ISA) conditions; these are, however, assumed to be valid for altitudes below 3,000 ft. Another limitation is due to the assumption that emission indices vary linearly with the thrust level, which is obviously not the case in real life.

CO<sub>2</sub>, SO<sub>2</sub> and H<sub>2</sub>O emission levels are directly proportional to the calculated fuel burn and are estimated using the following emission coefficients:



Table 3. Emission Factor from Sourdine II

Reference (g/kg fuel)	CO <sub>2</sub>	H <sub>2</sub> O	SO <sub>2</sub>
Emission Indices	3149	1230	0.84

### **Artemis project "Assessment and reliability of transport emission models and inventory systems"**

It proposed to combine the experience from different emission calculation models and other research in order to arrive at a harmonized methodology for emission estimates at the national and international level.

The project developed a harmonized emission model for all transport modes, which aims to provide consistent emission estimates at the national, international and regional level. This requires first of all additional basic research and a better understanding of the causes of the differences mainly with respect to emission factors.

This project applied existing knowledge and closed some of the major gaps for updating the existing emission database (primarily MEET data) for the influence of maintenance and ageing of engines on emissions, aircraft/engine combinations not covered in the current database, e.g. turbo props, new airframes or former Soviet aircraft and allocation of emissions.

The original MEET data is used in a software tool called *AvioMEET* based on the data published in the Emission Index Sheets of MEET. However the inventory tool *AvioMEET* includes already some improvements:

- Some more aircraft types are added like Boeing B737-400, B737/500/600/700/800, B747-400, ATR42, ATR72, BAe 146
- Emission Indices were harmonized with ANCAT/EC2 data within United Nations Economic Commission for Europe (UNECE) Emission Inventory Guide Book
- Fuel consumption and emissions for climb to 3000 ft and final approach down from 3000 ft which is necessary to calculate ground related emissions are added for COST 319 category
- Fuel consumption and emissions for climb to 3000 ft and final approach down from 3000 ft which is necessary to calculate ground related emissions are added for ICAO category.

AvioMEET generated emission profile for the component CO<sub>2</sub>, H<sub>2</sub>O, SO<sub>2</sub>, NO<sub>x</sub>, CO and HC. The minimum input data to generate such an emission profile is aircraft type, number of aircraft (of this type) on this mission, distance of mission in km.

For measurement methodology, ARTEMIS was used two methods: Intrusive method and Non Intrusive method. In intrusive method and Non intrusive method they used Fourir transform infrared (FTIR) spectrometer.

AvioMEET inventory tool cannot be used to estimate emissions properly according to Kyoto Protocol option 8 (Allocation to the Party of emissions generated in its national space and 3D methodology). Only MEET methodology and its emission function can. Measured NO<sub>x</sub> emission indices are lower than given by the ICAO from certification measurements. There is a high variance of emission indices for each engine type during idle conditions.

Emission indices for main engines are measured of nearly 100 different aircraft, measured by FTIR emission spectrometry. All measurements were performed during summertime (mean air temperature about 20°C). Only the measurements of some B747-236, B747-436, and B777-236 were in March 1999 with temperatures around 11°C.

**AERONET III** with regard to aircraft emissions and reduction technologies provides the tools to:

- exchange information gathered in the different aviation emissions-related projects of the Sixth Framework Program in Aeronautics, related projects in the Atmospheric Research Program, and in other areas such as transport or energy;
- raise the level of personal and corporate knowledge and confidence within the community;
- identify gaps in knowledge and needs for further research and development, and facilitate the development of the appropriate research proposals;
- support interdisciplinary relationships and increase knowledge through joint actions such as workshops, meetings, studies and reports;
- support the policy and regulatory process by utilizing the potential of the AERONET III forum to generate policy-relevant material.

This project still ongoing and has not provided the result yet.

## Additional and open studies

There have been a few studies of aircraft emissions. Some of these studies focused on measurement of aircraft emissions using remote sensing and Fourier transform infrared (FTIR) emission spectroscopy (Heland and Schafer, 1998; Schafer, 2001, Schafer *et al.*, 2003) and using visible spectroscopy from aircraft for measuring reactive nitrogen emissions from point source (Melamed *et al.*, 2002). Other studies focused on modeling the local and regional impact of aircraft emissions.

Moussiopoulos *et al.* (1997) quantified the potential impact of emissions from a planned airport on the Athens basin using an Eulerian dispersion model. They showed an increase in NO<sub>x</sub> concentrations in the vicinity of the airports, though the contribution to regional air quality was found to be minimal.

Dameris *et al.* (1998) a first approach to estimate the sensitiveness of the atmosphere on aircraft NO<sub>x</sub> emissions using the coupled 3-D dynamic-chemical model ECHAM3/CHEM. The results demonstrate the global 3-D effects of aircraft NO<sub>x</sub> emissions on the atmosphere and, therefore, stress the need of 3-D modeling. A valuation of the model results must consider that the emission data sets, especially from other sources than aircraft, still have large uncertainties. The impact of other aircraft emissions i.e. water vapor, carbon monoxide and dioxide, sulphur oxide or soot not yet considered in this investigation.

Plummera *et al.* (2001) were used regional-scale models to assess the effects of various hydrocarbon and NO<sub>x</sub> emission control strategies on ozone concentrations (e.g. NO<sub>x</sub>/VOC-SP, 1997). These models calculate the effects of chemical and physical processes on trace species distributions and require as input, spatially and temporally distributed estimates of the emission of hydrocarbons and NO<sub>x</sub>.

Yu *et al.* (2004) utilized the nonparametric regression method to estimate the average concentration of pollutants such as sulfur dioxide (SO<sub>2</sub>) and carbon monoxide (CO) as a function of wind direction and speed near Hong Kong and Los Angeles airports based upon observational data. However, their monitoring sites were very close to highways and were most likely affected by roadway vehicle emissions. Although their method might be useful to determine the impact of pollutants emitted solely from airport operations, it would not be accurate enough for others particularly if chemical reactions play an important role.

Pison and Menut (2004) quantified the impact of aircraft emissions on ozone

concentrations over the Paris area. For this purpose they used a mesoscale air quality model, CHIMERE, with  $150 \times 150 \text{ km}^2$  resolution and a vertical extension of 3100 m. They found that, during the night time, ozone levels decrease as much as 10 ppb in the vicinity of airports due to the titration effect of  $\text{NO}_x$  emissions from aircraft. During the daytime, ozone levels increase as much as 10 ppb in  $\text{NO}_x$  limited areas. None of these previous studies quantified the impact of aircraft emissions on fine particulate matter (i.e., particulate matter with aerodynamic diameters less-than 2.5  $\mu\text{m}$ ,  $\text{PM}_{2.5}$ ).

Unal *et al.* (2005) quantified the impact of aircraft emissions on regional air quality, especially in regards to  $\text{PM}_{2.5}$  and ozone, focus on the Hartsfield–Jackson Atlanta International Airport which is the busiest airport in the world based on passenger traffic. A comprehensive modeling approach was taken to assess the impact of the Hartsfield–Jackson International Airport. First, aircraft  $\text{PM}_{2.5}$  emissions were estimated using a first-order approximation where emission rates are a function of Smoke Number (SN) and fuel flow rate for different engine types in different modes of operation.

Gauss *et al.* (2005) presented results from an extensive model study performed for the TRADEOFF project focusing on the environmental impact of aircraft emissions and options to reduce the impact for present conditions (year 2000) and on the impact of aircraft emissions in a future (year 2050) atmosphere. They have used a 3-D chemical transport model including comprehensive chemistry schemes for the troposphere and the stratosphere in order to take into account all chemical processes relevant for the upper troposphere and lower stratosphere region (UTLS). Significant perturbations in  $\text{NO}_y$  and  $\text{NO}_x$  are modeled in the tropopause region of the Northern Hemisphere with a strong zonal variability in the case of  $\text{NO}_x$ .

Kesgin (2005) deals with estimating aircraft landing and take-off (LTO) emissions ( $\text{HC}$ ,  $\text{CO}$ ,  $\text{NO}_x$ ,  $\text{SO}_2$ ) at 40 Turkish airports including the biggest airports, i.e. Ataturk International Airport (AIA) in Istanbul, Antalya Airport in Antalya and Esenboga Airport in Ankara in 2001. The calculation model is based on flight data recorded by the State Airports Authority and using MEET methodology. The flight data include the type and number of aircraft, number of passengers, amount of cargo etc., which depend on day-time and date. For the emission calculations the ICAO Engine Exhaust Emission Databank, which includes minimum and maximum values for both fuel flow rates and emissions factors, is used. By using first the minimum and the maximum values from the data bank, two estimations of aircraft LTO emissions at

Turkish airports are calculated: i.e. minimum and maximum estimations. Total LTO emissions from aircrafts at Turkish airports are estimated to be between 7614.34 and 8338.79 t/year. These results are comparable with those from USA airports. Approximately half of these amounts are produced at AIA. To predict future emissions, it is estimated that an increase of 25% in LTO cycles might cause a rise of between 31 and 33% in emissions. The estimations show that a decrease of 2 min in taxiing time results in a decrease of 6% in LTO emissions. The estimation model used in this study can be used for expansions and planning of airports from an environmental point of view.

Sidiropoulos *et al.* (2005) calculated emission factor for selected airports in Greece following the analytical methodology incorporated in the EMEP/CORINAIR Atmospheric Emission Inventory guidebook. This process considered the topography of each airport and consequently the different times in mode within the LTO cycle. Time in mode of each aircraft engine is derived from the ICAO Engine Exhaust Emission Databank and so emissions are estimated per time in mode for each aircraft. Emission estimations were performed following both the simple and the detailed methodology. A comparison between the outcome of the two methodologies shows that the simple one tends to overestimate emissions, which are 9.05 times higher in the case of VOCs emissions (Rhodes airport), while in the case of CO are 3.86 times higher (Thessaloniki airport). Only in the case of NO<sub>x</sub> the methodologies seem to have a good agreement. These deviations can be mainly attributed to the fact that in the detailed methodology the actual operational times in mode used are significantly lower than the standard times of the simple methodology. LTO cycle lasts 24.2 min at Kavala airport, 24.7 min at Rhodes airport and 21.9 min at Thessaloniki airport, while the standard LTO cycle duration is considered 32.9 min for all airports. The local topographical condition and the air traffic composition which vary from airport to airport influence the total emissions in each airport. The detailed methodology calculated operational time in mode representative of each airport, thus providing a higher degree of accuracy in the resulting emissions.

Morris and Buttress (2005), used ICAO methodology to calculate the total NO<sub>x</sub> emissions from aircraft during Engine Ground Running for the whole of Heathrow airport as approximately 15.6 tons per annum, with the majority being emitted in the airport's Engineering Base (excluding ground run pens, 4.2 tons per annum), and the two dedicated ground run pens: TE1 "Tristar" pen (3.3 tons per annum) and TA9 (6.3 tons per annum). British Airways ground runs contribute about 80% of this total. For the period December 2000 and September 2005, British Airports Authority (BAA)

recorded statistics for the number of engine ground run tests per month, show little variation in the number of runs per month for engine runs at ground idle power settings, and a decline of about 25% for “high power” runs above ground idle.

Anderson *et al.* (2006), they report selected carbon species emission indices (EIs) for a Rolls Royce RB211-535-E4 turbofan engine that were acquired during the National Aeronautics and Space Administration (NASA) Experiment to Characterize Aircraft Volatile Aerosol and Trace-species Emissions (EXCAVATE). The mission focused upon characterizing the exhaust constituents of the NASA Boeing 757 aircraft during ground-based operation. Carbon species concentrations were determined by chromatographic analyses of whole air samples collected 10m behind the engine exit plane as engine power was varied from ground idle to about 60% of maximum rated thrust.

Graver and Frey (2009) was created an airliner emissions inventory for Raleigh-Durham International Airport, based on landing and take-off (LTO) data for commercial passenger air carriers for 2006. The emissions from each airliner were determined using engine emissions databases. The total emissions (HC, CO, NO<sub>x</sub>) were estimated from commercial aircraft at RDU for 2006.

Wayson *et al.* (2009) discuss related assumptions and derived equations for the First Order Approximation (FOA) 3.0 methodology used worldwide to estimate PM emissions from certified commercial aircraft engines within the vicinity of airports. The methodology uses the latest scientific information available and unlike previous methods is restructured in a flexible manner to accommodate new scientific advancements as they become available.

FOA3.0 provides a greater confidence in the estimation of PM from certified commercial aircraft at airports. These estimations provide a means to analyze the emissions and the effects in changing operations or aircraft types. Teamed with dispersion models, FOA3.0 can also permit evaluations compared with standards or regulations that are health-based. FOA3.0 results are intended strictly for airport operations inventory purposes at this time, but future work has been identified to continue to increase the accuracy, applicability, and confidence in the FOA methodology. Once an accepted, repeatable method for direct measurement of PM emissions is established and today's fleet is sufficiently represented, the FOA methodology will eventually become obsolete.

## **Comparison of methods**

ICAO and EEA/EMEP have three approaches to quantifying aircraft engine emissions. The Approaches are Simple Approach, Advanced Approach and Sophisticated Approach for ICAO and Tier 1, Tier 2 and Tier 3 for EEA/EMEP. These approaches are depending on the level of accuracy or complexity need.

Simple Approach is more detail compared Tier 1, Simple Approach specific data required are the number of aircraft movements (over a certain period such as a year) and the type of each aircraft involved in each movement. This approach does not utilize engine-specific emissions data but uses the most common type of engine in operation internationally for that aircraft type. The emissions factor is provided in terms of kg of each emission species per LTO cycle per aircraft. These have been calculated based on the representative engine type for each generic aircraft type and using ICAO TIM, thrust settings and other basic assumptions.

The Tier 1 approach is based on the premise that data on the quantities of fuel sold for aviation use are available, most probably from nationally collected data. It also assumes that the annual quantity of fuel used is the same that sold. The Information on the country's total number of LTOs needs to be available, preferably also the destination (long and short distance) for international LTOs, together with a general knowledge about the aircraft types carrying out aviation activities.

The Advanced Approach represents a more accurate estimation of aircraft engine emissions compared to Tier 2 because it attempts to account for the specific engine model on the aircraft under study. Further, because each mode of the LTO cycle will be calculated individually, the practitioner has the option to add aircraft-specific operating times for the taxi/idle mode according to the unique taxi-way characteristics linking the terminal area with the runway ends.

The Tier 2 methodology is a top down (fuel sold) methodology that uses statistics on aviation fuel consumption (split by domestic and international). To split the fuel use by LTO and cruise detailed LTO activity and knowledge of aircraft fleet composition are needed to provide a more accurate inventory as opposed to using only average emission factors per mass of fuel used (the Tier 1 approach). The Tier 2 methodology should include all types of aircraft frequently used for domestic and international aviation.

The Sophisticated Approach has greater level of accuracy; the actual and refined

data required for the analysis is obtained from real-time measurements, reported performance information and/or complex computer modeling outputs. At a high level, these data and information characterize the actual fleet composition in terms of aircraft types and engine combinations, TIM, thrust levels, fuel flows and possibly, combustor operating conditions for all phases of ground-based and take-off operations. This approach is almost similar to Tier 3 methodology. The Tier 3 methodologies are based on actual flight movement data, either for Tier 3A origin and destination (OD) data or for Tier 3B full flight trajectory information. Hence these methodologies are bottom-up, flight-based, rather than top-down calculation-based on the fuel consumed.

EPA emission calculation is based on the weighted-average emission factor that represents the average emission factor per LTO cycle for all engine models used on a particular type of aircraft. This method is almost similar to the ICAO methodology. The differences is only in the emission factor calculation, EPA used the emission factor for each pollutant in pounds of pollutant per 1000 pounds of fuel (or kilograms pollutant per 1000 kilograms fuel), for each engine model and operating mode. Total emissions for each aircraft type are computed by multiplying the emissions for one LTO cycle by the number of LTO cycles then summed to yield total commercial exhaust emissions for the facility.

The pollutant emissions considered by ICAO is almost similar to EEA/EMEP and EPA. ICAO considers the pollutant emission of NO<sub>x</sub>, CO, HC, SO<sub>2</sub>, CO<sub>2</sub>, SO<sub>x</sub>. Whilst EEA/EMEP considers pollutant emission of CO, NO<sub>x</sub>, NMVOC, CH<sub>4</sub>, N<sub>2</sub>O, PM<sub>2.5</sub>, CO<sub>2</sub>, SO<sub>2</sub>, PM<sub>10</sub> and pollutant emission of VOC, NO<sub>x</sub>, CO, SO<sub>2</sub> considered by EPA.

ALAQS and MEET, they are using almost the same method created by the ICAO, but not all of them only partially. ALAQS describes flight operations encompass the entire landing and take-off (LTO) cycle as defined by the ICAO. Emissions of each aircraft type are computed by knowing the emission factors for the aircraft's specific engines at each power setting or mode of operation and the time spent in each mode. In ALAQS methodology for a specific scenario, aircraft movements table is prepared for this specific period. For each movement: date, time, aircraft type, arrival/departure flag, gate (stand) and runway are specified. ALAQS has a toolset calculate hourly emissions at gates, taxiways, queues and runways. The advantage of using ALAQS is that ALAQS Emission inventory methodology can be developed with spatial information and future application of dispersion modeling to this inventory with use of GIS technologies. But ALAQS is used only for calculating Total engine emissions in



LTO cycle defined by the ICAO. And there are some uncertainties about the accuracy or the consistency of the data used. For example for emission inventories it is important to gather all the necessary information about the pollution sources, their operations and, appropriate emission factors.

Whilst MEET uses emission factors are based on engine certification data in the ICAO Engine Exhaust Emission Databank. It contains data sets of thrust (engine performance), fuel flow and emissions of components CO, NO<sub>x</sub> and VOC which apply to four different power settings. The methodology and data set provided will enable users: to build air traffic emission inventories for a region (spatial resolution > 10 km), to assess the impact of changes in the number of aircraft movements, to assess impacts from changing the distance flown (e.g. reducing time spent in holding patterns). The advantage of using MEET methodology is that MEET can be used for calculated air traffic emissions not only local but also regional region. The MEET methodology is also used by ARTEMIS. For inventory tools, ARTEMIS used UNECE methodology and AvioMEET but those inventory tools cannot be used to estimate emissions properly according to Kyoto option 8.

Sourdine II has innovative procedures assessed emission from aircraft using specific tool called TBEC. TBEC calculates total fuel burn and total emissions of CO, NO<sub>x</sub>, SO<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>O, VOC and Total Organic Gases (TOG). The overall calculation principle consist of estimating the fuel burn and emission level produced by each segment and summing them (over the flight profile) to obtain the total fuel burn and emission of each pollutant. The limitation of TBEC is that it does not take into account the variation of the emission indices with altitude due to temperature and pressure changes. Another limitation is due to the assumption that emission indices vary linearly with the thrust level, which obviously not the case in real life.

Heland and Schafer have been measured aircraft pollutant emission by using remote sensing and FTIR emission spectroscopy and Anderson et al. by using chromatographic analysis of whole air samples collected 10m behind the engine to determine Carbon species concentration.

Various methods in some studies have been used to quantify the impact of emissions. For quantifying NO<sub>x</sub> emission Moussiopoulous et al. used an Eulerian dispersion model, Pison and Menut used a mesoscale air quality model (CHIMERE) with 150 x 150 km<sup>2</sup> and a vertical extension of 3100 m, Dameris et al. used the coupled 3D dynamic chemical model ECHAM3/CHEM, Gauss et al. used a 3D chemical transport model and Plummera et al. were used regional scale model. Yu et

al. utilized the non parametric regression method to estimate the average concentration of pollutants such as SO<sub>2</sub> and CO as a function of wind direction and speed. Unal et al. used first order approximation for assessing PM<sub>2.5</sub> emissions in different mode operations. Kesgin estimated aircraft LTO emissions (HC, CO, NO<sub>x</sub>, SO<sub>2</sub>) at Turkish Airport and Ataturk International Airport in Istanbul based on flight data recorded by the State Airports Authority and using MEET methodology. Wayson et al. used and discuss related assumptions and derived equations for the First Order Approximation (FOA) 3.0 methodology to estimate PM emissions from certified commercial aircraft engines within the vicinity of airports. Sidiropoulos et al. calculated emission factor for selected airports in Greece following the analytical methodology incorporated in the EMEP/CORINAIR Atmospheric Emission Inventory guidebook. This process considered the topography of each airport and consequently the different times in mode within the LTO cycle. Time in mode of each aircraft engine is derived from the ICAO Aircraft Exhaust Emission Databank and so emissions are estimated per time in mode for each aircraft. Emission estimations were performed following both the simple and the detailed methodology.



## RESEARCH METHODOLOGY

### Activities that Have Been Done and to Be Done

It has been showed that the varieties of different systems have been and are being used for assessment of aircraft pollutant emission both historically and around the world. The use of different and separate methodology causes a wide variation in results of emission indexes.

The common approach to the assessment of aircraft pollutant emission would be beneficial in order to allow easy comparison of pollutants around different airports throughout the world. It would be beneficial for similar criteria to be adopted internationally. Emission factor used by organizations, studies and projects for aircraft pollutants assessment is commonly based on the ICAO engine exhaust emission database that contains data sets of thrust (engine performance), fuel flow and component emissions.

The various organizations in the EU and the United States, the fundamental approach to analysis and management or control of aircraft pollutant emissions are almost similar. They used the methodology to calculate pollutant emission by using the LTO cycle method that provided by ICAO.

Each methodology of some organizations, projects and studies has the advantages and disadvantages method. To choose which the best method can be used to calculate/estimate the pollutant emissions from the aircraft precisely is difficult to decide and need to prove.

There are some methodologies to choose which one the most accurate method for assessing aircraft pollutant emissions can be used, such as Multi-criteria Decision Making, Analytical Hierarchy Process, etc. We have reviewed some of methods, the methodology for assessing aircraft pollutant emissions that more representative in this project is the MEET methodology that because of some criteria such as emission factors used are based on engine certification data in the ICAO Engine Exhaust Emission Databank that contains data sets of thrust (engine performance), fuel flow and emissions of components CO, NO<sub>x</sub> and VOC which apply to four different power settings and data set provided will enable users: to build air traffic emission

inventories for a region (spatial resolution >10 km), to assess the impact of changes in the number of aircraft movements, to assess impacts from changing the distance flown (e.g. reducing time spent in holding patterns) and also the advantage of using MEET methodology is that MEET can be used for calculated air traffic emissions not only local but also regional region. This methodology is also used by Kesgin study and ARTEMIS project.

In the future, technology will continue to play a significant role in reducing the pollutant emissions around airports. Advances in future technologies become candidates for gradual adoption into derivatives of existing production aircraft and the next generation of airliners. Some concepts, such as improved wing tip devices and smoother surface areas, can be considered for derivatives of existing designs. Advanced weight reduction technologies, aircraft control systems, and airframe concepts such as Blended Wing Body could be developed for more futuristic concept approach. Fuel efficiency improvement and aircraft efficiency increases will expect decrease the aircraft pollutant emissions from air traffic.

### Research Plan Activity in the 1<sup>st</sup> Year

No	RESEARCH ACTIVITIES	First Year											
		1	2	3	4	5	6	7	8	9	10	11	12
1	<i>Activities at UI:</i> Aircraft emissions inventory and comparison with already implemented solutions showing the interest and the stakes of this research.												
2	<i>Activities at UI and INRETS:</i> State of the art: aviation and the environment / the balance approach of ICAO												
3	<i>Research Team at UI:</i>												
4	<i>INRETS research team will come to Indonesia in autumn 2010 and or April 2011. Research Team arranges strategy for the PhD objectives and the future prospect</i>												
5	<i>Activities at UI and INRETS:</i>												
6	<i>UI research team will visit</i>												

	<i>INRETS in December 2010.</i>																		
7	<i>Activities at UI and in INRETS:</i> Identification of methods assessing and measuring noise and pollutant emissions. Have to be analyzed the benefits of the incoming aeronautical fuels combined with the new aircraft design and engines. What are the impacts compared to the previous aircraft fleet?																		
8	<i>Activities at UI and INRETS:</i> Development of new method based on fuzzy network combining noise and pollutant emission factors calculation. Theoretical tools have to be finalized this year.																		
9	<i>Activities at UI and INRETS:</i> Development of new method based on fuzzy network combining noise and pollutant emission factors calculation. Theoretical tools have to be finalized this year.																		
10	<i>Seminars and Publications of research results</i>																		

**Research Plan Activity in the 2<sup>nd</sup> Year**

No	RESEARCH ACTIVITIES	Second Year																	
		1	2	3	4	5	6	7	8	9	10	11	12						
1	<i>Activities at UI:</i>																		
2	<i>Activities at UI and INRETS:</i> Algorithm and method have to be developed to solve the fuzzy network problem with the answer to the following question: how to obtain an accuracy solution that should be implemented in-flight to manage noise and pollutant emissions																		
3	<i>Activities at UI and INRETS:</i> <i>Cont.</i>																		
4	<i>Activities at UI and INRETS:</i> The new model has to be achieved																		

	taking into account air traffic																	
5	<i>INRETS Research Team will visit UI in Indonesia in autumn 2010 and or April 2011. Research Team arranges strategy and objectives for the in-site validation of the incoming demonstrator</i>																	
6	<i>Activities at UI and INRETS: Dispersion modeling calculation development on the basis of EDMS or other available software has to be used to validate the developed method</i>																	
7	<i>UI Research Team will visit INRETS October? 2011 to ??</i>																	
8	<i>Activities at UI and INRETS: Cont.</i>																	
9	<i>Activities at UI and INRETS: Prepare written report of the second year research. Write paper for international publication.</i>																	
10	<i>Seminars and Publications of research results</i>																	

**Research Plan Activity in the 3<sup>rd</sup> Year**

No	RESEARCH ACTIVITIES	Third Year																
		1	2	3	4	5	6	7	8	9	10	11	12					
1	<i>Activities at UI and INRETS: Explore the latest international research</i>																	
2	<i>Activities at UI and INRETS: Analysis of results and data collection for validation step</i>																	
3	<i>Activities at UI:</i>																	
4	<i>INRETS Research Team will visit UI to arrange strategy for implementing method and its validation</i>																	







## BUDGET PROPOSAL

### Cost Recapitulation to Conduct Research in the 1<sup>st</sup> Year

No	ITEMS	DIKTI		French Embassy	
		Total (Rp)	%	Total (Rp)	Total (Euro)
1	Honorarium	60,000,000,-	30		
2	Material and Research supporting	59,955,000,-	30		
3	Mobility	37,520,000,-	19	64,500,000,-	5000
4	Data, Report, etc	40,000,000,-	20		
	Total amount	<b>197,475,000,-</b>	<b>100</b>	<b>64,500,000,-</b>	<b>5000</b>
	<b>Total first year</b>	<b>Rp.261,975,000,-</b>			

### Honorarium for Indonesian Researcher

No.	Research Team	No	Hour (Week)	Honorarium (Hour)	Total Week	Total (Rp)
1	Main Researcher	1	12	50,000	40	24,000,000
2	Senior Researcher	1	10	45,000	40	18,000,000
4	Supporting staff	3	10	20,000	30	18,000,000
						60,000,000

### Material and Research Supporting

No.	ITEMS	Unit	Vol	Unit Price (Rp)	Sub-Total (Rp)
1	????	pc	1	???	???
2	????	pc	1	????	????,000
3	Color Cartridge	pc	5	275,000	1,375,000
4	Black Cartridge	pc	5	250,000	1,250,000
5	HVS A4	pack	8	35,000	280,000
6	Blank CD	Pc	20	15,000	300,000
7	Communication and Internet Connection	ls	10	200,000	2,000,000

8	Stationary	ls	1	1,000,000	1,000,000
9	Photocopy	ls	1	750,000	750,000
<b>Total</b>					<b>59,955,000</b>

## Mobility

Mobility for UI Research Team to INRETS under DIKTI financing support.

No	Items	Unit	Vol	Unit Price (Rp)	Sub-total (Rp)
1	Ticket flight (2-ways) for UI Researcher to INRETS-France (USD 1600)	person	2	15,680,000	31,360,000,-
2	Train Ticket (2-ways): Airport CDG-Lyon (200 Euro)	person	2	2,580,000	5,160,000,-
3	Local transport to Bandara Soekarno Hatta PP and Airport tax.	person	2	500,000	1,000,000,-
<b>Total</b>					<b>37,520,000,-</b>

INRETS Research Team to UI under French Embassy financing support

No	Items	Unit	Vol	Unit Price	Sub-total
1	Ticket flight (2-ways) for INRETS Researcher to UI	Person	2	Rp.15,480,000,- (1200 Euro)	Rp.30,960,000 (2400 Euro)
2	Train ticket (2-ways) from Lyon to CDG Airport	Person	2	Rp.2,580,000,- (200 Euro)	Rp.5,160,000 (400 Euro)
4	Accommodation for 2 UI Researcher at INRETS-Lyon-France for 10 days.	Person-day	20	Rp.1,419,000,- (110 Euro)	Rp.28,380,000 (2200 Euro)
<b>Total</b>					<b>Rp.64,500,000 (5000 Euro)</b>

## Data, Report for Indonesian Researcher

No.	Items	Unit	Vol	Unit Price (Rp)	Sub-total (Rp)
1	Mid Report	set	8	75,000	600,000
2	Final Report	set	8	125,000	1,000,000

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3	Attend to Seminar	person	3	1,000,000	3,000,000
4	Focus Group Discussion	set	1	15,400,000	15,400,000
5	Accommodation for 2 researcher from INRETS at UI for 10 days	person-day	20	1,000,000	20,000,000
<b>Total</b>					<b>40,000,000</b>

**Remark:** 1 EUR = Rp. 12900 and 1 USD = Rp. 9800,-



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## APPENDIX

### Memorandum of Understanding



**Memorandum of Understanding**  
between  
**UNIVERSITAS INDONESIA**  
**University of Indonesia**  
and  
**INSTITUT NATIONAL DE RECHERCHE SUR LES TRANSPORTS ET LEUR**  
**SÉCURITÉ**

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MoU is a available agreement at INRETS and UI administrations

## **Facilities**

Research activities will be conducted at the Laboratory of Environmental in Civil Engineering Department of Universitas Indonesia (UI) and the INRETS-Transports and Environment Laboratory, Bron Cedex 69675 in France. Laboratory facilities to be used are testing equipment and software owned by UI and INRETS.

1. Laboratory: Describe the facilities to be used, including the capacity, the ability, and the importance of the equipment in supporting the research activities (in percentage). If any, explain the required coordination with other related institution.

This project aims to develop more extensively the scientific exchanges and excellence between the two research laboratories of the two countries. In particular, these works and exchanges should be developed through the organization of several internships for high-school students on the above topics, and which should be managed jointly by the French and Indonesian partners to favor the bilateral partnership. Ideally, a PhD thesis and two Master students should be proposed (at the issue of a first period). For this project, we will use software and processing facilities already available in the laboratory presented below:

Transports and Environmental laboratory presentation: The two main environmental nuisances that have been studied for a long time at LTE (Transport and Environment Lab) are:

- Noise: which is the main environmental nuisance experienced by the citizens (information confirmed by the national survey carried out by LTE in 2005-2006).
- Air pollution and greenhouse gases, considering their major impacts on health and climate.

LTE also develops its scientific skills to study jointly all the environmental nuisances from transport aiming to develop decision making tools

Regarding these nuisances, the research works carried out at LTE mostly aim at:

- Qualifying the environmental and energy impacts (road, railway and airplanes): understanding of the phenomena, characterizing and quantifying emissions, assessing impacts (perception, effects) by means of measurements, models, experiments and field surveys.
- Developing, assessing and optimizing solutions aiming at reducing environmental nuisances and energy consumption.

Concerning the energetic and environmental impacts of transport, researches address:

- The knowledge of the vehicle fleets, traffic conditions, and vehicle usage
- The emission laws (pollutants, noise and vibration)
- The energy consumption and greenhouse gas emitted by vehicles
- The perception and effects of these nuisances on man

Concerning the solutions aiming at improving the quality of the environment, the research work focus on:

- The energy optimization and the reliability of vehicles equipped with innovative motors (hybrid, electric...)
- The reduction of greenhouse gas, air pollutants, noise and vibrations,
- The social demand for the reduction of nuisances and the acceptability of the potential solutions

These research works are mostly part of the 1<sup>st</sup> Axis of the 4-year INRETS research program. They are carried out by four teams involved in social and human sciences as well as engineering sciences.

In accordance with the INRETS objectives, these research works aim to produce scientific knowledge and know-how that provide assessment tools to the public authorities and that contribute to build and to improve regulations. The results of these research works are also intended for the industry and to the operators of transport for the development of solutions that fit well with the environment.

LTE employed about 45 people, divided into 4 research teams:

- Physical Accoustics: activity research on noise emission and vibrations from transport
  - Energy and air pollution: activity research to characterize air pollutant emissions and their physical impacts
  - Electric and Hybrid vehicles: activity research aiming to assess, optimize and make reliable low emission and energy consumption vehicles
  - Perception, acceptability and behaviors: activity research on perception of environmental nuisances and acceptability of solutions and public policies.
2. Additional Information: Additional information about the situation where the activities will be conducted. Mention also the supporting facilities, including workshop, which can be useful during the research time.

**Students have to spend 50 % of the time in INRETS and 50 % in UI.**

## Letter of the project acceptance by Indonesian Ministry of Education



**KEMENTERIAN PENDIDIKAN NASIONAL**  
DIREKTORAT JENDERAL  
PENDIDIKAN TINGGI

Gedung DIKTI Lantai 4 Jl. Jenderal Sudirman Pintu I, Senayan, Jakarta 12001  
Telepon: (021) 57946100 Ext. 0433 Faks. (021) 5731846 <http://dp2m.dikti.go.id>

Nomor : 1108/D3/PL/2010 Jakarta, 4 Juni 2010  
Lampiran : 1 (satu) set  
Perihal : Hasil Evaluasi Penelitian Kerjasama  
Antar Lembaga dan Perguruan Tinggi, Penelitian Kerjasama  
Luar Negeri dan Publikasi Internasional, dan  
Penelitian Hibah Kompetensi

Kepada Yth. : Ketua Lembaga Penelitian dan Pengabdian kepada Masyarakat

Diberitahukan dengan hormat bahwa Direktorat Penelitian dan Pengabdian kepada Masyarakat, Direktorat Jenderal Pendidikan Tinggi telah melakukan evaluasi Penelitian Kerjasama Antar Lembaga dan Perguruan Tinggi, Penelitian Kerjasama Luar Negeri dan Publikasi Internasional, dan Penelitian Hibah Kompetensi untuk pendanaan tahun 2010 dengan hasil evaluasi penelitiannya sebagaimana tersebut pada lampiran.

Sejalan dengan itu kami mohon perhatian Saudara terhadap beberapa hal sebagai berikut:

1. Penelitian tersebut baru dapat dibiayai apabila Surat Perjanjian Pelaksanaan Penelitian dengan para dosen penerima Penelitian Kerjasama Antar Lembaga dan Perguruan Tinggi, Penelitian Kerjasama Luar Negeri dan Publikasi Internasional, dan Penelitian Hibah Kompetensi telah ditandatangani oleh Pejabat Pembuat Komitmen Direktorat Penelitian dan Pengabdian kepada Masyarakat dan Ketua Lembaga Penelitian dan Pengabdian kepada Masyarakat.

Untuk itu bersama ini kami sampaikan format Daftar Isian Surat Permintaan Pembayaran Hibah Penelitian untuk diisi (harus diisi secara benar, lengkap dan jelas) dan di fax kepada kami melalui Nomor. 021-5731846. Asli Daftar Isian tersebut akan diisi pada saat penandatanganan Surat Perjanjian.

2. Perlu kami ingatkan kembali bahwa seorang peneliti hanya diperbolehkan sebagai ketua dan sebagai anggota di judul penelitian lain atau sebagai anggota di 2 (dua) kegiatan penelitian yang berasal dari skim penelitian DP2M.

Demikian untuk dapat diketahui, atas perhatian dan kerjasamanya diucapkan terima kasih

A.n. Direktur Jenderal Pendidikan Tinggi  
Direktur Penelitian dan  
Pengabdian kepada Masyarakat

ttd

Suryo Hapsoro Tri Utomo  
NIP. 19560901 198503 1 003

**Tembusan :**

1. Yth. Dirjen Dikti (sebagai laporan)
2. Arsip

## Lampiran\_2 Surat No. 1108/D3/PL/2009

## HASIL EVALUASI KERJASAMA LUAR NEGERI DAN PUBLIKASI INTERNASIONAL TAHUN 2010

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2	Abdul Hadi	Universitas Lambung Mangkurat	REDUCING GREENHOUSE GAS EMISSIONS (>26%) FROM PEAT SOIL CULTIVATED TO OIL PALM IN BORNEO ISLAND
3	Agus Saleh Atmadipoera	Institut Pertanian Bogor	INDOMIX Program: Investigations on the Internal Tides and Mixing in the Indonesian Throughflow Region and Their Impact on Biogeochemical Distribution and Climate Variability
4	Agus Setiawan	Universitas Pendidikan Indonesia	Methodological Approaches for Tapping Skilled Work for Technical and Vocational Education and Training (TVET) Curriculum Development
5	Agus Sunjarianto Pamitran	Universitas Indonesia	Tube Inclination Effect on Pressure Drop and Heat Transfer Coefficient of Two-Phase Flow Boiling of Refrigerants for Design Parameter of Evaporator
6	Ahmad Rifa'i	Universitas Gadjah Mada	EFFECT OF SATURATED-UNSATURATED SOIL CONDITION ON SLOPE STABILITY AND COUNTER MEASURE USING RECYCLING MATERIAL
7	Ahmad Rusdiansyah	Institut Teknologi Sepuluh November	DESIGNING MODEL OF AN INDUSTRIAL CLUSTER FOR ICT-BASED CREATIVE INDUSTRIES: A BENCHMARKING STUDY TO TAIWAN'S EXPERIENCE
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13	Aripin	Universitas Haluoleo	Development of Microwave Absorber Material from Sago Hampas Fibre Derived Silica Xerogel Filled in Al <sub>2</sub> O <sub>3</sub> Ceramic Matrix
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Hal. 1.



NO	NAMA	PERGURUAN TINGGI	JUDUL
21	Budi Santosa	Institut Teknologi Sepuluh November	Using Metaheuristic Method In Solving Cabin Crew Rostering Problem
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57	M. Baiquni	Universitas Gadjah Mada	REIMAGING AND PROMOTING THE THREE WORLD HERITAGE SITES BOROBUDUR, PRAMBANAN AND SANGIRAN
58	M. Nizar Machmud	Universitas Syiah Kuala	Multilayer Structures of Immiscible Polycarbonate/ABS Blends and their Performances under Impact
59	Maggy Thenawidjaja Suhartono	Institut Pertanian Bogor	Characteristics of Proteases From Mutant Bacillus licheniformis F11 and Its Derivatives F11.1-F11.4
60	Mamduh M Hanafi	Universitas Gadjah Mada	Ownership Concentration, Commissioner Power and Risk Management in Indonesian Banking
61	Mochamad Agoes Moelyadi	Institut Teknologi Bandung	Development of Flapping Wing Micro Aerial Vehicle Model
62	Mohamad Djaeni	Universitas Diponegoro	Development of Energy Efficient Spray Dryer Using Air Dehumidified By Zeolite to Produce High Quality Carrageenan Powder

NO	NAMA	PERGURUAN TINGGI	JUDUL
63	Mohamad Syahril Badri Kusuma	Institut Teknologi Bandung	Optimization of Tsunami Evacuation Plan : Case Study Padang City
64	Mohammad Affan Fajar Falah	Universitas Gadjah Mada	Development of Automated Hydroponic Food Production System for Improving Fresh-Food Quality in Tropical Controlled Environment
65	Muh. Aris Marfai	Universitas Gadjah Mada	Risk and Resilience in Megacity (Case study Jakarta Coastal City-Indonesia)
66	MUH.YUSRAM MASSIJAYA	Institut Pertanian Bogor	DEVELOPING HIGH QUALITY GLUED LAMINATED LUMBER (GLULAM) MADE OF SMALL DIAMETER LOGS FROM COMMUNITY FOREST
67	Murwantoko	Universitas Gadjah Mada	Development of Polymerase Chain Reaction and Loop-Mediated Isothermal Amplification Of DNA Methods for Detection of Iridovirus In Indonesia-Australia
68	Mustanir	Universitas Syiah Kuala	Nanocrystalline Magnesium Based Hydrides Prepared by Reactive Mechanical Alloying as Hydrogen Storage Materials for Fuel Cell Powered Vehicle Application
69	Nasril Nasir	Universitas Andalas	Distribution and molecular identification of Banana Bunchy Top Virus in Sumatra
70	Nasrul Arahman	Universitas Syiah Kuala	Development and modification of polyethersulfone hollow fiber membrane for water purification of groundwater in Tsunami affected area
71	Nur Indrawaty Lipoeto	Universitas Andalas	The Impact of Maternal Obesity on Maternal and Neonatal Health Outcomes During Antenatal, Intrapartum, and Postpartum: A Cohort Study
72	Nurfina Azman	Universitas Negeri Yogyakarta	Development of Bioactive Compounds from Some Species Indonesian Traditional Plants as Antiviral
73	Nurul Ilmi Idrus	Universitas Hasanuddin	Stigma among High Risk Group: Control and Prevention on HIV/AIDS
74	Paramasari Dirgahayu	Universitas Sebelas Maret	Molecular Epidemiology Database Of HIV, HBV, HCV, HDV, HTLV-1/2, And TTV In Central Of Java, Indonesia
75	Pramita Gayatri Dwipoerwantoro	Universitas Indonesia	Selenium and antioxidant status in children with persistent diarrhea: Its influence on gut integrity
76	PRATIWI PUDJIASTUTI	Universitas Airlangga	Exploration of alkaloid content from Erythrina spp. As inhibitor of Plasmodium Dihydrofolate Reductase (pDHFR) enzyme as antimalarial therapeutic target
77	Remy E.P. Mangindaan	Universitas Sam Ratulangi	Screening of Anticancer substances from Marine Invertebrate in North Sulawesi
78	Ria Millati	Universitas Gadjah Mada	Development of Biological Pretreatment of Oil Palm Empty Fruit Bunch using White-rot Fungi for Bioethanol Production
79	Riana Dewi Nugrahani	Universitas Hasanuddin	The Social Interaction among High Risk Groups of HIV/AIDS
80	Rina Devnita	Universitas Padjadjaran	Global Warming and its Effect to the Characrestics and Productivities of Volcanic Soils
81	Rina K. Kusumaratna	Universitas Trisakti	Comprehensive health services access model to improve elderly health
82	Risqa Rina Darwita	Universitas Indonesia	The Improvement of Indonesia's Public Health Dentistry
83	Romie Oktovianus Bura	Institut Teknologi Bandung	Development of Natural Laminar Flow Wing for Supersonic Biplane Transport Aircraft

NO	NAMA	PERGURUAN TINGGI	JUDUL
84	S. Imam Wahyudi	Universitas Islam Sultan Agung	Polder System Development Management Model for Handling of Water Level Rising Caused by Global Warming
85	Salmah	Universitas Gadjah Mada	Hybrid Modeling and Control for Intelligent Unmanned Aerial Vehicle
86	Setyo Sarwanto Moersidik	Universitas Indonesia	Combined Effect of Aircraft Noise and Pollutant Emissions in the Intermediate Atmospheric Layers
87	Sri Juari Santosa	Universitas Gadjah Mada	Fundamental Aspect and Application Study of Peat Soil Humin for the Selective Recovery of Gold as Pure Gold Metal
88	Sri Wilarso Budi R.	Institut Pertanian Bogor	Population Genetics And Ecophysiology Of Meranti Species Which Are Threatened With Extinction
89	Sugito	Universitas Negeri Yogyakarta	A Study on the Multicultural Education model for Elementary Education in Indonesia and Malaysia
90	Suherman	Universitas Diponegoro	Development of Fluidized Bed Coating and Granulation Technology for Protection of Sensitive Liquids and Particles: Urea Particle Coating for Controlled Release
91	Sukendah	Universitas Pembangunan Nasional Veteran Jatim	Development of Sustainable Agroforestry System of Sengon ( <i>Albizia Falcataria</i> ) in East Java Indonesia by Providing Selected In Vitro Seeding
92	Sulistiyani	Institut Pertanian Bogor	The Cellular Mechanisms of Jati Belanda ( <i>Guazuma umnifolia</i> ) and Salam ( <i>Syzygium polyanthum</i> ) leaves extracts in the Therapy for Cardiovascular Disease
93	Sunarso	Universitas Diponegoro	Empowering of Cattle Farmers through Integration of Complete Feed Technology and LEISA Concept
94	Suripto Dwi Yuwono	Universitas Lampung	Utilization of Cassava Bagasse as Raw Material of Bioplastic
95	Suwarno	Institut Teknologi Bandung	Partial Discharges in High Voltage Insulations and Their Applications for Diagnosis of High Voltage Equipments
96	Suyono	Universitas Negeri Jakarta	Stochastic Processes and Applications In Reliability
97	Tatat Hartati	Universitas Pendidikan Indonesia	Video Streaming for Creative Writing at International Elementary School
98	Totik Sri Mariani	Institut Teknologi Bandung	Production of Red and White Variegated Leaf of <i>Aglaonema</i> for Domestic and Export Purpose
99	Totok Prasetyo	Politeknik Negeri Semarang	A Novel Modification of Cassava Starch by Combining UV Reactor and Solar Drying to Increase Baking Expansion
100	Tri Desmana Rachmildha	Institut Teknologi Bandung	Development of active power filters and boost inverters by using the predictive control to achieve good dynamic response.
101	Tutuk Djoko Kusworo	Universitas Diponegoro	Production of High Grade Carbon Nanotubes using Modified of Catalytic Chemical Vapor Deposition for Hydrogen Storage
102	Vanessa Gaffar	Universitas Pendidikan Indonesia	Comparative Study of Tourist's Profile and Behaviour on Heritage Tourism Sites in The South of East Asia Region - Case Study on Indonesia and Thailand Heritage Tourism
103	Wahyu Wilopo	Universitas Gadjah Mada	Immobilization of Heavy Metals in Water by Using Natural Geologic Materials
104	Wilson Lodewyk Tisera	Universitas Kristen Artha Wacana	Ecology, Genetic and Restocking of Giant Clams : A Strategy of Strengthening Marine Conservation and Management of Marine Protected Areas Around East Nusa Tenggara Province

NO	NAMA	PERGURUAN TINGGI	JUDUL
105	Wisnu Jatmiko	Universitas Indonesia	Development of Smart Cardio Device for Early Detection of Heart Disease Based-On Electrocardiogram Signal
106	Yessi Permana	Institut Teknologi Bandung	Polymerizations of Pine Trees Derived $\beta$ -Pinene using Zr-Supported Clays: Heat Resistant Polymers from Biomass
107	Yoga Dharma Setiawan	Universitas Diponegoro	Control System Development for Smart Flying Robots
108	Yohanes Aris Purwanto	Institut Pertanian Bogor	Studies on long-term storage of tropical fruits by cold method combined with Near-Infrared spectroscopy
109	Yohanes Merryanto	Universitas Kristen Artha Wacana	Genetic Variation and Gene Flow of Hard Coral Population in Sawu Sea Marine National Park Indonesia
110	Yose Rizal	Universitas Andalas	Improving the Nutrient Quality of Carrot and Fruit Juice Wastes Mixture for Poultry Diet
111	Yunardi	Universitas Syiah Kuala	Modelling Soot Formation and Oxidation in Turbulent Non-Premixed Flames
112	Zullies Ikawati	Universitas Gadjah Mada	Genetic Polymorphism Mapping of CYP2D6, 2C9, and 2 C19 on Makassar Population in Indonesia

Jakarta, 4 Juni 2010  
Kasubdit Penelitian

ttd

H. Ridwan Roy T.  
NIP. 1962 01 26 198403 1 001

## STATEMENT LETTERS

### Surat Pernyataan

Yang bertanda tangan di bawah ini:

Nama : Dr. Ir. Setyo Sarwanto Moersidik, DEA  
N I P :  
Pangkat/Golongan :  
Alamat :

Dengan ini menyatakan bahwa proposal research saya yang berjudul:

***Combined effect of Aircraft Noise and Pollutant Emissions in the Intermediate Atmospheric Layers.***

Yang diusulkan dalam skim International Joint Research and International Publication T.A. 2010-2012 **bersifat original and belum pernah dibiayai oleh lembaga/sumber dana lain.**

Bilamana di kemudian hari ditemukan ketidak sesuaian dengan pernyataan ini, maka saya bersedia dituntut and diproses sesuai dengan ketentuan yang berlaku dan mengembalikan seluruh biaya penelitian yang sudah diterima ke kas negara.

Demikian pernyataan ini dibuat dengan sesungguhnya dan dengan sebenar-benarnya.

Depok, 15 Mei 2010

Mengetahui,  
Ketua DRPM-UI

Yang menyatakan,  
Peneliti Utama

Materai 6000

**Bachtiar Alam, Ph.D**  
NIP 195803061986031001

**Dr. Ir. Setyo Sarwanto Moersidik, DEA**  
NIP

## **Statement letter from French Embassy**



As an Attachee of Scientific Cooperation of French Embassy in Indonesia, by this Letter of Statement, I agree to assure a co-financing support with DIKTI for research team to be lead by **Dr. Ir. Setyo Sarwanto Moersidik** at Civil Engineering Department of the Universitas Indonesia (UI) in Indonesia and by **Dr. Salah Khardi** at INRETS, Bron Cedex, Lyon in France. Both parties agree to conduct a Joint Research in Title:

### ***Combined effect of Aircraft Noise and Pollutant Emissions in the Intermediate Atmospheric Layers.***

The financing support will be given in total of 5000 Euro each year, which is allocated for:

1. Flight ticket and train ticket for two INRETS researchers from Bron Cedex France to Jakarta (two ways).
2. Accommodation (hotel, local transport, lunch) for two UI researchers during 10 days in Lyon, France.

This Letter of Statement is effective within the three year period of 2010-2012.

Jakarta, May 15<sup>th</sup>, 2010.

### **Dominique Dubois**

Attaché de Coopération Scientifique et Technique  
SCAC - Ambassade de France  
Jl. Panarukan no.35, Jakarta- Indonesia.