# 1. BACKGROUND

This report describes a framework for a high level assessment of the environmental impact of changes in air traffic management or other aspects of aviation.

# 2. EMISSIONS FROM AIRCRAFT

Figure 1, below, summarises the overall environmental effect due to air transport. It shows the effects of both gaseous and noise pollutants from ground to cruise levels in access of 30,000ft., related to the standard phases of flight. The column shading indicates the relative concentration of effects.

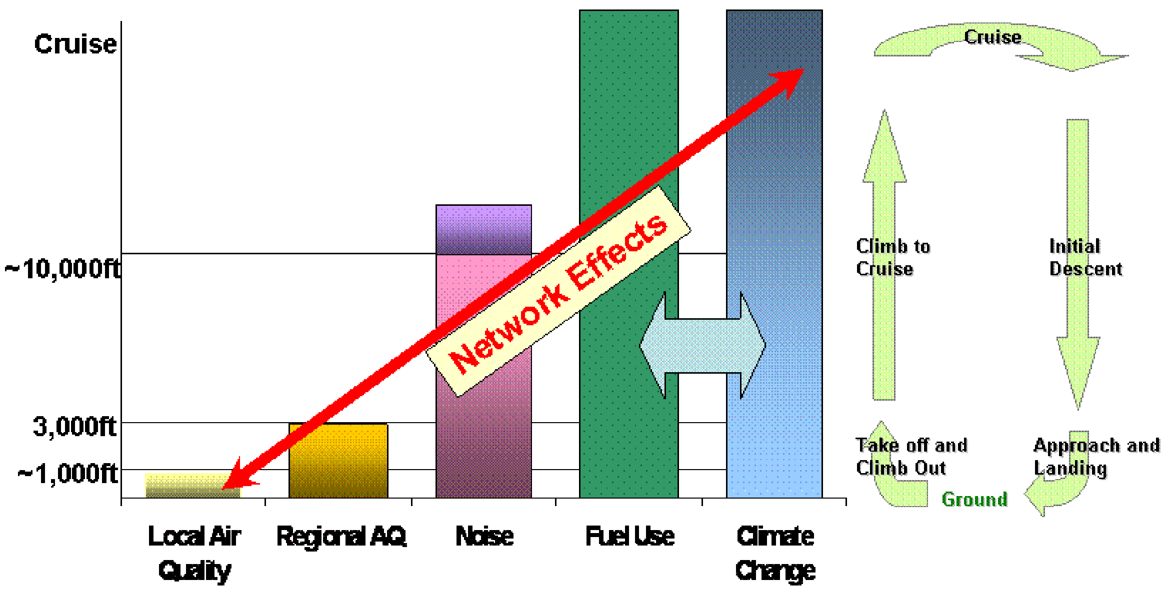


**Figure 1: Effect of Air Transportation on the Environment**

Locally, excessive noise affects people's health and quality of life through stress and disturbance and can also affect education in schools close to airports. Annoyance caused by noise is also the key driver for local constraints and non-optimal operations on airports and hence the ATM system. Air pollutants (including secondary products) from aircraft can also directly affect people's health in the short and long term. Many of these effects are also applicable regionally.

Globally, it is generally recognised that climate change may cause a significant economic burden on mankind, affecting people's quality of life and may be contributing to disastrous weather events. Climate change may also present direct problems for aviation in terms of safety, efficiency and capacity. The general policy trend is towards the internalising of external costs, i.e. the air transport polluter pays for the climate change effects, and this may provide a growing constraint on aviation. Any measure to reduce these impacts, therefore, will improve people's quality of life, health and education, and further, it will reduce the external costs borne by aviation and passed through to passengers.

## 2.1 Components of Atmospheric Pollution

Atmospheric pollutants fall broadly into two categories; those species that vary simply according to the amount and composition of the fuel consumed, and those for which quantities are also influenced by other factors such as engine power settings and the type of combustor.

The products of complete combustion are carbon dioxide ($CO_2$) and water vapour ($H_2O$), together with small amounts of sulphur oxides (SOx)[1]. Their quantity is directly related to fuel-burn across all phases of flight.

Incomplete combustion results in unburnt or partially burnt hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen ($NO_x$) and microscopic particulate material including carbon compounds (as soot and smoke), which vary according to engine power settings and combustor type. This group of pollutants are regulated by the ICAO engine emissions certification regime; however this currently applies only to operations in the landing and take-off cycle of subsonic jets.

The main emission species have the following impacts:

**$CO_2$** is a greenhouse gas; Because it stays in the atmosphere for a long time and becomes well mixed, it is the quantity emitted rather than where it is injected that matters;

**$H_2O$** also is a greenhouse gas; along with the small concentrations of **$SO_x$ and particulates**, it is also of global concern because, at altitude, these emissions contribute to the formation of contrails and cirrus cloudiness;

**$NO_x$** is of concern throughout all phases of flight but in particular contributes:

- to local air quality below 1000 feet by increasing the formation of ground level ozone ($O_3$)
- to regional air quality through dispersion of emissions at up to 3000 feet which may also promote $O_3$ formation at ground level
- at altitude where it is relatively long-lived and has complex effects for global climate on both $O_3$ and methane ($CH_4$) concentrations.

**HC particulate and CO gas** products of incomplete combustion are principally produced at idle and low power settings with a primary impact on local air quality in the vicinity of airports.

There are, therefore, three main areas of concern with atmospheric pollution. It contributes to:

*global climate change* through direct production of greenhouse gases and from particular effects at cruise altitude around the tropopause (in the upper troposphere and lower stratosphere - about 9 to 13kms), where emissions alter greenhouse gas concentrations and also form contrails and encourage cirrus cloud formation;

*local air quality* around airports where aircraft emissions from ground level to 1000 feet contribute to pollution, including $O_3$ formation; and

*regional air quality* where pollutants emitted up to 3000 feet may be dispersed and *impact* ground level concentrations of pollutants over a wider area *than the vicinity of the airport itself.*

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[1] SOx is derived from the small sulphur content of fuel that is provided for lubricity

Emissions indices vary with a number of conditions, including engine operating regime (idle, take-off, cruise). The emission index chosen must be appropriate for the conditions under consideration.

## 2.2 Noise

The main impact from aircraft noise occurs *in the vicinity of airports* when *aircraft take-off and land*. This is sometimes referred to as air noise and aircraft noise models are used to map different levels of the resulting noise exposure around airports. Noise modelling (unlike emissions) has long established international guidance, most recently ECAC Doc 29 (3$^{rd}$ Edition); these approaches are also being incorporated in revision ICAO Circular 205. Essentially it combines the noise footprints of all aircraft operations over a given period of time.

Major reductions in noise exposure were observed from the phase-out of older, noisier aircraft types during the 80's and 90's. Further improvements in aircraft design and increased engine power, coupled with noise abatement operating procedures (NAOPs) mean that, for example, modern aircraft climb relatively quickly so that the latest types have smaller noise footprints, weight for weight, compared with airframes certificated 10 years ago. Therefore, as fleets evolve, there is a trend towards a reduction in noise per flight, although overall exposure may increase as traffic grows.

Current practice for airport noise management focuses on the ICAO balanced approach - technological improvements which subsequently maybe reflected in tougher noise certification standards for aircraft coupled with NAOPs, and better management of land-use around airports. Where it can be demonstrated that these measures are insufficient, administrations or airports may impose operating restrictions on noisier aircraft.

*Ground noise* arising from taxiing and other operations at airports also has to be considered. There are no internationally agreed methods for assessing ground noise, and in general ground noise levels are lower than those resulting from take-offs and landings. However impact may be significant in particular local circumstances, or for example at night when ambient noise levels are lower.

*Disturbance* has also been noted at greater distances from airports where aircraft may be flying at up to 10,000 feet. There have been cases where new flight paths or increases in aircraft traffic have given rise to complaint. This seems to reflect perceived disturbance from the presence or intensification of air traffic, rather than absolute noise exposure. But in extreme cases action to modify airspace usage may result (as when the FAA introduced new high level East Coast routes in the early 1990s).

## 2.3 Relationship Between Environmental Effects and Phase of Flight

In this section we consider the environmental effects in each phase of flight in order to establish a framework against which we can compare the CONOPS for the OI under consideration. Reference is made to current ICAO guidance (*Circular 303/AN/176 Operational Opportunities to Minimize Fuel Use and Reduce Emissions- ICAO February 2004*) because this provides some indications of what (fuel and) emissions savings might technically be possible.

### 2.3.1 Ground Operations

Any reduction in ground running time of individual operations would

improve *local air quality*, by reducing emissions below 1000 feet of $NO_x$ CO and HC, and visible smoke emissions at the low power settings (taxi and ground idle condition reported as part of the ICAO engine exhaust emissions database from engine certification data)

reduce *ground noise*.

Most of the opportunities for fuel savings from ground operations noted in ICAO Circular 303 do not arise from aircraft operations, but from other activities such as towing, additional concrete, other vehicular traffic etc. Cutting running time to address fuel burn and engine emissions is noted but not quantified.

### 2.3.2 Take-Off and Climb

In fuel usage terms, these phases are relatively important particularly for shorter flights. However, opportunities to modify take-off and climb may be limited. These are safety-critical stages of flight, governed by aircraft design and performance. Additionally, operating procedures designed to reduce noise impact in the vicinity of airports, (Noise Abatement Departure Procedures - NADPs) may limit opportunities to save fuel and optimise climb performance.

Normal practice for take-off often employs reduced thrust. Thrust reductions are determined by factors including take-off weight, ambient temperature and runway altitude. Reduced thrust is a trade-off between using slightly more fuel because of the slower climb rate and prolonging optimum engine performance that otherwise deteriorates with usage at higher power. Then NADPs, used in accordance with ICAO PANSOPS, or other operating requirements, will determine at what altitude further cut back may be applied. With NADPs these modify the noise footprint and benefit the noise climate by redistributing noise away from people living under the flightpath. Reduced thrust and cutback also reduces $NO_x$ which may benefit *local and regional air quality.*

Performance in climb is already determined by airlines applying fuel saving practices in conjunction with ATC rules. There may be some trade-off between the fuel expended on climb and achieving a better cruise level. Overall, ICAO (Circular 303) concluded that the potential for fuel saving (and consequent emission reductions) in take-off and climb were small with negative effects from noise constraints.

Opportunities to reduce noise exposure may depend on either permitting more use of NADPs, or achieving greater adherence to them.

## 2.4 CRUISE

Operators want cruise speeds and altitudes that will deliver economic performance, including saving fuel, which will also reduce emissions. Optimum operating conditions depend on many factors relating to the aircraft, its operating weight, operational requirements of the operator etc. The length of time aircraft operate at cruise, and the efficiency of those operations, are particularly important for climate change because of the sensitivity of the atmosphere to injections of $NO_x$, $H_2O$ $SO_x$ and soot around the tropopause, which lead to changes in greenhouse gas concentrations, contrail production and cirrus cloudiness.

Efficient operation at cruise is very important because if an aircraft cannot fly at its design speed and altitude it will burn more fuel. Achieving optimum cruise conditions is a challenge for aircraft flying some shorter routes within European airspace.

The adoption of RVSM was an important step in counteracting this problem and ICAO estimated that without RVSM there might be penalties in terms of fuel burn at cruise of the order of 2.5% to 3.5% while with RVSM it should be possible to operate within 1% of optimum.

These benefits were confirmed by the Eurocontrol Experimental Centre report ' The EUR RVSM project Environmental Analysis', EEC/ENV/2002/008, based on pre- and post-RSVM radar recordings, which showed that, "…*for the high altitude band along and above tropopause,* $NO_x$ *emissions are reduced by even 2.3 - 4.4%, fuel burn and directly proportional emissions like* $CO_2$, $SO_x$ *and especially of interest* $H_2O$ *are reduced by 3.5 – 5.0%.*"

In addition to optimum vertical profiles in cruise, airline operators seek, in principle, to fly the shortest route to their destination in order to reduce fuel burn and aircraft operating time. However, operators make trade-offs between potential delays and the cost of en-route charges so that their preferred route may not always be the most fuel efficient.

## 2.5 Descent, Approach and Landing

The goal in descent is to apply low-power low-drag configurations for as long as possible, consistent with safety and ATC requirements, to minimise fuel burn. Avoiding or reducing the need for changes in configuration and keeping a clean profile reduces fuel burn. In addition, route mileage and fuel burn are reduced by avoiding the need to enter holding patterns, indeed airline operators may also reduce speed, thereby reducing fuel burn, in order to arrive at known congestion point ahead later, for example, entry into a holding stack.

ICAO noted there were opportunities to reduce the impact of delays and avoid holding if delays could be identified sufficiently early to allow adjustments of speed at cruise. Aside from this ICAO estimated that opportunities to save fuel by optimisation of descent profiles were small (less than 1% fuel saving overall).

Applying Continuous Descent Approach (CDA), that incorporates low-power low-drag techniques to the extent possible, offers further benefits. Minimising drag during approach, is an important measure for fuel saving and a Noise Abatement Operating Procedure (NAOP). ICAO suggested there was scope for further fuel savings of up to 1% of overall block fuel usage, dependent on the nature of the approach profile.

# 3. PROCESS FOR MAKING ENVIRONMENTAL IMPACT ASSESSMENT

## 3.1 Mapping Environmental Impact To Elements Of An Operational Improvement

In considering the environmental impact of an operational improvement, it is necessary to consider each element of the improvement, its key features and its main impacts in each relevant phase of flight.

For example, one of the element of considered in the initial environmental impact assessment for DMEAN was the Consolidated Capacity Planning Process. This is a rolling programme designed to match delivery of capacity to demand, for time horizons ranging from initial long-term service planning to short-term tactical planning on the day of operations. The process includes identifying and addressing bottlenecks and co-ordinating the enhancements being made by ANSPs with route enhancements and network efficiency improvements being initiated by EUROCONTROL programmes.

By achieving a better match between demand and capacity it is anticipated that main impacts of this process will include:

The overall predictability and efficiency of aircraft operations will be improved so that fewer aircraft are required to deliver the same level of services and there is a saving in resources and energy in the manufacturing process

Ground movements become more predictable and shorter and aircraft are more able to take off at their predicted times. Consequently, there will be less fuel burnt in ground movement and a commensurate improvement to local air quality and to a minor extent ground noise

Improved en-route capacity will allow better horizontal and vertical profiles and therefore reduced fuel burn

Better co-ordination between en-route and airport capacity will reduce holding and therefore fuel burn

## 3.2 Identifying SMART Environmental Targets

In order to present a good environment case for an operational improvement, it is necessary to demonstrate the contribution the OI will make in meeting European-wide aviation environmental targets. Three key sources of relevant environmental targets are Eurocontrol's Strategic Environmental Objectives, ACARE "Challenge for the Environment", and the EATM business plan objectives. Three related ECIP objectives are also noted. Performance targets are also being developed as part of SESAR Work Package 2.1.

### Eurocontrol Environmental Strategy:

Eurocontrol has the following General Strategic Objective with regard to environmental issues:

> *"to work with ICAO and its Member States to obtain improvements in ATM, in particular the accelerated implementation of CNS/ATM concepts, procedures and systems which help to mitigate the impact of aviation on the environment."*

Within this context, the following specific environmental targets for ATM have been set for the EUROCONTROL Organisation:

- to permit daily aircraft operations in such a way that all ATM-related environmental impact is minimised;
- to be compliant with the appropriate international standards, statutory and regulatory requirements in respect of environmental demands;
- to support actions which will contribute to reduce or limit noise and aircraft emissions.

The EUROCONTROL Organisation has also set itself the general medium-term objective to reduce aircraft noise and emissions levels by 2008.

### ACARE targets

ACARE (the Advisory Council for Aeronautics Research in Europe) [REF: ACARE: Challenge for the Environment] has identified four specific goals for a more environmentally sustainable air transport system by 2020:

- To reduce fuel consumption and $CO_2$ emissions by 50%;
- To reduce perceived external noise by 50%;
- To reduce NOx by 80%;
- To make substantial progress in reducing the environmental impact of the manufacture, maintenance and disposal of aircraft and related products.

These goals apply to the aviation industry as a whole and cover airframe design, engine/combustor design and choice of fuels as well as Air Traffic Management. ACARE anticipates that the specific contribution of ATM to these targets will be:

- 5–10% lower fuel consumption through reducing in-flight delays, route inefficiencies and taxiing times.
- new ATM approaches that will enable low noise flight profiles to be developed to minimise noise pollution
- taxi-time reduction to reduce NOx emissions at ground level.

Only the ATM contribution to fuel consumption and $CO_2$ emissions is quantified by ACARE.

To meet to the higher ACARE target of a 10% reduction in fuel burn and $CO_2$ emissions by 2020 through ATM efficiencies, an annual reduction of approximately 0.75% would be required, or a reduction of around 3% by 2010 and 6.5% by 2015.

To meet the lower ACARE target of a 5% reduction in fuel burn and $CO_2$ emissions by 2020 through ATM efficiencies, an annual reduction of just under 0.4% would be required, or a reduction of 1.5% by 2010 and 3.25% by 2015.

The extent to which the relevant OI contributes the ACARE targets should be seen in the context of other development activities in the same timeframe.

### EATM Business Plan targets

There are a number of tentative environmental and procedural targets for improving the environment in the EATM Business plan [REF: EATM Service Business Unit, Business Plan 2006-2010, Edition 2.0, dated 20-12-2005]:

- Annual average CO2 kg per distance / productivity unit reduced by [to be defined in REF: EATM Service Business Unit, Business Plan 2006-2010, Edition 2.0, dated 20-12-2005]
- 20 airports adopting ECTL harmonised guidelines for Continuous Descent Approaches (as per ECIP OI ENV01) by 2010
- 25 airports formally reporting using Collaborative Environmental Management (CEM) as per ECIP OI ENV02 by 2010
- All Agency Business Units using Environmental Management System by 2010
- 70% of agency staff and 80% of ANSPs receive environmental training by 2008
- ICAO-CAEP and ECAC endorsement of ECTL through environmental assessment by [to be defined in REF: EATM Service Business Unit, Business Plan 2006-2010, Edition 2.0, dated 20-12-2005]

### ECIP objectives:

Finally there are currently two ECIP objectives related to the environment, and a third, proposed, objective:

- ECIP OI ENV01: Implement Basic Continuous Descent Approach (BCDA) procedures
- ECIP OI ENV02: Implement Collaborative Environmental Management (CEM) at Airports
- ECIP OI ENV03 : foster better understanding and information exchanges with stakeholders (*proposed*)

## 3.3 Determining Appropriate Key Performance Indicators (KPIs)

We recognise that work is still continuing on developing environmental indicators, in particular:

- The work being performed under the Agency's Environmentally Sustainable Airspace Network (ESAN) initiative and the associated PAGODA project [source: ESAN Eurocontrol web site] which provides environmental performance indicators through monitoring and assessing the design and operation of the ATM network. These provide an important link to the Performance Review Reports and the objectives of the PRC to incorporate environmental measures,

  As well incorporating the ANCAT 3 based calculation of aviation emissions (as recommended by the ECAC Directors General) and the AEM3 based fuel burn and greenhouse gas emission estimates, a particularly relevant aspect to PAGODA will be the systematic assessment of en-route horizontal flight efficiency;

Note that ANCAT3 is based on an inventory approach with generalised city pairs and is estimated to have around a 12-15% accuracy, whilst AEM3, which can handle individual profiles, has an accuracy of around a 3-5%.

- ALAQS: Local Air Quality (LAQ) is an increasingly important issue for airports. Faced with demands on capacity and pressure from local communities, airport operators need to understand and plan their environmental impact to help mitigate the impact of noise and pollution whilst improving safety and airport capacity. The EUROCONTROL Airport Local Air Quality (ALAQS) project was started in 2002 to address these issues.

- The stakeholder focused analysis carried out by the EEC in support of management of sustainable growth, which identified environmental impact indicators of particular interest for each stakeholder group, for example CO2 per passenger kilometre (passengers), flight efficiency (ANSPs) etc.[source: Indicators for the Management of Sustainable Growth in the Air Transport System, EEC/SEE/2004/013.

- The EEC study into Enhanced Flight Efficiency Indicators that investigated the feasibility of assessing horizontal flight efficiency from a environmental viewpoint across the whole of the ECAC airspace [source: Enhanced Flight Efficiency Indicators, EEC/SEE/2004/011]

- [REF: "Indicators for the Management of Sustainable Growth in the Air Transport System EEC/SEE/2004/013"] has proposed a number of social, environmental and economic indicators for each stakeholder group within the air transport network. The environmental indicators proposed include:

  **ANSPs:** (horizontal) flight efficiency

  **Airports:** local air quality (as measured by NOx)

  **Civil Airspace Users:** total fuel burn

  **Military Airspace Users:** total fuel sold to military sector

  **Passengers:** $CO_2$ emitted per passenger kilometre

  **Manufacturers:** average fuel flow for class of aircraft

  **Society:** share of aviation in total $CO_2$ emissions

  The proposed indicators should, where appropriate, reflect these recommendations.

### 3.3.1 Units of Measurement

This framework is focussed on assessing the impact of an OI on noise and emissions per 'unit', i.e. it assumes that the growth in traffic predicted in STATFOR's Medium Term Forecast will take place with or without the OI and looks at the proportionate impact of the OI on noise and emissions. The appropriate measures for emissions reductions may therefore be couched as:

- Kg reductions per 'unit'

- MKg reductions per annum for a given growth in flights

- % reduction per 'unit' or per annum

The choice of 'unit' needs to be carefully considered, in that:

Horizontal efficiencies are achieved by reducing the distance flown (and hence the duration of each portion of flight) and therefore do not affect the fuel burn or emissions per kilometre or per minute. In this case, fuel burn / emissions per flight would seem to be the appropriate indicator;

Vertical efficiencies to affect the rate of fuel burn. It is therefore possible to consider computing changes in fuel burn per kilometre (or per passenger kilometre);

However, if an overall figure for the impact of the OI is required, then the appropriate 'unit' will probably be per flight;

In this case assumptions will have to be made about the average length / duration of a flight. The granularity of these assumptions will depend on the detail being considered (e.g. estimate for the whole region vs. case study of a single city pair or airport operation).

In practice, a mixture of measurement units will be required in order to present the effect of the OI on the environment, specifically both per flight measures and annual reductions; although in the latter case it will be important to "decouple" the gross annual figure from the projected increase in air traffic, i.e. present it, for example, as the amount of contribution to overall emission reduction targets.

## 3.4 Proposed KPIs

The following sections provide an initial list of potential KPIs for environmental impacts potentially relevant to a given OI. The list includes measures that may be desirable, but not necessarily practical to achieve.

### 3.4.1 En Route Emissions: contribution to climate change

#### Impact of Horizontal Efficiency:

The efficiency of the horizontal route network and the extent to which actual flight profiles use the current route network efficiently is already being considered annually by PRR. The impact of of an OI on horizontal efficiency can be estimated using, for example, modelling carried out in FAP.

However, the environmental impact of horizontal inefficiency is to some extent influenced by where, in the vertical plane, efficiencies are achieved. Changes in the horizontal profile will, for example, have the greatest impact on climate change emissions if they occur around and above the level of the tropopause, in the upper troposphere and lower stratosphere. Changes below 3000 feet, on the other hand will affect noise footprints and, to some extent, local air quality.

| KPI | Notes | Means of measuring /modelling |
| --- | --- | --- |

| | | |
|---|---|---|
| Reduction in $CO_2$ emissions in cruise as a result of horizontal efficiencies | - proportional to fuel burn;<br><br>- based reduction in route length<br><br>- above 3000' | |
| Reduction in $H_2O$ and $SO_x$ emissions around and above tropopause (taken as above FL260) as a result of horizontal efficiencies | - proportional to fuel burn;<br><br>- based reduction in route length[2]<br><br>- limited to FL270 and above | **Measure:** reduction in route length between TMA exit and TMA entry |
| Reduction in emissions of NOx around and above tropopause as a result of horizontal efficiencies | - non linear (depends on height, thrust setting etc);<br><br>- based on route length reduction<br><br>- limited to FL270 and above | |

***NOTE:*** These indicators are used in the high level assessments of horizontal efficiencies (see Section 4), where the effects at tropopause and at Top of Cruise on $CO_2$, $H_2O$, $NO_x$ and $SO_X$ for horizontal route efficiency gains are calculated.

### Impact of Vertical Efficiency:

The impact of improved vertical profiles on fuel efficiency, and hence on emissions, may be significant. However, as noted above, measuring the improvement in vertical efficiency is limited by the extent to which we understand the degree of inefficiency in the present system. Furthermore, it is considerably more difficult to measure the impact of vertical efficiency (as compared with horizontal), as the definition of an 'optimum' profile varies with aircraft type, distance to be flown, and other factors.

The EEC are developing a set of indicators for vertical efficiency, based on time spent at optimum cruise level [REF: Enhanced Flight Efficiency Indicators EEC/SEE/2004/011]. These indicators are still under development, and two options are considered:

- First, using a tool such as AEM (relying on BADA fuel flows figures), vertical profiles that would respect both the real horizontal flight path, and the aircraft arrival time can be generated. Computing such an indicator for all flights would allow the impact of the vertical profile on fuel consumption (both horizontal route and arrival time remaining constant) to be calculated. The indicator would allow both the benchmarking of airport pairs against each other, and the study of the variability of vertical flight efficiency within an airport pair.

- Secondly simpler indicators can be obtained by comparing the range of cruise FL occupancy, and the time spend in cruise, or the % time spent in cruise. These indicators are directly computable from CPR data, or could even be assessed from CFMU Model 3 flight plans.

[2] Route length reduction in network compared to current (route optimisation) plus route length reduction from more efficient use of network (take-up of CDRs use of NOP etc)

A means is required to model the impact of the OI on vertical profiles flown, the output of which could then be input to AEM3 for an accurate assessment of changes in emissions.

A comparison of the distribution of actual flight levels flown around operator requested flight levels, with and without the OI would given an indication of environmental impact. However, it needs to be remembered that operators trade-off fuel consumption against other considerations such as delays and route charges when selecting their flight profile. The operator preferred profile is not, therefore, necessarily environmentally optimal.

The environmentally optimum flight profile itself depends on a number of factors, including length of flight (city pair); aircraft type (fuel performance of different a/c engine combinations, different optimal cruise etc); load factors and even company policy.

| KPI | Description | Means of measuring /modelling |
|---|---|---|
| Reduction in $CO_2$ emissions in cruise as a result of vertical efficiencies | - proportional to fuel burn;<br>- based on improvements in vertical profile<br>- limited to 3000’ and above | |
| Reduction $H_2O$ and $SO_x$ emissions around and above tropopause (taken as above FL260) as a result of vertical efficiencies | - proportional to fuel burn;<br>- based on improvements in vertical profile<br>- limited to FL270 and above | **Measure:** actual profile flown vs. requested |
| Reduction in emissions of NOx, above tropopause as a result of vertical efficiencies | - non linear (depends on height, thrust setting etc);<br>- based on improvements in vertical profile<br>- limited to FL270 and above | |

***NOTE:*** A variation of these indicators is used in the high level assessment of the impact of vertical efficiencies (see section 4), where the effects on $CO_2$, $H_2O$, $NO_x$ and $SO_X$ for potential vertical efficiency gains in terms of optimal flight levels are calculated for city pair case studies.

### 3.4.2 Local and Regional Air Quality

#### Climb and Approach

Fuel burn is minimised by maintaining low power low drag for as long as possible from descent through approach.

Such approaches could be modelled compared with current approaches (RAMS Plus has been used in similar projects to model different approach concepts, with the results fed into AEM3 to determine emissions impact)

Assumptions would have to be made about the extent to which such approaches are used as a result of the OI.

Local air quality (chiefly $NO_x$, CO and HC) is also affected by the time aircraft spend in the hold over airports.

[REF 'Environmental Impact of Delay, EEC/SEE 2006/06] has looked at ways of modelling the environmental impact of airborne holding, based on the average consumption of fuel in cruise at FL80 (75% of time in hold) and the average fuel consumption in descent at TAS (True Air Speed) 230kt (25% of time in hold).

Baseline data would be required on airborne holding in the current system. PRR8 notes the lack of data on airborne holding times (the requisite data are only published for London airports) and emphasises the need for this data to be collected from other major airports.

Modelling would be required to determine the impact of the OI on airborne holding as a result of the use of the Network Operations Plan and the incorporation of the airport into the network.

| KPI | Description | Means of measuring /modelling |
|---|---|---|
| Reduction in $CO_2$ (and $NO_x$, HC and CO below 3000') emissions as a result of (e.g.) Continuous Descent Approaches incorporating low power low drag techniques. | - requires comparison with current procedures<br><br>- Impact of CDAs?<br><br>- impact of OI on use of CDAs? | **Measure**: Time spent in modified approaches (i.e. smoothed) compared with current approaches.<br><br>LCIP reports against objectives |
| Reduction in $CO_2$ (and $NO_x$, HC and CO below 3000') as a result of reduced time in hold | - requires baseline data to be obtained<br><br>- use existing model of fuel burn / emissions in hold<br><br>- need to model impact of OI on time spent in hold | **Measure:** reduced holding time compared with current baseline<br><br>LCIP reports against objectives |

## Ground Operations

Environmental benefits are typically as a result of reduced ground running. An estimate is required of the impact of the OI, and of modelling the resulting effect on emissions.

[REF: The Environmental Impact of Delay EEC/SEE 2006/06] calculated the environmental cost per "standard" minute of ground delay, using the ALAQS model to compute the fuel and emission rates for each type of power setting (taxi, idle etc), for categories of aircraft.

| KPI | Description | Means of measuring /modelling |
|---|---|---|

| | | |
|---|---|---|
| Reduction in $CO_2$, as a result of reduced ground running | - proportional to fuel burn<br><br>- based on reduced taxi time etc on ground | **Measure:** time spent in taxi / idle compared with current.<br><br>LCIP reports against objectives |
| Reduction in CO, HC and $NO_x$ and particulates as a result of reduced ground running | - dependent on aircraft thrust ratings<br><br>- requires some modelling of aircraft types<br><br>- based on reduced taxi time etc on ground | |
| Reduction in particulates as a result of reduced ground running | - based on engine Smoke Number<br><br>- requires some modelling of aircraft types<br><br>- based on reduced taxi time etc on ground | |

### 3.4.3 Noise Impact around airports

Noise impact is highly airport specific.

The OPTIMAL project is developing optimised procedures for aircraft - both fixed-wing and rotorcraft - during approach and landing. Work under the MONICA umbrella on OPTIMAL will involve performing noise and emission modelling studies on aircraft trajectories flown using the proposed procedures. This type of modelling would be required to assess impact.

It would also be necessary to determine the extent to which these approach procedures (CDAs etc) were being used as a result of this OI.

| **KPI** | **Description** | **Means of measuring /modelling** |
|---|---|---|
| Reduction in noise as a result of CDAs | | LCIP reports against objectives |
| Reduction in noise as a result of reduced ground running | - minimal impact | LCIP reports against objectives |

# 4. ASSESSMENT METHOD FOR INITIAL IMPACT ASSESSMENT

Many of the KPIs listed above require the use of sophisticated tools such a AEM3 or ALAQS to obtain results. However, Icon has developed a method for assessing the environmental impact of horizontal and vertical flight efficiencies on the basis of data that is typically generated in the course of the validation process for an operational concept.

## 4.1 Horizontal Route Shortening

An initial quantification of the environmental impact of the horizontal route savings carried out based on a simplified AEM3 approach using the horizontal efficiency indicators discussed in Section 3.3.1 above, with the following assumptions:

- Route length reductions have been estimated for the operational concept based on FAP modelling or equivalent..
- In an approach consistent with the [REF: Performance Review Report 2005, Chapter 6 Flight Efficiency] it is assumed that these route length reductions all take place outside the 30nm radius around arrival and departure airports, which represents the Terminal Manoeuvre Areas.
- A single global average speed is used
- A typical fleet mix is assumed .
- Standard emissions indices are used.

Two scenarios are then considered.

In **Scenario One**, conservative assumption is made that all reductions on route length occur at the top of cruise for a given aircraft type, where the rate of fuel burn is in any case lowest.

In **Scenario Two**, it is assumed that all reductions on route length occur at FL260, around the area of the tropopause, where emissions may have the greatest impact on climate change.

The appropriate emissions indices are used in each case to calculated the saving in emissions per annum and the savings in emissions per flight.

These are then compared with the appropriate targets to show the contribution of the OI in question to the meeting the targets.

## 4.2 Vertical Flight Efficiency

The method for assessing the impacts of vertical flight efficiency is much less well developed than that for assessing horizontal efficiencies. This is because, whilst the concept of the ‘ideal’ or shortest route between two airports is quite easy to define, then ideal vertical profile in contrast depends on many factors and can be individual to an airline and / or to an aircraft type.

The approach used is use representative case studies to examine potential measures of *vertical* flight efficiency.

- CASE 1: a city pair with a good horizontal efficiency[3], high direct distance and a large number of flights

- CASE 2: a city pair, also with good horizontal efficiency, high direct distance, and a low number of flights

- CASE 3: a city pair with a low horizontal efficiency[4] high direct distance and a low number of flights.

As has already been discussed, an objective of delivering flight profiles that better meet operators' needs does not directly equate to delivering environmental benefit. Logically, operators will want profiles that are more economically efficient. In turn, that may be determined by a number of criteria which may be individual to the operator and to the city pair, of which fuel efficiency is only one, albeit important, factor.

Improved environmental efficiency will, therefore, be an indirect, rather than direct, consequence of the changes in vertical profiles brought about by an OI and – although likely – is not automatically guaranteed.

Icon has used the case studies, as the basis for a preliminary assessment of what environmental benefit *could* be achieved for a range of possible changes to the pattern of observed flight levels in cruise; i.e. that because of an OI more aircraft will be able to fly at their **maximum observed** cruise flight level.

~From the case studies data, we extract:

- The fleet mix observed for each city pair

- The fuel burn for different aircraft types for the median and maximum observed flight levels

- The average time spent in cruise.

From this we have calculated the **weighted average difference in fuel burn per minute** and the **weighted average difference in fuel burn per flight** [5] that would result if all observed aircraft types were to achieve their maximum observed flight level as opposed to their median observed flight level..

For each case study we can make an assessment of the reduction in fuel burn in terms of the difference between fuel burnt at the median observed flight level compared with that at the maximum flight level.

As expected, the theoretical savings per flight vary significantly between the cases. This depends in part on the fleet mix on the route, the observed differences between median and maximum flight level, and the duration of the flight.

So far we have made no assumptions about whether such changes are feasible in practice. An ideal profile for fuel efficiency would see the aircraft climb to an initial cruise altitude and

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[3] "Good horizontal efficiency" means, in terms of route distance, most flights on this route have an inefficiency of between 0 and 5%

[4] "Low horizontal efficiency" means, in terms of route distance, most flights on this route have an inefficiency of between 5 and 15%

[5] Note that these preliminary calculations do not take into account the additional fuel that would be required for aircraft to climb to their maximum flight level, nor the potentially reduced time spent in cruise.

then continue to rise as fuel is consumed, with effects depending on the duration of cruise, other factors such as operating mass, including level of fuel tankering.

Furthermore it is clearly not reasonable to expect that any operational concept would allow all aircraft to fly at the maximum observed cruise level at all times. Thus the next stage in the process is to make an assumption regarding the additional proportion of flights that may be permitted to fly at the maximum observed flight level (for that aircraft type on that route).

The **annual** fuel savings would then depend on the number of flights per annum on routes conforming to these three different types, for the OI under consideration, These fuel savings can then be translated into emissions savings.

## 5. CONCLUSIONS

The results obtained with these analyses are indicative only. However, this framework provides a method for carrying out an initial environmental analysis without needing to use expensive modelling tools. The method was tested when, in 2006, Icon carried out the Initial Environmental Impact Assessment for DMEAN on behalf of Eurocontrol.