EUROPEAN AVIATION SAFETY AGENCY
AGENCE EUROPÉENNE DE LA SÉCURITÉ AÉRIENNE
EUROPÄISCHE AGENTUR FÜR FLUGSICHERHEIT

Research project EASA.2006/C40

Study on a basic Economic and Environmental Modelling system for Aviation (EEMA)

30 September 2007

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Study on a Basic Economic and Environmental Modelling System for Aviation (EEMA) FINAL REPORT

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QinetiQ/07/02028
NLR-CR-2007-676
September 2007

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Release Authority	
Name	Andy Stapleton
Post	Technical Manager
Date of issue	September 2007

Record of changes

Issue	Date	Detail of Changes
0.1 (draft)	August 2007	Preliminary draft
0.2 (draft)	19 Sept 2007	Final Draft
1.0	30 Sept 2007	First Issue

Executive Summary

The aim of the EEMA study has been to further develop European economic and environmental modelling capabilities in aviation environmental policy and rule making. Modelling in this context means the assessment of aviation's environmental impact and the associated costs.

There is significant existing modelling capability around Europe in the form of individual models, addressing individual aspects of noise, emissions, impacts and economics. These European models have evolved in relative isolation, and as such, there is a need to develop common interfaces such that the models can work together and perform comparable assessments which are able to identify environmental trade-offs.

The EEMA project has developed a prototype basic modelling system, based on an analysis of potential European policy options. A data warehouse concept has been developed and implemented, key to the linking of modelling capability such that common data can be shared by otherwise incompatible models. A number of applicable sub-models to calculate greenhouse gas, local air quality and noise burdens have been selected. This prototype system has then been subjected to a practical demonstration, in which modelling a change in an aircraft engine NOx emission regulation was simulated using the data warehouse and the current range of available models. Out of this prototype development and demonstration, a small number of “gaps” emerged – gaps being items of work which are required to take the prototype system to a final stage. These gaps include the development of a technology modelling protocol or model, the identification of appropriate economic data needed for aviation environmental policy modelling and its incorporation into an economic tool. In addition, the prototype capability developed here is recommended to be taken forward within an overarching European modelling management structure - a small agency, an independent European Modelling Management Group or a Network of Excellence – in order to make the capability available and affordable for policymakers Europe wide.

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1 Introduction

The aim of this study has been to further develop European economic and environmental modelling capabilities in the area of aviation environmental protection. Modelling in this context means the assessment of the aviation industry's environmental impact and the associated costs. When considering future policies, both on a European and global scale, a cost-benefit analysis is required in order to assess the proposed options or support a Regulatory Impact Assessment. The benefits can be expressed as reductions in aircraft noise and emissions, and the subsequent impact on local populations around airports or global climate change. As reductions in both noise and emissions are becoming harder to achieve, there are inevitable trade-offs between these benefits and, of course, the costs of achieving them, expressed in monetary terms.

The recent increase in awareness on the subject of interdependencies between environmental objectives has arisen from an improved understanding of the potential trade-offs between noise and emissions and between different emissions species (e.g. CO2, NOx). It is recognised that there is a growing need to simultaneously consider multiple environmental factors (noise, local air quality, greenhouse gas emissions) when assessing policy options, and their associated costs, in order to identify the optimum way forward. These can take a short, medium or long term perspective.

There is significant existing modelling capability around Europe in the form of individual models, addressing individual aspects of noise, emissions, impacts and economics. These European models have evolved in relative isolation, and as such, there is a need to develop common interfaces such that the models can work together and perform comparable assessments which are able to identify environmental trade-offs. Such improved modelling coordination would benefit Europe by providing support to Regulatory Impact Assessments, supplying environmental performance indicators, and supplying input to European policymakers. The AERONET-sponsored EFEMTA study[1] developed an initial list of European Policy measures and three modelling system concepts by which these might be addressed – naming them "basic", "responsive" and "aircraft-level" systems. In EEMA, the initial steps are taken in realising the first of these concepts – the basic modelling system.

This report describes the development and testing of this EEMA prototype basic "modelling system". The next section (Section 2) describes the policy priorities and available tools which could form part of the overall toolset. Section 3 then outlines the basic modelling system to address these priorities. Detail of the prototype implementation of this system is described in Section 4 including the development of the data warehouse concept, key to the linking of modelling capability such that common data can be shared by otherwise incompatible models. Section 5 examines the need for down-selecting the list of available models to identify best practice when addressing the widely differing policy modelling requirements. The demonstration of the prototype basic modelling system is described in Section 6 – in which modelling a change in an aircraft engine NOx emission regulation was simulated using the data warehouse and the current range of available models. Having established this basic system, issues and solutions for the ongoing management and further development of the system are described in Section 7. Sections 8, 9 and 10 cover project management, conclusions and recommendations.

2 WP1 Policy Priorities and Available Tools

European Union policies relating to the environmental effects of aviation are manifold and complex. They involve the policies of individual States, of the groups of States, such as the European Union and of global organisations such as ICAO CAEP. Together these policies seek to mitigate the impacts of noise, air quality and climate change resulting from aviation. This section reviews the current policy scene as far as it relates to modelling their effects.

Having established the policy scene, this section then goes on to describe the current and emerging European and non-European models which might be considered for analysis of policy effects. Gaps in the European capability are identified.

2.1 THE NEED FOR AVIATION ENVIRONMENTAL POLICIES

Aircraft engines produce emissions that are similar to other emissions resulting from fossil fuel combustion. While aircraft are the main sources of aviation emissions, aircraft emissions are distinct in that a significant proportion is emitted at altitude. However, all these emissions give rise to environmental concerns regarding their potential local air quality and global climate impacts. At ground level, in the immediate vicinity of airports, and regionally, concerns focus on the potential health and environmental effects of emissions such as NOx, volatile organic compounds and particulates. At altitude, aircraft emit CO2, NOx, SOx and particles directly into the upper troposphere and lower stratosphere where they have an impact on atmospheric composition. These gases and particles alter the concentration of atmospheric greenhouse gases, including CO2, ozone and methane; trigger formation of condensation trails (contrails); and may increase cirrus cloudiness – all of which contribute to climate change.

In parallel, noise from aircraft continues to be regarded as an increasing social nuisance, particularly in areas of improving living standards and affluence, and with increasing air traffic. This is in spite of the significant improvement in aircraft noise attained over the past few decades.

To address these concerns, European policymakers have developed extant and potential policies to address these environmental concerns. These include:

- Source emission and noise regulation
- International agreements (e.g. Kyoto)
- Operational measures
- Air quality standards
- Technology insertion
- Economic measures such as taxation, charging and trading
- Land use planning

It is well known that aviation has made substantial reductions in noise, emissions and costs since the introduction of the jet airliner. As some level of technological maturity is reached, these former win-win situations regarding noise, emission and cost reductions are becoming rare, resulting in further aviation system development now requiring trade-off between these factors. This interdependency is equally important in policymaking as it is in the aircraft design itself.

2.1.1 The Need for Policy Modelling

The recent growth in interest in interdependency modelling springs from a realisation that not only do we need to understand the interrelationships between all the different technical environmental and economic factors that affect aviation but also that we now have the technical know-how and computing power to fully integrate all the major influencing variables in aviation into a single model or modelling system and to use that system to inform policy decision making.

2.2 POLICY REVIEW AND THE REQUIREMENTS FOR MODELLING

An initial review of European aviation environmental policy was carried out in the AERONET EFEMTA study and this section draws heavily on that work whilst also updating it. Current policy options – within Europe and ICAO CAEP are described. The policy needs referred to in this Section are the policies of the EC States collectively and individually as they relate to emissions and noise from commercial aircraft. They include national policies as well as those negotiated internationally for example via ICAO CAEP. They include issues of noise, air quality and climate change.

2.2.1 Source Emission and Noise Regulation

Source emissions stringency is currently coordinated globally through ICAO CAEP, resulting in the Recommended Standards for NOx, HC, CO and Smoke set out in ICAO Annex 16 Volume II, which is then adopted into EU legislation. These Standards apply only to turbofan engines above 26.7kN thrust and are based on operation in and around airports (ie the landing and take-off (LTO) cycle). There are no current plans to set Standards for emissions at altitude as recent work suggests that, for current technology, technological improvements to reduce LTO emissions would also result in similar reduction at altitude. ICAO has historically relied on the strong market based incentive to mitigate CO2, which is directly related to fuel burn and, as such, it is also currently not regulated. ICAO is in the early stages of considering a possible increase in LTO NOx Stringency which would be applicable at some point after 2010. This would follow the previously agreed stringency increase coming into force on 1st January 2008.

Aircraft source noise standards are set in a similar way through ICAO CAEP and Annex 16 Volume I. They are based on certification noise limits for a particular aircraft-engine combination carrying out a reference landing and take off flight profile. CAEP is reviewing the potential of a further noise stringency increase and expects to report back at their meeting in 2010.

Traditionally, CAEP emissions and noise Standards are not technology forcing and are built on consensus consideration of economic reasonableness and environmental benefit. Modelling these factors is key to the ultimate CAEP decision.

Following discussion with European Policymakers, the EFEMTA study concluded that from a European point of view, potential global-scale source regulation in the medium term includes:

- NOx stringency
- Noise stringency (including their emissions effects)

- SSBJ[1] noise and emissions
- Particulate matter emissions
- Cruise/climb emissions

Given the global nature of aviation, EC-wide or national emission and/or noise source regulation has significant disadvantages in terms of economics and flexibility. However, it is a powerful policy option and one which would, if implemented, require powerful modelling of the economic and environmental consequences in order to implement it.

2.2.2 International Agreements

Beyond the ICAO CAEP source emission Standards, there are other international agreements limiting emissions. In the Kyoto Protocol for example, Annex I Parties committed to individual CO2 emissions targets adding up to a total cut in greenhouse-gas emissions of at least 5% from 1990 levels in the commitment period 2008-2012. These targets include domestic aviation but, at time of writing, specifically exclude international aviation.

Other potential agreements could include stabilisation targets and allocation. Modelling requirements would include modelling the effects of these measures as well as the analysis of various scenarios and noise/emission trade-offs resulting from any such potential agreement. Modelling of the effects of these global agreements would require modelling on a global scale, capable of allocation on a regional and national basis.

2.2.3 Operational Measures

Operational measures include improved air traffic control and airline practices, both at the airport and en route. Examples are:

- CNS/ATM measures
- Emissions procedures and their effects on noise
- Noise procedures and their effects on emissions
- Airside emissions options
- Free and Green flight
- Operational restrictions (including phase-out and night noise schemes)

These types of measures are implemented on international, national and local bases. Their benefits, globally and locally, require modelling at global and local scales in order to assess benefits and costs. Often these will require assessment of airline economic effects as well as air traffic system capacity and environmental benefit. Trade-offs between emissions, noise and economics are particularly important in this analysis.

2.2.4 Standards and Caps for Air Quality and Noise

Air Quality (AQ) Standards are applied only around ground level and thus are affected only by emissions close to ground (ie up to the local mixing height). Globally, AQ Standards vary by country in terms of the level applied and the period over which they are measured, although minimum AQ standards have been harmonised within

[1] SSBJ – Supersonic business jet

the EU under Directive 1996/002 and subsequent daughter Directives. There are AQ Standards for all the major aircraft engine emissions which have AQ impacts[2]. Being absolute levels of pollutant concentration, Air Quality Standards do not relate directly to the source emission and for airport localities, exceedences are as much dependent upon outside sources as on aircraft emissions.

As a result, any modelling relating to air quality standards requires accurate simulation of both on-airport and off-airport sources, together with high quality dispersion modelling. Benefits of AQ Standard reduction might be seen in improvements in aircraft emissions but are more likely realised through other emission reduction measures in and around the airport.

A simpler approach to air quality control can be implemented via an emissions cap ie a fixed limit on the amount of emissions generated in a given period. Modelling would again be on a local scale, assessing the various options available to maximise operations within the cap and the consequential effects on emissions, noise and economics.

Similarly for noise, there are standards for noise exposure, although these are not relevant to the periodic nature of commercial aviation noise. More important from a policy viewpoint is the concept of noise caps, as implemented for example at Schiphol Airport in the Netherlands. In this latter case, airport scale modelling is required to optimise operations within the noise cap, to test the impact of future operational and fleet changes and to evaluate changes to the details of the cap and any associated restrictions (for example, runway usage).

2.2.5 Technology Insertion

States have the policy option, individually or collectively, to encourage the development of technology which will reduce noise and emissions from aircraft. Key examples are the research programme part or fully sponsored by the EC and NASA. Whilst generally long term and susceptible to the vagaries of research, these policies have been key to the introduction of step-improvements in noise and emissions reduction technology into the global aircraft fleet. Modelling the emissions and noise effect, and economic costs, of these developments requires both a global and an airport level approach in order to help identify which research has the potential to provide the greatest overall benefits, and thus direct future research programmes. Examples of possible future technical developments are:

- New fuels, such as synthetic fuel, hydrogen
- New engine technology e.g. Lean Premix, pre-vaporised combustion
- New aircraft technology e.g. laminar flow wings, blended wing bodies

2.2.6 Economic Measures

Economic measures cover a range of instruments. Examples are:

- Taxation
- Local air quality and GHG emissions charges
- Noise charges
- Emissions trading
- Carbon offsets

[2] CO_2 and H_2O emissions do not affect AQ directly and are not regulated.

Economic measures operate by influencing the behaviour of stakeholders – manufacturers, airlines, airports, passengers, through adjusting the fiscal consequences of any given activity. Advanced capitalist society is tuned to react rapidly and flexibly to economic changes and whilst this applies to all the measures in this overview, predicting the consequences of economic measures requires particularly sensitive modelling, involving changes in demand resulting from cost changes from the measures, the reaction of the various stakeholders and the consequences of those reactions.

2.2.7 Land Use Planning

Aviation's relatively high profile in terms of emissions arises partly from its relatively slow rate of technology change, due to long aircraft operational lifetimes, and partly from its growth rate – the latter sustained at 4% to 5% per year for some decades. Such growth is anticipated to continue at similar rates[2] and will require significant development of new and extended airports to accommodate the additional traffic. In common with other developments outside aviation, States have the option to limit development unless environmental conditions are met. For emissions and noise, these planning constraints are usually applied in the environs of the airport but can in addition include global emissions. States also have the option to limit development around current and potential airport sites such that local impacts of current and future operation are minimised.

Modelling of new and expanded airports requires careful assessment of emissions sources and dispersion in order to correctly predict the contribution of the development to local air quality and how that contribution will affect compliance with LAQ limit levels. Similarly, noise contour assessment is required to judge the overall noise impact. However, as with all impact assessment, the actual impact can be highly dependent upon many societal factors as much as on the levels themselves. That said, such detailed single airport modelling is not normally part of global, regional or even national level modelling for policy purposes.

2.2.8 Other Policy Related Modelling Requirements

The EFEMTA study also highlighted the existence of other policy-related modelling requirements. These included:

- Sustainability assessment
- Evolution and goals assessment

Such assessments would be expected to be within the scope of modelling systems capable of assessing the global and regional policy measures covered earlier in this Section.

The control of acidification and regional/intercontinental emissions transportation was also discussed, although it was concluded that such specialised modelling would be outside of the scope of this policy-focussed exercise.

Having listed and described the main aviation environment-related policy areas, the question remains as to who may be implementing these policies. The following sections describe the likely activities by ICAO CAEP, which generally have a global scope, and those policies which, under current understanding are more likely to be implemented regionally or nationally.

Analysis is divided into:

- Modelling for CAEP/8 (2007-2010)
- Beyond CAEP/8
- Priority non-CAEP Europe-only requirements

Differences between the tightly prescribed CAEP modelling and the more flexible and wide ranging European policy modelling are highlighted, as is the importance of input data. The concept of "granularity" is introduced and the different timescales for a working modelling system are identified.

2.3 CAEP POLICIES AND MODELLING REQUIREMENTS

Following the decisions made at CAEP/7 in February 2007, the short-term CAEP modelling needs can be identified and addressed, leaving longer term (post-CAEP/8) requirements for subsequent attention. Both short and long terms are covered in this section.

2.3.1 CAEP/8 Modelling Requirements (Short Term)

Following CAEP/6 in 2004, A35-WP/352 identified likely candidates for analysis in the CAEP/8 work program. These included:

- a new **NOx stringency** LTO standard
- certification of NOx that would encompass all phases of the flight regime. This could include the analysis of a **new NOx cruise standard**, including potential tradeoffs with LTO stringency
- Groups have additionally asked that work progress on how to address **particulate matter**, including both local air quality and climate impacts
- studies be performed that would determine the need for new **regulations for aircraft noise**
- studies to assess the benefits achievable through **CNS/ATM**
- to assess the erosion of noise mitigation benefits due to **population encroachment** on airports.

Subsequently, other modelling related requirements emerged during the CAEP/7 work programme:

- **ICAO Environmental Goals** - assessing trends in the noise, LAQ and climate change impacts of the aviation industry
- **LTTG NOx Tech goals** - assessing of the potential benefits in achieving these goals
- **Operational measures** - assessing the trade-off in fuel consumption, noise and emissions, primarily for CAEP guidance
- **Economic measures** - potential modelling to support arguments for the effectiveness of economic measures such as taxes and charges.

Finally, at CAEP/7 itself, additions and changes to the above-listed requirements were made, including:

- Examining the technical potential for a new **NOx standard (LTO)**

- Reporting only on certification **noise levels** for transport category jet aircraft to understand the current state-of-the-art of aircraft noise technology
- Limiting the consideration of a **new NOX cruise standard** to a technical monitoring role
- Increasing the scope of modelling the trends toward achieving **ICAO's Environmental Goals** to include technical, operational and other effects
- Introducing new work to determine **technology goals for CO2 and noise**
- Ongoing discussion of the approach to various **economic measures**

Further details of modelling requirements emerging from CAEP/7 are in Appendix A

The key lesson from this time scaled analysis is the constantly developing and changing emphasis in the requirements, even within the relatively stable CAEP environment. Clearly any modelling system needs to be flexible enough to accept these changes with minimal adaptation.

Distilling the CAEP/8 (short term) modelling requirements from these lists, reveals the following key requirements which need to be addressed by modelling for CAEP/8, and, if feasible, by the prototype modelling system developed under EEMA:

- Increased NOx Standard stringency (LTO) (sample problem plus possible rule change)
- Trends towards ICAO's Environmental Goals
- The effects of achieving technology goals
- The effects of operational changes

As with CAEP/7, other requirements may emerge during the CAEP/8 work cycle of which analysis of economic measures is the key unknown.

2.3.2 Modelling Beyond CAEP/8 (Medium and Longer Term)

With the absence of analysis of economic measures, much of the subtlety of full interdependency modelling has been deleted from the requirements for CAEP/8. However they have not been deleted from the CAEP programme and are likely to be considered in some form during the later cycles for application to later analyses. In preparation, many features of extended interdependency analysis such as emissions impact assessment, monetisation as a common currency between impacts, and market elasticities are being provided alongside traditional CAEP/8 analyses as sample information. There are many sceptics, particularly in Europe, regarding the value of applying monetisation to aviation. However its application to other areas of environmental assessment, including other transport modes, is growing in Europe and the trend may be difficult to resist.

Beyond economic measures, there is a long list of possible measures which may require CAEP analysis – evidenced by the list in Appendix A. However, this EEMA work is focussed on providing a short term basic modelling capability which can be built on in the future.

2.3.3 CAEP Evaluation of Models

CAEP's emerging methodology for evaluating models was described in the EFEMTA report. Since then, model evaluation for "traditional" GHG, LAQ and noise models has slipped both time-wise and in importance, to be replaced by a focus on completion of a Sample Problem. This considered NOx Stringency policy options in order to demonstrate a capability to assess trade-offs between difference modelling domains. The CAEP process is now managed by a new group, the Modelling and Databases Task Force (MODTF).

There is no doubt that once the NOx Stringency Sample Problem is substantially complete, there will be a return to model evaluation for the traditional models. However, successful completion of the NOx Sample Problem by any particular model will make it difficult for the model to be rejected on other evaluation grounds. Hence successful completion of the NOx Sample Problem is important for all the European models – a process which has been assisted by the same models performing the NOx Stringency based EEMA modelling demonstration described later in this report.

In addition to the traditional models, including the Netherlands' AERO-MS modelling system, CAEP is evaluating economic and technology response models. Currently, Europe has no candidate models in this area, however, if the development of these models are taken forward, it is to be expected that they will also be subjected to the CAEP evaluation process. The precedents set by the current evaluation of equivalent US tools is being viewed from the perspective of the subsequent evaluation of the European tools.

2.3.4 Common Inputs

In addition to the modelling requirements, CAEP is also seeking to improve the quality of the input data, again including some evaluation. Input data includes current fleet information, aircraft performance, a current operations database plus details of airports and population. A representation is shown in Figure 1. It is planned that all CAEP modellers use this common input data once commercial constraints have been removed.

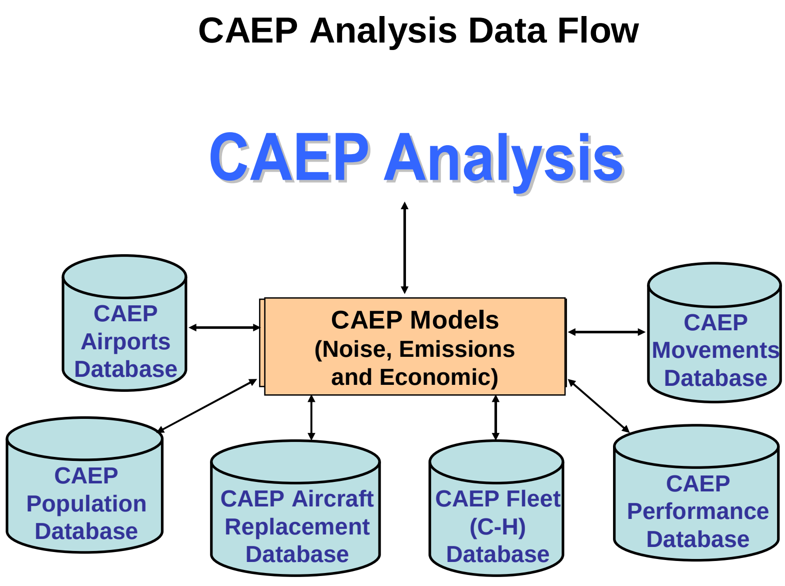


Figure 1: CAEP Analysis Data Flow

2.3.5 The European Response to CAEP Requirements

European models are well represented in the list of models submitted to CAEP. However, there is no common approach by which the European models can work together to produce a consistent assessment for noise, LAQ, GHG and economic impacts of any given measure. By contrast, the US have, through the FAA, invested a significant amount of resources to develop a modelling capability in this area for US domestic purposes, and which has also been put forward for use within CAEP. In view of this, one could take the perspective that input from Europe is not essential from a CAEP point of view. However, European modelling input provides a useful balance to US focused assumptions, and the availability of modelling resources, to ensure European interests are represented in global decision-making processes.

It is clear that a European input will provide substantial value in global policy-making. The total extent of the European response is yet to be determined. However this EEMA work represents the first steps in putting together a modelling system and identifying any areas for improvement.

As an objective, the existence of a CAEP-endorsed European modelling input should allow:

- Assessment of the effect of non-European assumptions
- Use of alternative future scenarios and fleets
- Increase in the number and type of policy options modelled

2.4 EUROPEAN POLICIES AND MODELLING REQUIREMENTS

The previous paragraphs dealt with meeting ICAO CAEP modelling needs and assessing the effect on Europe of global policies. Additionally Europe's own regional policies will require assessment, with potentially more Eurocentric assumptions, to ensure a robust decision-making process. Regular reviews on the effectiveness of these policy decisions are also essential in order to ensure they are achieving their objectives and identify further improvements.

The capabilities required to analyse European policies are similar to that in CAEP and, as such, there are considerable synergies between these two areas and therefore economies of scale. Policies of particular interest to EASA, and therefore to this study, are listed in Appendix B.

The European Environment Agency is implementing a system of indicators tracking transport and the environment in the European Union, called "TERM – Transport and Environment Reporting Mechanism". An initial review of the requirements for aviation suggests that a European Basic modelling system should be able to report on these indicators from an emissions and noise point of view.

2.5 GENERAL MODELLING ISSUES TO MEET POLICY NEEDS

The constantly changing nature of policy-making means that the required capabilities of the modelling system will need to be continuously adapted and therefore needs flexibility.

Europe has the distinct advantage of having a number of modelling elements already available, and, due to the ongoing duplication inherent in competitive national and regional research programme, this multiplicity of models is likely to continue. As a result a flexible system can be achieved by:

- Availability of good quality input data sets (various sources)
- Availability of processes to translate this data into common (ie understood) formats usable by noise , emissions and finance models
- Availability of data pre-processors to allow individual models to take the common data into each individual model
- Availability of models (and resources) to process the data to obtain results
- Availability of common (or agreed) assumptions
- Only loose association of the various models (ie modular format where links are in data transfer only)
- Availability of processes to transfer between granularity levels (see Section 2.7), either in the preparation of input data or the model pre-processing phases
- Availability of funds and management to resource the modelling data preparation and model runs

These issues are addressed in Sections 3, 4 and 7 of this report.

2.6 THE IMPORTANCE OF INPUT DATA AND ASSUMPTIONS

Once the methods and implementation of a GHG, LAQ and noise "basic" modelling system have been determined, these models essentially become calculating machines providing the output data. The differences between policy options will then be primarily driven by the differences in the input data generated for each policy scenario, and by any changes in the assumptions/data within each "calculating machine" resulting from the policy measure and changed by the analyst. In some cases, many major assumptions are included as part of the modelling process. These can be discussed and agreed with policymakers before and during the modelling process. Alternatively, modellers make these assumptions themselves.

For most policy analysis requirements undertaken by a single analyst, this process is summarised in Figure 2 .

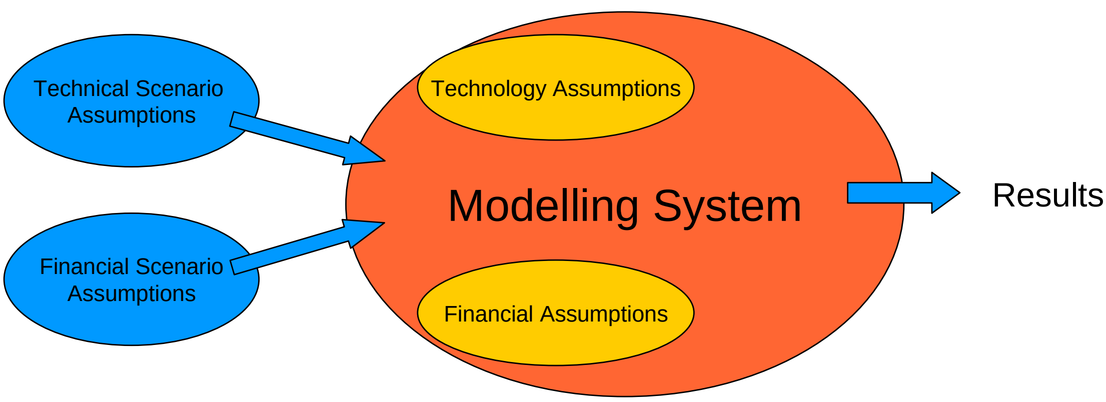


Figure 2: Assumptions in a basic modelling system

By contrast, in CAEP Stringency modelling, the vast majority of the key assumptions which affect the cost benefit case are decided prior to modelling – primarily by the technical and financial/economic groups. These groups are represented in the following Figure 3 by the WG1-WG3 TIG[3] and FESG[4] respectively.

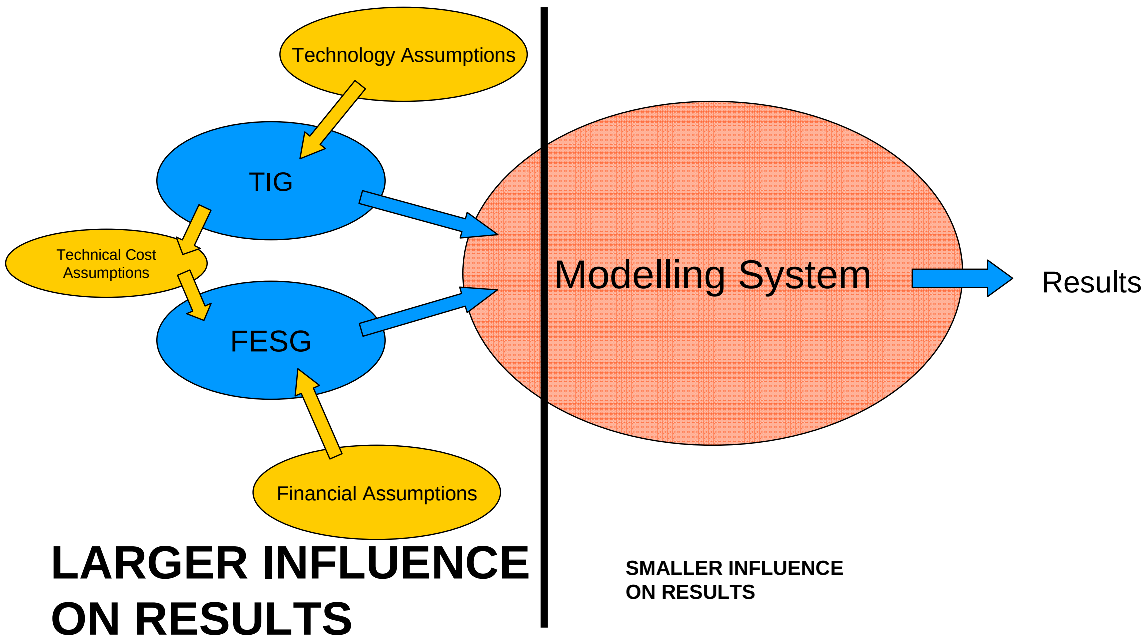


Figure 3: CAEP "basic" modelling system

Clearly indicated in Figure 3 is the importance of these input assumptions in determining the actual result obtained. For this type of modelling, it is important that due emphasis is placed on examining both these input assumptions and the methods used within the actual modelling system.

In the CAEP context, examples of major influencing factors are:

- Technical input
    - Which aircraft/engines are included in the Growth and Replacement database used to populate future fleets
    - The non-recurring development costs of making the worst of these compliant (ie are they still actually marketable, when were they last sold etc)
    - The trade-off between Noise, NOx and fuel (CO2) performance for "new" types
- Financial Input
    - Residual value and double counting
    - Discounting of costs and impacts
    - The time horizon for benefits
    - The time when products need to become compliant in order to continue selling

[3] WG1-WG3 Technology Interdependencies Group
[4] Forecasting and Economic Analysis Support Group

- The mission/payload retention costs which may be dominant for higher stringencies
- The effect of capacity constraints (mainly noise). Where do the extra flights go?
- The magnitude of increased landing fees.

All these key assumptions are inputs.

2.7 GRANULARITY

Granularity is intended to convey the concept of working at different levels of detail. An example would be modelling on a flight-by-flight basis or on a regional traffic flow level. Figure 4 provides an overview.

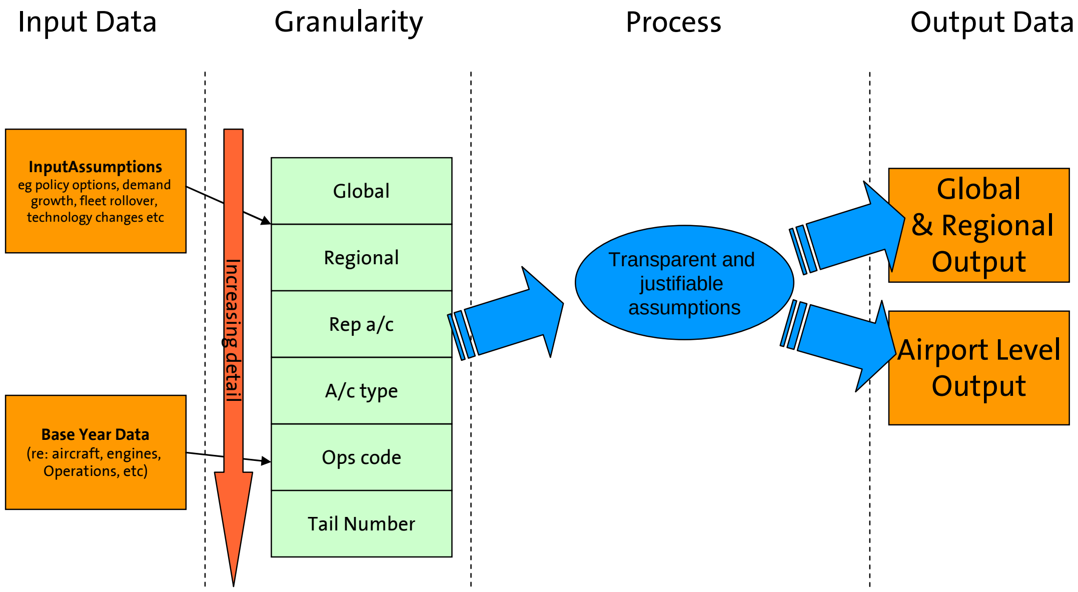


Figure 4: Granularity within the modelling system

Both can provide valid results. The appropriate level of granularity is dependent upon the problem to be modelled and upon the requirement for transparency (clarity) in separating the effects of different assumptions. There is concern that whilst complex models would appear to model more accurately, the actual assumptions or model characteristic which is driving a policy response result can be hidden in the complexity. A greater number of sensitivity tests with simpler models may yield a more reliable and comprehensible result. In addition, input assumptions may be available only at a coarse level of granularity (eg future aircraft technology, future fleet mix, future demand, future costings). In most cases, modelling at finer granularity than the input assumptions provides a spurious level of detail in the model output

To summarise, the principal pros and cons or modelling at different granularity are set out in the following table:

- FINE GRANULARITY
  - Can cover all requirements
  - Expensive
  - Time-consuming
  - Best applicable to detailed, short term modelling
  - Best applicable to small changes
  - Results drivers can be difficult to identify
  - Can give spurious impression of accuracy when used with coarser grained input assumptions
- COARSE GRANULARITY
  - Cannot cover all requirements
  - Economical
  - Nimble
  - Best applicable to longer term, scenario type modelling
  - Best applicable to larger, system-level changes eg goals

European models and policy analysts have the choice of which level of granularity is most appropriate.

2.8 TIMESCALES

Policy analysis is an ongoing topic. In an ideal world, a suitable modelling system would be available now. The realisation of such a system is however dependent upon funding and for Europe, the full process is not yet clear. The EEMA project represents a significant first step. Further work is planned both from national sources and in a submission to EU FP7. If the FP7 bid is successful, a complete system can be envisaged around 2010.

In the meantime, CAEP MODTF has declared a timescale for acceptance of models for analysis of CAEP/8 policy options. This currently requires models to be evaluated by April 2008. The individual models used in EEMA have been submitted to this process. Consideration needs to be given as to whether any other technology, economics or data elements from Europe can be added to the evaluation process. It is the view of the EEMA consortium that European technology and economics models are not yet ready for (re)evaluation. The EEMA Data Warehouse into the CAEP process would also assist the smooth flow of data to European models.

2.9 MODEL REVIEW

As described above, “basic” modelling involves taking the agreed inputs related to fleet, ops, technology and finance and calculating the emissions mass, population exposed to noise and costs for each policy option and related sensitivity cases. If required, further impacts and monetisation can be calculated as an “add-on”, although these do not form part of a “basic” modelling system as defined in EFEMTA.

Components of such a system are:

- Technology modelling systems
- Economics modelling systems
- Noise calculation
- LAQ calculation
- GHG calculation
- (Impact modelling system add-on)
- (Monetisation calculation add-on)

These elements are shown assembled into a modelling system in Figure 5.

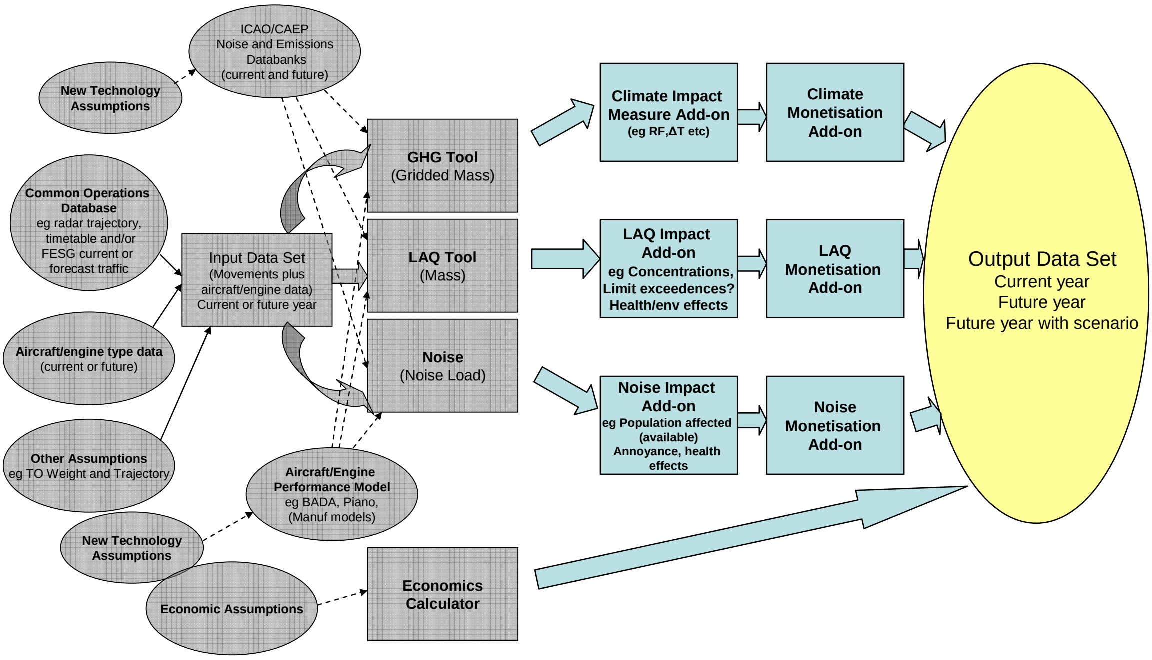


Figure 5: Outline basic modelling system plus impact and monetisation add-ons

Each element of the modelling system is briefly described in the following paragraphs, together with examples of available models:

Input data

Aviation environment modelling requires input information of the aircraft fleet, its noise and emission characteristics, aircraft performance and weights, details of the airports used and the flights between them, the operational practices used, typical meteorological conditions, population and, in some cases, economic data. Many models have some of this data built in to the model. However to allow the use of a common set of input data for interdependency modelling, a common data source is required. The EEMA Data Warehouse described in Section 4.1 meets this requirement.

Technology modelling systems

Technology modelling systems assess the effect of future technologies on aircraft performance, operation, noise and emissions. Primarily based on an expert view of technology development over the foreseeable future, these models can assess interdependency between performance, noise, emissions and costs. Very few such models exist outside manufacturers – this modelling is in fact the aircraft outline design process. Whilst there are a number of partial models in the public domain, there do not appear to be any available tools suitable for use in EEMA. Expert input is however available, on a case-by-case basis, to estimate generic improvements based on technology assumptions.

Economics modelling systems

Economics models can vary from simple spreadsheets to complex economic models incorporating passenger and freight demand and socio economic factors. By definition, the basic system requires only the calculation of costs associated with the policy change. This can normally be accomplished by development of a spreadsheet or by use of individual modules taken from more complex economic models. In this project, the AERO-MS tool appears to be the only widely known European economic tool focussed on commercial aviation, although no doubt there are generic economics calculators which could be adapted.

Noise calculation

Noise calculation requires taking the noise characteristics from a given aircraft and, based upon its expected flight trajectory; determine the propagation of that noise to ground level. Noise effects are non-linear and the summation of the effects of individual flights at any given airport requires the analysis of each individual flight and its trajectory in the region of the airport. Once ground level noise contours have been established, based on accepted noise measures which account for, for example, time of day sensitivities, these contours can be combined with population data to produce a count of the number of people exposed to noise ie the number of people living and/or working within a given noise contour. This is, in reality, the beginnings of an impact calculation (see below). A methodology to carry out this calculation which has been generally accepted in Europe, and now worldwide, is ECAC Doc29R [3].

The main models known to carry out this type of modelling are:

INM/MAGENTA (FAA)

INM/Enhance (Eurocontrol)

ANCON (CAA)

SONDEO (ANOTEC)

The first of these models uses proprietary airport data in the MAGENTA element of the model and, whilst INM is publicly available, the overall INM/MAGENTA package is not available for use outside the FAA. The other three models have been taken forward into this study, including INM/Enhance which does use the FAA's INM model as its basis.

LAQ calculation

In the context of aviation, Local Air Quality models compute the emissions from aircraft engines and place these in the context of the background concentration of other pollutants at or around airports. These spatially and temporally defined inputs, together with meteorological data, are treated by a dispersion model to establish concentrations around airports, expressed either as peak values or as temporal means.

There are a significant number of models carrying out general dispersion calculations. However a small number of these have been adapted for specific airport use. Three of them, currently being the CAEP candidate models from Europe, have been linked to this study, namely:

ADMS (CERC)

ALAQS (Eurocontrol)

LASPORT (Janicke Consulting)

An additional model, EDMS is also available from the FAA and could have been included in this study. However no funds were available to carry out familiarisation and running of the model. It is also known from UK PSDH studies that considerable adaptation of the model is needed to obtain reliable results. A comparison of EDMS, ADMS and LASPORT is contained in the PSDH report [4].

The three named models were taken forward into this study.

GHG calculation

Greenhouse gas models compute emissions for the whole flight using aircraft and engine performance models to compute emissions during each phase of flight. Sets of global flights for whole days, weeks or years are computed. Some models take trajectory information to improve accuracy. Where necessary, emissions below 3000ft can be discounted to avoid double-accounting with LAQ models.

Three GHG inventory models were available to engage with EEMA, namely

AEM (Eurocontrol)

AERO2k (EC/QinetiQ)

FAST (MMU)[5]

Other GHG tools are available. The Netherlands AERO-MS has an inbuilt module within the larger AERO-MS model. However enhancements to the model and its interconnectivity were being considered at the time of the EEMA study. A methodology called ANCAT/EC2 was also developed in the 1990's but this is generally considered to be superseded by AERO2k and AEM. The FAA have developed a global inventory tool named SAGE[6], now part of the AEDT tool suite. However, this tool is not publicly available and is not planned for public release.

Hence the three GHG models listed were included in the EEMA study.

Impact modelling system add-on

Impact modelling is not strictly part of the basic modelling system. However there is an interface between the emissions and noise outputs of the basic system and the input requirements of the impacts models. As far as can be ascertained without detail specification of any particular impacts models, the spatially and temporarily defined GHG emissions, the LAQ concentrations and the noise contours output by the three types of model provide the necessary input for impact assessment. Detail data compatibility and any additional input data (such as health effects or climate sensitivity) fall outside the remit of this work.

Monetisation calculation add-on

As for impact modelling, monetisation of the impacts is outside the EEMA remit. Again, however, it is anticipated that the basic modelling described will provide the necessary inputs in terms of emissions and noise.

Use of and Collaboration with non-European Models and Modellers

A common thread through all the model types above is the existence of other aviation environmental models outside Europe. As an alternative, or a supplement, to the use of European-based models, the question arises as to whether benefit can

[5] As noted in later sections, the FAST model was engaged in EEMA data requirements specification, but was unable to provide the resources to supply modelling demonstration results within the period of the study.

[6] System for assessing Aviation's Global Emissions

be gained from use of or collaboration with such non-European models. Key in considering such use and collaboration are their suitability and availability.

A brief survey of non-European models revealed the well-publicised FAA AEDT/APMT modelling suite, which contains models under each of the categories in this section. Other models exist, for instance in Japan, but full assessment of their availability and suitability were considered to be outside the scope of this study. Consultation with the AEDT/APMT global model survey (private communication) confirmed the multiplicity of US and European models, highlighting the models selected for FAA purposes. Other than those selected by the FAA for onward support and development, the non-European models in this survey do not appear to offer any outstanding merits over existing European models.

Addressing the question of suitability and availability of the FAA AEDT/APMT suite, only two elements of the suite are planned for public release – EDMS and INM. EDMS is addressed above under LAQ model calculation. INM is already part of Eurocontrol's ENHANCE noise model (again see above). However, as an alternative, it may be feasible to engage the FAA or their agents to run European modelling requirements through the AEDT/APMT suite. At the current stage of development of these tools, the availability of such an option is not clear. It is anticipated that for resourcing reasons, such an option is unlikely during the initial years of operation of the suite. In addition, it is already clear that for some modelling, the assumptions are focussed on US assumptions with more generalised application to the rest of the world. Application of the suite to the European region may require further adaptation. Additionally, the political element as to whether it is prudent to assess European aviation environmental policy options in the US would need to be resolved.

Whilst direct use of the AEDT/APMT suite for European policy option studies appears to have significant shortcomings, or at least uncertainties, there are certainly significant advantages in collaboration with the US model development on methodologies and results. This is already underway through the SAE A21 committee (UK and Eurocontrol) and through CAEP Model assessment. Eurocontrol also have separate initiatives directly with the FAA in improvement of databases and model compatibility issues.

In summary, the selection of primarily European models to take forward does not unduly constrain the capability of the potential modelling system. However, ongoing and improved collaboration with the FAA would seem to offer opportunity for European database and model improvement. Further downselection issues are addressed in the next section.

2.10 GAPS AND DOWNSELECTION

The EEMA Work Programme identified the need for a European strategy and funding to address the identified gaps in the basic modelling system. During the course of the project, it has become clear that this strategy will continue to be coordinated by the ANCAT Modelling and Interdependencies Task Group (MITG) for the foreseeable future. MITG have taken direct input from the EASA project in coordinating future FP7 proposals and ongoing requests for funding to individual States through ANCAT.

More directly related to the EEMA prototype basic modelling system are the activities required after the completion of EEMA in order to realise a fully capable basic modelling system. These take one of two forms – those "gaps" within the EEMA prototype system itself and those "gaps" related to inputs and outputs from the EEMA basic system.

Gaps in the core system are dependent upon the implementation of the work in the EEMA project and are covered in detail in the following sections of this report. However it is clear that outside the basic system being developed within EEMA there will be further work required on the associated inputs and impact tools, specifically:

Technology evaluation – the development of models or methodologies to evaluate technology interdependencies – by a process of expert evaluation assisted by modelling

Economic models – the creation of or updating of economic models to model complex economic policies, noting that simple economic consequences can be modelled by simple spreadsheets

Impact models - the embodiment of scientific understanding into models to assess climate, health and other environmental impacts of noise and emissions. Many such models exist, particularly in the climate area. It is already known that the gridded output of the EEMA GHG models is compatible with many climate models. For LAQ and noise, this linkage has not been tested

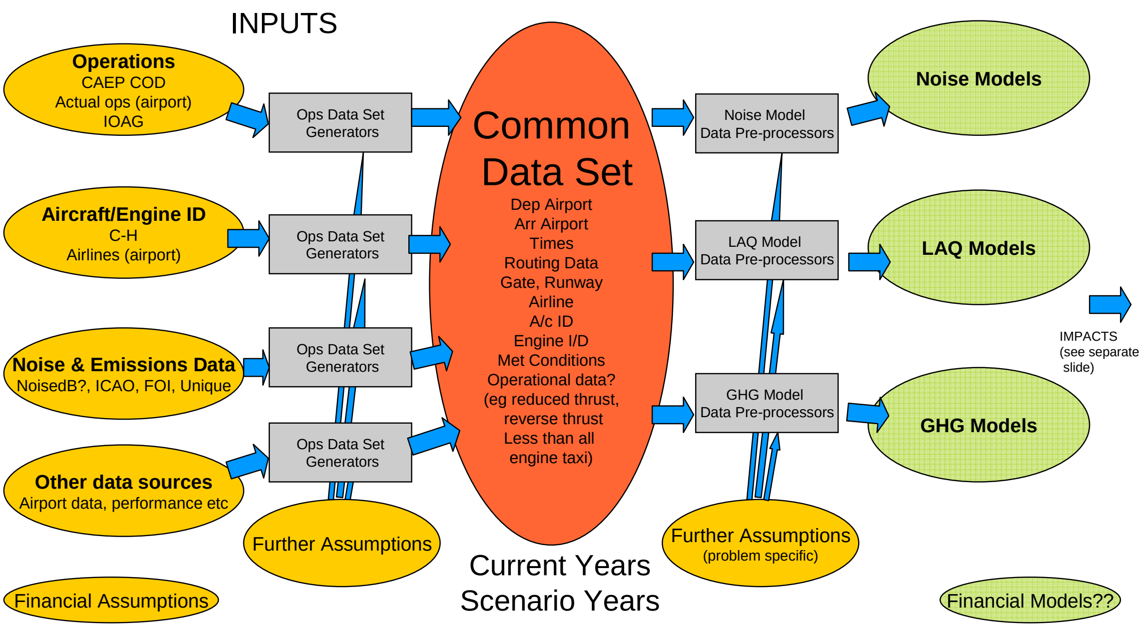
Monetisation methods – the development of methodologies to take emission and noise or their impacts and translate these into accepted monetary values

All these elements form part of the ANCAT MITG-based plan.

One additional issue for consideration when developing a modelling system is which models to use for the individual elements of the system. With many candidate models potentially available for use a process of down selection may be required. The criteria used and the down selection process are described in Section 5.

2.11 STRATEGY FOR THE BASIC MODELLING SYSTEM

Taking account of the issues raised in the sections above, a series of concepts for the prototype basic modelling system were developed. In supporting multiple models and multiple customers, a flexible system is required in which input data and assumptions from many sources are made available in compatible format to a number of models.



The wholly-centralised system illustrated in Figure 6 provides all the input data required to run the analysis models in one central "warehouse". In this case, data sets are produced for each case being analysed by processing the input data (eg to produce future year fleets for all scenarios) in the central warehouse. Only minimum data pre-processing is left to individual modellers. This system requires the most effort by the data warehouse providers but provides maximum commonality between the models. One disadvantage is that centralised data such as aircraft performance may not be compatible with all individual models. The CAEP modelling methodology is moving toward this system.

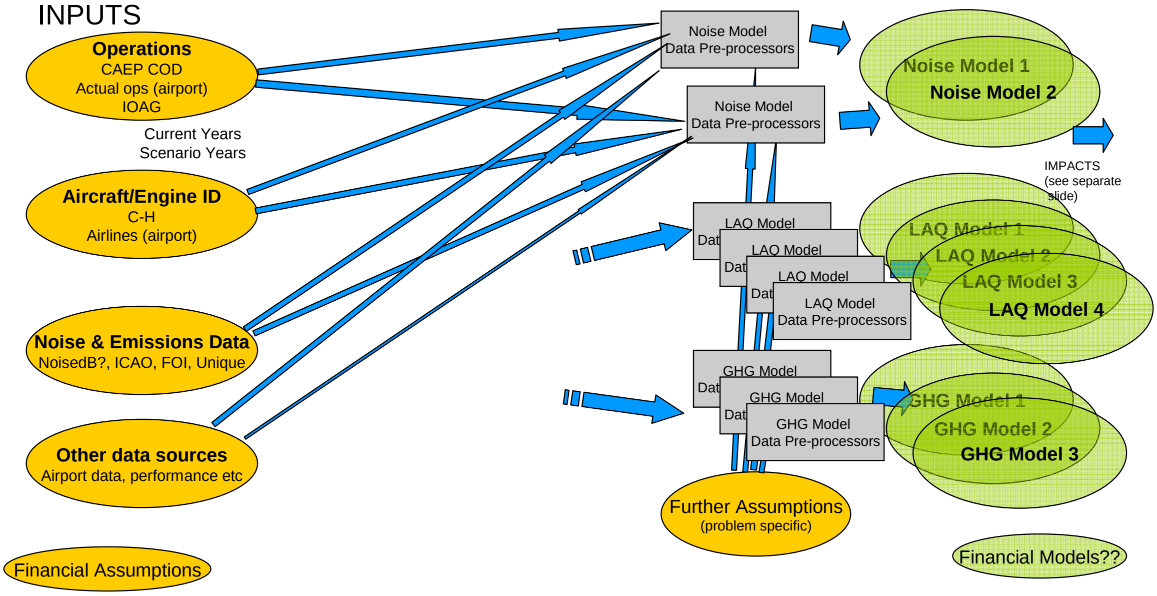


Figure 7: Model-specific data transfer protocols

In contrast, Figure 7 illustrates a system where a minimum of data is held centrally such that a policy analysis would refer modellers to data sources but rely on each individual modeller to interpret the data. This system retains the autonomy of each model but requires similar work to be repeated by each modeller.

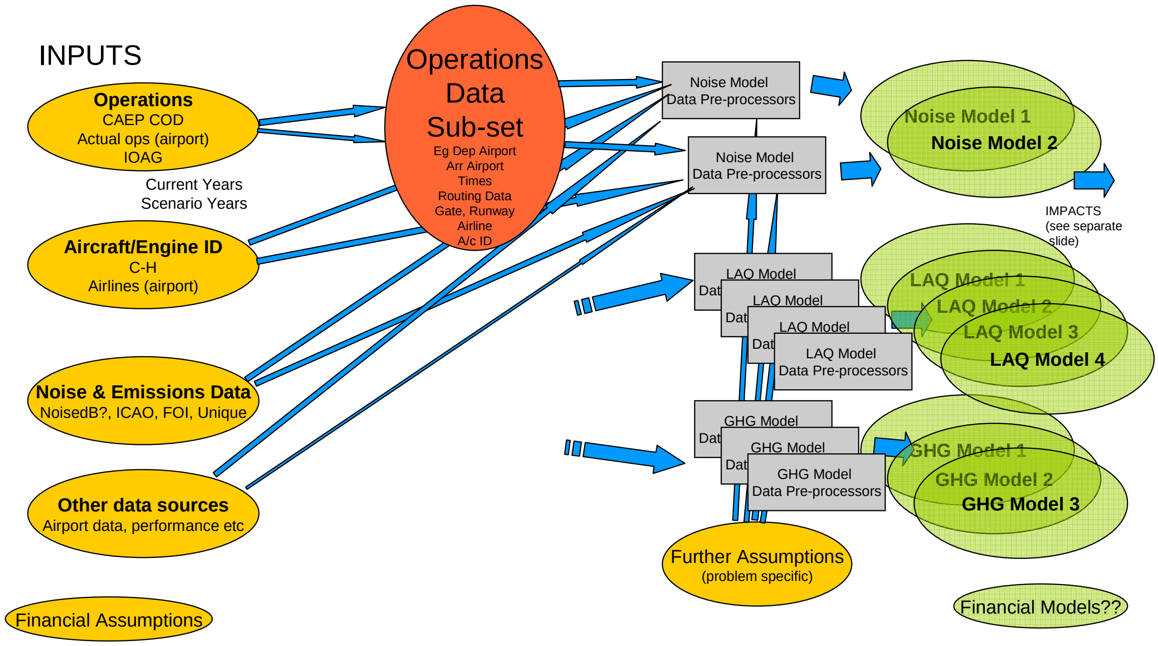


Figure 8: Combination data transfer protocol

Finally, Figure 8 is a half-way house between the two previous systems. In this case, policy scenario fleets are provided but individual models have their own sources of other data.

Further development of these concepts is carried out in EEMA WP2 (see Sections 3 and 4), focussing on the "Combination" concept, which appears to be the most practical and flexible for the range of European models.

This approach requires the development of a common operations dataset, capable of taking input assumptions to quickly generate future year datasets for various scenarios. It is likely that, in some instances one model will use the common future year dataset, while other models will use the raw input data. This can be accommodated to allow modellers to select the data best suited to them.

The requirements for any other input data pre-processing needs examination of the individual models

However some initial gaps and actions can be identified by attempting to build the Basic System along these lines. Figure 9 depicts the key building blocks and links.

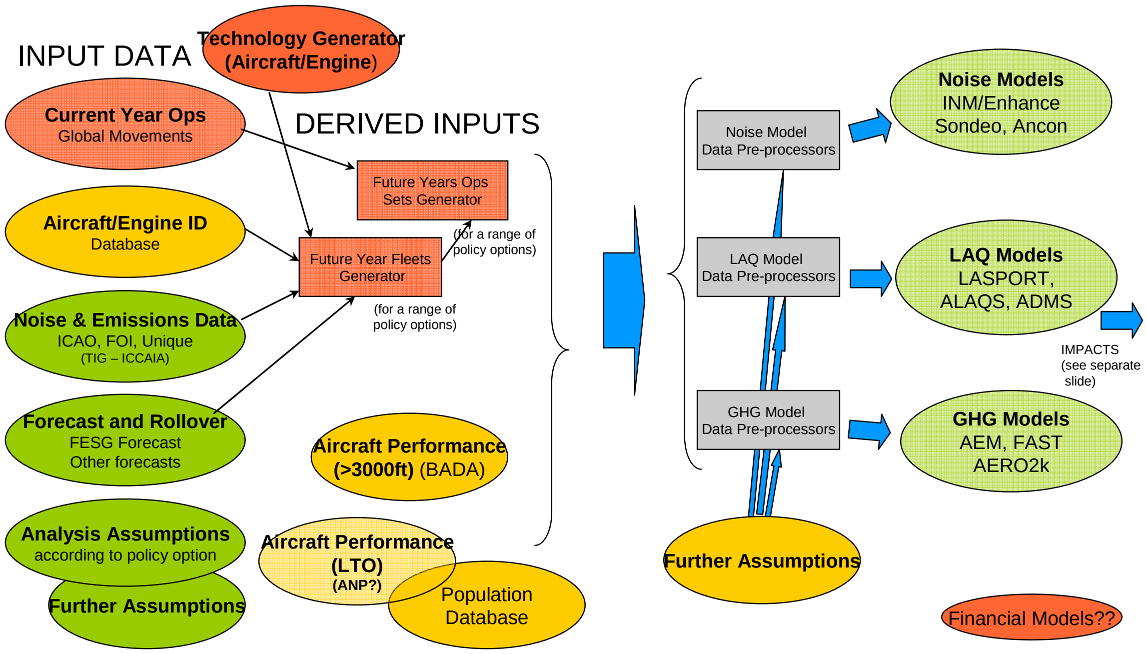


Figure 9: The Basic Modelling System

To realise this system, there are numerous relatively detailed tasks to be performed. These include the evolution of a suitable methodology, the identification of suitable sub-models and the creation of a data warehouse to provide and control the data used by each model. These steps are described and where feasible, addressed in EEMA Work Package 2. Going into the WP2 work, the major gaps appeared to be:

- Input data
  - Freely available fleet and movements data
  - “Approved” Future Aircraft performance generator – key to interdependency
  - Performance profiles for other than full thrust
  - European derived data for future fleets and ops
- Models
  - Global airport data
  - Performance based and multi-airport input capability for noise and LAQ models
- Approach to (impacts) and monetisation
- Approach to common data transfer
- Euro model management

In the next Section, the principles, priorities and issues raised in this section are distilled into the actual realisation of a prototype “basic” modelling system to address those policies amenable to basic-type modelling.

3 WP2 Specifying the System – Task 1 Modelling Methodologies

The next three sections (3, 4 and 5) present the consecutive steps carried out during the specification process of the Basic Economic and Environmental Modelling System for Aviation discussed in Work Package 1. Section 3 gives an inventory of the modelling methodologies that are incorporated in the Basic System. Section 4 describes how the system's input, output and data exchange protocol were built. Finally, Section 5 presents the criteria used to assess the best existing models for the system.

3.1 INTRODUCTION

While Work Package 1 introduced the concept of a Basic Modelling System based on existing European aviation modelling capabilities, Work Package 2 establishes technical specifications for the system and sets up a first version of its core *Data Warehouse*. The process has been split into three distinct tasks:

- Task 1 presents the emission and noise modelling methodologies to be incorporated into the Basic System, such as the latest ICAO/CAEP and ECAC/ANCAT guidance. This methodology assessment enables the selection of a first model list to be included in the system. Potential methodology gaps are identified, which should be addressed for future evolution of the system.
- Task 2 defines the overall structure of the Basic System and introduces the concept of *Data Warehouse*, which serves as a link between existing input data sources and European models by storing static datasets and converting them into formats directly readable by models. With this objective, European modellers were asked to provide specification on their models' input and output data. On the basis of this survey, a first version of the Data Warehouse was built in MS Access that includes all necessary data for models to perform the Euro-Modelling Demo described in Section 6 – which was being defined in parallel.
- Task 3 investigates whether the models surveyed in Task 2 all comply with the methodology and data exchange flexibility standards required by the Basic System, or some down-selection should be carried out to ensure the operability of the system.

The outcomes of Work Package 2 consist of a list of 10 European models with their input and output data specifications – see Appendices E and F -_ as well as an ftp based version of the Data Warehouse currently hosted by EUROCONTROL, which was used for coordinating the first Euro-Modelling Demo in Section 6.

3.2 WP2 SPECIFYING THE SYSTEM

From interdependency modelling work carried out to date – primarily the AERONET EFEMTA study and the current EASA EEMA study – it is clear that the component elements of the basic modelling system exist within Europe. The gaps consist mainly of the methodologies and protocols used to allow the models to work together in an interdependent manner – both technically and organisationally.

3.2.1 Objectives and Activities re Modelling Methodologies

The main objectives concerning modelling methodologies are:

- To make decisions on what mechanisms and interactions (not) to include in the basic modelling system from a modelling point of view
- To ensure that a (minimum) set of requirements – as defined in EEMA WP1 – will be met
- To define the modelling system-of-systems characteristics, taking account of existing individual noise, emissions, impacts and economic models – identified in EEMA WP1
- To develop the necessary methodologies required for a basic modelling system; alternatively, to develop interim modelling solutions (i.e. "workarounds") suitable for the test sample analysis in EEMA WP3 (see Section 6) and to formulate recommendations for future steps to be taken for development of the final methodology.

Aimed at meeting these objectives, the following activities took place in the framework of the EEMA WP2.1 (considered in Section 3) when it concerns modelling methodologies, and partly in EEMA WP2.2 (addressed in Section 4) when it concerns input, output, interfaces and data exchange issues:

- Investigate what needs to be calculated and which mathematical models to use in order to comply with EEMA WP1 findings (see Section 2)
- Specify the chain of calculations (required and preferred)
- Specify the input & output sensitivities (variables) of the full chain and preferred dimensions (mainly in Section 4)
- Compare inputs/outputs of existing models – identified in EEMA WP1 (mainly in Section 4)
- Identify missing computational steps
- Identify missing variables/dimensions (mainly in Section 4)
- Develop - within project time and budget constraints – missing modelling methodologies or interim alternate modelling solutions (i.e. "workaround") just to be able to perform the test sample analysis in EEMA WP3 (see Section 6).

3.2.2 Specifications and Requirements re a Basic Modelling System

EEMA work is focussed on providing a basic modelling capability for the short term. In the previous Section 2, the basic modelling system and its key building blocks and links and chain of calculations have been outlined (Figure 10).

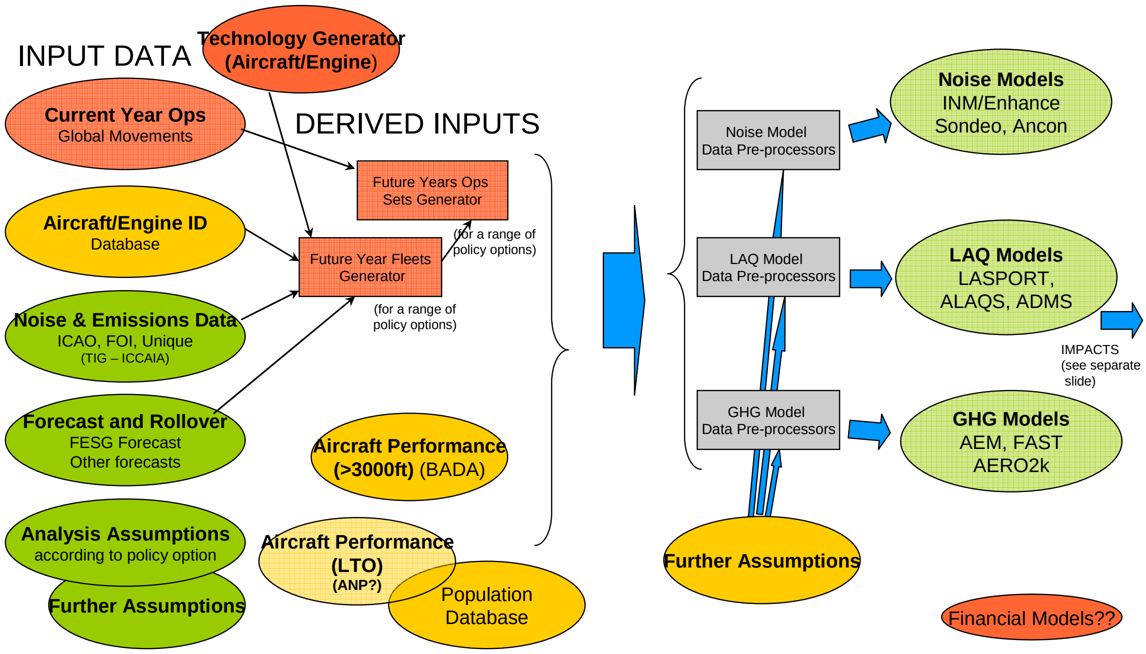


Figure 10: The Basic Modelling System

In summary, the basic modelling system takes an agreed set of inputs – related to fleet, operations, technology and finance – and calculates the local and global emissions masses, noise population and costs for a specified case. Further impacts and monetisation can be calculated as "add-ons", however, these do not form part of the basic modelling system. The main components of the basic modelling system were identified as:

- Data warehouse system
- Technology modelling (sub)system [at fleet or generic aircraft type level]
- Economics modelling (sub)system [simple economic parameters calculation]
- Noise calculation
- Local air quality (LAQ) emissions calculation
- Greenhouse gas (GHG) emissions calculation

The so-called data warehouse system is a flexible system of data storage and exchange between the (above-mentioned) computational models which has been developed as part of the EEMA project and is discussed in more detail in the next Section 4.

Once the methods and implementation have been determined, the models for calculating GHG and LAQ emissions and noise essentially become calculating machines in a basic modelling system, delivering the output data. The differences between policy options then rely on the differences in the input data generated for each policy scenario as well as by any changes in the assumptions/data within each "calculating machine" resulting from the policy measure – changed by the analyst.

Section 2 also identified the list of key (ICAO CAEP) modelling requirements – which need to be addressed by a basic modelling system – which contains the following issues:

- Revised stringency LTO NOx standard
- Trends towards ICAO's Environmental goals

- Effects of achieving technology goals
- Effects of operational changes

Other requirements might emerge in the next years to come, of which analysis of economic measures is the key unknown.

Moreover, European modelling input – at ICAO CAEP level as well as at European and/or Member State level – should allow:

- Working at different levels of detail (appropriate level of granularity, see section 2.6)
- Opportunities for more Eurocentric assumptions
- Assessment of the effect of non-European assumptions
- Use of alternative future scenarios and fleets
- Increase in the number and type of stringencies modelled
- Modelling of European style CNS/ATM improvements
- Modelling of emissions trading and charging scenarios

Table 1 elaborates on the above-mentioned specifications and short term requirements re the basic modelling system. In more detail it provides information on what needs to be calculated following EEMA WP1 requirements, which mathematical model (or data) is required for this calculation and an answer to the query whether the EEMA prototype basic modelling system already meets these requirements.

What needs to be calculated following EEMA WP1 requirements re a basic modelling system?	Which mathematical model (or data) to use?	Checklist – does the current prototype basic modelling system meet the requirement?
@ individual model level		
Technology parameters – at fleet or generic aircraft type level; assessment at detailed aircraft type level requires the aircraft type modelling system as defined in the AERONET EFEMTA study Future fleet-rollover Future operations Working at different levels of detail (appropriate level of granularity) Opportunities for Eurocentric and non-European assumptions and impact assessment Use of alternative future scenarios and fleets	Technology modelling (sub)system Development of future fleet-rollover models using, e.g., Campbell-Hill data, new aircraft assumptions, current fleet Development of future operations – future fleet plus current operations (e.g., CAEP COD – Common Operations Database)	Technology development issues are currently introduced via input data generation using expert engineering judgement applied to the existing fleet replacements
Economic parameters – simple calculations; sophisticated economic assessment requires the responsive modelling system as defined in	Economics modelling (sub)system Economic analysis in	Not yet. Stand-alone version of one or

What needs to be calculated following EEMA WP1 requirements re a basic modelling system?	Which mathematical model (or data) to use?	Checklist – does the current prototype basic modelling system meet the requirement?
the AERONET EFEMTA study Working at different levels of detail (appropriate level of granularity) Opportunities for Eurocentric and non-European assumptions and impact assessment Use of alternative future scenarios	CAEP has traditionally been carried out by spreadsheet activity within FESG, but has limited economic impact assessment capabilities.	more AERO-MS modules is expected to fulfil requirements in the short term.
Noise: the number of people exposed to noise. As noise nuisance is highly correlated to local ATM procedures and population distribution, modelling "the system" to illustrate a general case for policy making is a significant challenge. Options include trying to model a large number of airports or modelling a smaller number of "representative" airport configurations or case studies. Working at different levels of detail (appropriate level of granularity) Opportunities for Eurocentric and non-European assumptions and impact assessment	Any model with noise modelling methodology according to ECAC Doc29R [3]	Partially. Models set up for individual airport rather then multiple batch analysis - ANCON2 -Yes - ENHANCE with Doc 29R non-compliant INM 6.2a version has been used; however, ENHANCE with Doc 29R compliant INM 7.0 version is now ready for use - SONDEO will be made compliant to Doc 29R in 2008
Local air quality (LAQ) emissions - CO2, NOx (HC, CO, particulates) mass assuming ICAO LTO (can be done by GHG models). Any further evaluation (including non-ICAO time in modes) requires airport level analysis. As add-on, not as part of basic modelling system: the impact of aviation emissions on local air quality around airports. NOx and PM are important to estimate, however other sources related to the airport activity also need to be modelled plus dispersion modelling is necessary to determine impact. Equivalent to noise nuisance, local air quality	Any model with LAQ emissions modelling methodology (as much as already possible) according to: - CAEP WG2-TG4 guidance material and modelling methodology [5] - SAE-AIR 5715 Procedure for the calculation of aircraft emissions [7] (Reference not yet	Neither document is yet finalised. -LASPORT is in agreement with the ICAO/CAEP document for the part of emissions inventory by way of both simple and advanced

What needs to be calculated following EEMA WP1 requirements re a basic modelling system?	Which mathematical model (or data) to use?	Checklist – does the current prototype basic modelling system meet the requirement?
impact is highly correlated to local activities and conditions. Modelling “the system” to illustrate a general case for policy making is again a significant challenge.. Noise-equivalent options include trying to model a large number of airports or modelling a smaller number of “representative” airport configurations or case studies. Working at different levels of detail (appropriate level of granularity) Opportunities for Eurocentric and non-European assumptions and impact assessment	publicly available)	method for aircraft -ADMS has not been evaluated based on these draft documents yet -ALAQS has not been evaluated based on these draft documents yet
Greenhouse gas (GHG) emissions - CO2, NOx (HC, CO, in future: particulates) mass: global Emissions: As add-on, not as part of basic modelling system: the impact of aviation greenhouse gas emissions on the global climate. Working at different levels of detail (appropriate level of granularity) Opportunities for Eurocentric and non-European assumptions and impact assessment	Any model with GHG emissions modelling methodology (as much as already possible) according to: - CAEP WG2-TG2 GHGM guidance material and modelling methodology [6] (Reference not yet publicly available) - SAE-AIR 5715 Procedure for the calculation of aircraft emissions [7] (Reference not yet publicly available)	Neither document is yet finalised. -AERO2k is expected to meet the requirements -AEM has not been evaluated based on these draft documents yet
@ system level		
Source emission and noise regulation, e.g., the revised stringency LTO NOx standard; requires powerful modelling of the economic and environmental consequences into to implement it Different number and type of stringencies to be modelled	Technology Economics Noise LAQ emissions GHG emissions	Yes for noise, LAQ and GHG emissions Partly for technology (via input data generation) Not yet for economics
Operational measures, e.g., effects of operational changes and modelling European style CNS/ATM improvements; their benefits – globally and locally – require modelling at	Technology at fleet level Economics Noise	Yes for noise, LAQ and GHG emissions Partly for

What needs to be calculated following EEMA WP1 requirements re a basic modelling system?	Which mathematical model (or data) to use?	Checklist – does the current prototype basic modelling system meet the requirement?
global and local scales in order to assess benefits and costs; often these will require assessment of airline economic effects as well as air traffic system capacity and environmental benefit; trade-offs between emissions, noise and economics are particularly important in this analysis	LAQ emissions GHG emissions PM: air traffic system capacity requires 4D modelling	technology (via input data generation) Not yet for economics Air traffic system capacity modelling not yet assessed as part of interdependency modelling
Technology insertion, e.g., effects of achieving technology goals; modelling – at fleet level – of the emissions and noise effect and economic costs of these developments requires both a global and an airport level approach	Technology Economics Noise LAQ emissions GHG emissions	Yes for noise, LAQ and GHG emissions Partly for technology (via input data generation) Not yet for economics
Not necessarily required as part of basic modelling system: Economic measures, e.g., modelling of emissions trading and charging scenarios; proposed instruments as a means to mitigate aviation environmental impact; the modelling system must be capable of representing (but not necessarily modelling) the costs resulting from the mechanisms of the civil aviation market; predicting the consequences of economic measures requires particularly sensitive modelling, involving changes in demand resulting from cost changes from the measures, the reaction of the various stakeholders and the consequences of those reactions	Usually needs the responsive modelling system (as defined in the AERONET EFEMTA study); however, simplified calculations possible with basic modelling system	Not yet, especially considering the economics part
Other policy-related modelling requirements, e.g., trends towards ICAO's Environmental goals; sustainability, evolution and goals assessments would be expected to be within the scope of modelling systems capable of assessing the global and regional policy measures covered earlier	Technology Economics Noise LAQ emissions GHG emissions	Yes for noise, LAQ and GHG emissions Partly for technology (via input data

What needs to be calculated following EEMA WP1 requirements re a basic modelling system?	Which mathematical model (or data) to use?	Checklist – does the current prototype basic modelling system meet the requirement?
		generation) Not yet for economics
Requirements as to the exact uses of the modelling system are unclear – and always will be; that is the changing nature of policy requirements; constantly developing and changing emphasis in the requirements; clearly any modelling system needs to be flexible enough to accept these changes with minimal adaptation Working at different levels of detail (appropriate level of granularity) Opportunities for Eurocentric and non-European assumptions and impact assessment Use of alternative future scenarios and fleets	Availability:- - of good quality input data sets (various sources) - of processes to translate this data into common (ie understood) formats usable by noise, emissions and finance models - of data pre-processors to allow individual models to take the common data into each individual model - of models (and resources) to process the data to obtain results - of common (or agreed) assumptions - only loose association of the various models, i.e. links are in data transfer issues only - of processes to transfer between granularity levels (see Section 2.6), either in the preparation of input data or the model pre-processing phases - of funds and management to resource the modelling data preparation and model runs (see Section 7) The “combination”	Most issues are still to be resolved when considering the specific policy option to be assessed.

What needs to be calculated following EEMA WP1 requirements re a basic modelling system?	Which mathematical model (or data) to use?	Checklist – does the current prototype basic modelling system meet the requirement?
	concept version, defined in section 2.10, appears to be the most practical and flexible one for the range of European models	

Table 1: Model Calculation requirements

It should be emphasised that the modellers' ability to invent better/fitter-for purpose models in the future should not be limited by strict adherence to documents with guidance materials and/or "gold standards". Moreover, when discussing "gold standards" – and this notion could apply to methodologies – it appears that, unlike noise, there are not yet any strict prescriptive standards for LAQ and GHG modelling.

This section considered the specifications, characteristics, mechanisms and interactions included in the basic modelling system. In addition, it presented the outcome of the check on whether or not a (minimum) set of requirements – as defined in EEMA WP1 – has been met. The next section addresses the still missing parts in – the EEMA prototype version of – the basic modelling system.

3.2.3 Missing Modelling Methodologies

The previous table shows that the major gaps in modelling are:

- Technology modelling (sub)system
- Economic modelling (sub)system

For the time being – and thus for the EEMA prototype version of the basic modelling system for use in the Euro-Modelling Demo (see Section 6) – specific technology developments are introduced via the generation of input data of (future) fleet technology and operations; this could be considered as a so-called "workaround" and discussed in more detail in Appendix C.

Economic assessment modelling is currently missing in the EEMA prototype modelling. Economic analysis in CAEP has traditionally been carried out by spreadsheet activity within CAEP's Forecasting and Economic Analysis Support Group (FESG). This has the advantage of simplicity but conversely does omit a number of economic effects. The current focus of CAEP is on four economic models of varying complexity and application – including the Netherlands' AERO modelling system (AERO-MS), the FESG CAEP/6 NOx Cost Model and two US models – APMT Cost-effectiveness and APMT Cost-benefit.

The Netherlands' AERO-MS contains sophisticated modules to calculate economic parameters related to the aviation system. As currently available, AERO-MS – in complete system setting – would not exactly process the 2005 and 2025 air traffic data as provided in the EEMA Data Warehouse as it should do. It would not calculate economic and environmental output parameters on the basis of the original flights. In practice, it manipulates, factorises and adjusts the original traffic data – via an internal loop system involving several AERO modules – in order to match balanced demand and supply parameters. These are fixed settings for a base year; currently in AERO, this is calibrated input data and assumptions for the base year 1992.

So, the final traffic data processed within AERO-MS will not be an exact copy of the original traffic data, but adjusted to demand & supply constraints in the base year. The currently available AERO model is fully calibrated for – the original base year – 1992. So in our case, output resulting from straightforward processing of the 2005 and 2025 traffic will be of little value. Full calibration of a new year (e.g., 2005) involves a work budget of around 100 kEuro and time needed to fulfil the calibration is about half a year. This is out of scope and beyond the budget and time limits of the EEMA project.

A stand-alone version of one or more AERO-MS modules seems to be the best candidate in order to fulfil requirements for the European modelling capability in the short term (Appendix D provides a summary of AERO-MS economic modelling capabilities). However again, time and budget needs are such that this cannot be done as part of the EEMA study.

3.2.4 Concluding Remarks and Future Recommendations

This section elaborated on the specifications and short term requirements re the basic modelling system. Following EEMA WP1 requirements, it provided more details on what needs to be calculated, which mathematical model (or data) should be used for this calculation and an answer to the query whether the EEMA prototype basic modelling system meets the requirements.

It was emphasised that the modellers' ability to invent better/fitter-for purpose models in the future should not be limited by strict adherence to documents, if any, with guidance materials and/or "gold standards".

Moreover, it was recognised that two major parts are still missing in – the EEMA prototype version of – the basic modelling system:

- Technology modelling (sub)system
- Economic modelling (sub)system

For the time being, specific technology developments are introduced via the generation of input data of (future) fleet technology and operations – using expert engineering judgement applied to the existing fleet replacements.

A stand-alone version of one or more AERO-MS modules seems to be the best short-term solution re the need for an economic modelling (sub)system – although out of scope of the EEMA project.

4 WP2 Specifying the System – Task 2 Input, Output, Interfaces and Data Exchange

This section focuses on the design of the EEMA Basic System, from general structure considerations to the listing of each model's inputs and outputs. The concept of *Data Warehouse* is introduced and detailed to refer to the system's data storage and exchange environment. The Data Warehouse serves as a link between the miscellaneous modelling data sources and models. It also stores the models' outputs and log reports for all runs performed in the context of an EEMA exercise, such as the Euro-Modelling Demo in Section 6.

4.1 DATA WAREHOUSE OVERVIEW

The term *Data Warehouse* has been chosen to describe the physical support of the EEMA Basic System. Indeed, aviation environmental modelling requires the management of numerous and large datasets, be they *static data* like airport references or *dynamic data* like flight movements. As shown in Figure 11 hereunder, the Data Warehouse plays an intermediate role between source data and models by storing and converting the former in a format directly reusable by the latter.

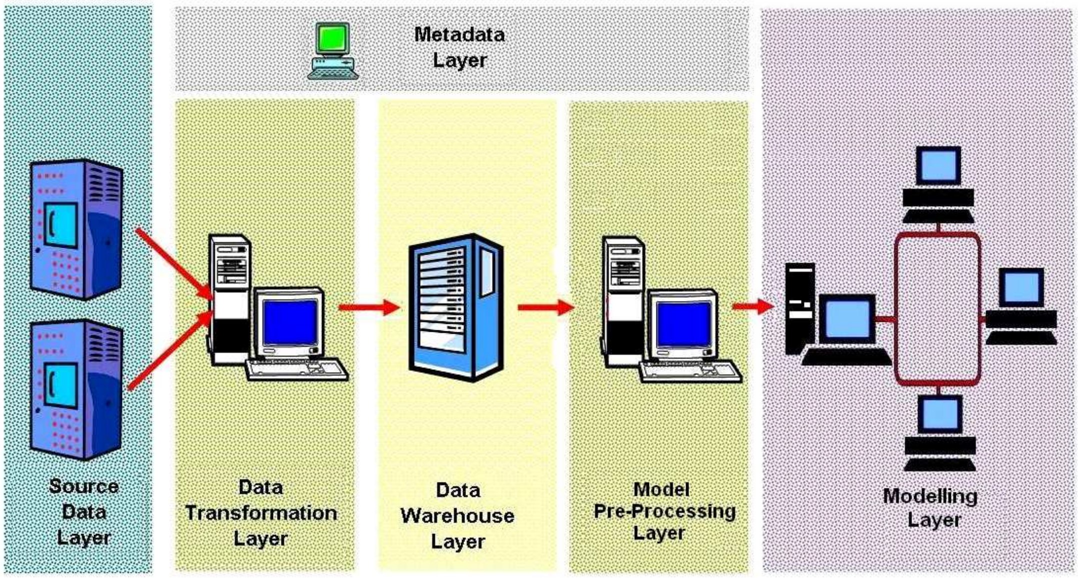


Figure 11: Data Warehouse and data exchange protocol

For the first Euro-Modelling Demo in Section 6, the Data Warehouse has been ported on an FTP (File Transfer Protocol) site. As a next-step improvement it could be moved to a web-based database allowing modellers to run queries and extract datasets directly adapted to their models.

A brief description of each layer in the above figure is given hereafter:

4.1.1 Source Data Layer

Included in the Source Data Layer are all the various input files, in whatever format and on whatever storage medium, that are routinely used by any of the models under consideration. This includes both *static* (e.g. airports, aircraft/engine data, ICAO engine emissions databank, aircraft equivalence table, BADA aircraft performance data, population statistics, etc.) and *dynamic* (such as aircraft movements, aircraft operations, meteorology, etc.) data sources. As a specific example of the static/dynamic divide, anything that is used to generate future fleets or operations (such as multiplying factors, etc.) should be seen as static while the fleets and operations themselves should be viewed as dynamic. It should be noted that static data may be updated as well, whenever new information is available.

4.1.2 Data Transformation Layer

The purpose of the Data Transformation Layer is to provide re-formatting functionality and/or instructions for importing and storing centralised data for use by all models (including future operations multiplication factors). Routines and/or importation specifications can be written (or supplied) for each static data source from the Data Source Layer. The re-formatting of data that need not or cannot be physically stored in the Data Warehouse (such as global flight trajectories) are handled by the Model Pre-Processing Layer.

4.1.3 Data Warehouse Layer

The purpose of the Data Warehouse Layer is to provide, in one place and in one common format, all centralized static data which is to be stored and used by all models. The Warehouse should also be used to archive models' outputs for all consecutive EEMA exercises.

It should be noted that in many cases the sizes of both the external input and output files for the dynamic data used by the various models (e.g. global flight trajectories) would, in general, be too large to be stored permanently within the Data Warehouse itself. As an alternative, data may be split into several downloadable files stored temporarily in the Warehouse, or (if still too time-consuming) they may be transferred to modellers via DVD, as has been done for the first Euro-Modelling Demo. This concerns GHG modellers performing global and/or long-time emission assessments essentially.

4.1.4 Model Pre-Processing Layer

The purpose of the Model Pre-Processing Layer is to output any of the static data fields to the specific data input formats required for any of the models. Routines can be written on an 'as-need' basis for each model, allowing for new ones to be plugged on the system. Dynamic data which has been re-formatted in the Data Transformation layer is also output for model accessibility.

4.1.5 Metadata Layer

The purpose of the Metadata Layer is the following:

i) to store in one location a list of all input and output data variables for all models, along with where, and how, they are stored;

ii) to keep a running log of system, model and data requirements changes;

iii) to provide a scenario-tracking system which records, for a particular study:

a) which models (and which version of models) were used,

b) time the models were run,

c) for what time period and location,

d) file name and location of external input dynamic data required for each model,

e) file name and location of all output dynamic data produced by each model,

f) contact information for the person conducting the study.

4.1.6 Modelling Layer

This layer includes all the actual noise/emission/economic calculation models (e.g. ANCON, SONDEO, LASPORT, ALAQS, ADMS, AEM, FAST and AERO2K). These models access both common 'cross-model' static data and other 'non-stored' dynamic data via the Model Pre-Processing Layer. Modellers remain in charge of running their own model and upload the output onto the Data Warehouse. The Metadata Layer tracks and logs the dynamic data files and common static data used, as well as logging the models and processes used during the modelling calculation.

4.2 MODELS INPUT & OUTPUT

This section details the process for building the EEMA Basic System's Data Warehouse. It is based on a survey of all candidate models in Work Package 1 about the input they require to run and the output they are able to produce. The final EEMA Models Input and Output tables are available in Appendices E and F.

4.2.1 List of Models

The table hereunder shows the list of the models that were included in the survey sorted by category – Greenhouse Gases (GHG), Local Air Quality (LAQ), Noise and Economics – along with the entity owning them or acting as focal point:

GHG	AEM	EUROCONTROL
	AERO2k	QinetiQ
	FAST	MMU
	AERO-MS	NLR
LAQ	LASPORT	Janicke Consulting
	ALAQS	EUROCONTROL
	ADMS	CERC
Noise	SONDEO	Anotec
	ANCON2	UK CAA
	ENHANCE	EUROCONTROL
Economics	AERO-MS	NLR

Table 2: List of the EEMA Basic System models

4.2.2 Input Data Categories

Input data were grouped into seven main categories, each of them divided into several sub-categories as show in the table hereafter:

Input Data Category	**Sub-Category**
Operations	Traffic Flight trajectory
Aircraft & Engine	Aircraft equivalent Aircraft list Aircraft / engine match Engine list Performance coefficients Standard LTO profiles
Airport	Airport infrastructure Terrain / population
Fuel, Emission & Noise	En-route fuel flows LTO emissions VOC / TOG[7] class constants Noise-Power-Distance data
Meteorological Data	Standard atmosphere Relative humidity Airport meteorological data
Traffic Forecast	Future fleet Future operations
Economics	Price of emissions Air transport data

Table 3: List of input data categories

It should be noted that the above classification does not necessarily reflect the actual structure of the models' input datasets: e.g. some noise models may actually need two distinct input files for flight trajectories – one for ground tracks, the other for flight profiles.

Each sub-category in Table 3 was detailed into more specific fields, e.g. for the *Operations / Traffic* sub-category: *Departure Airport*, *Take-Off Time*, *Aircraft Type*, etc. For each field, modellers were asked to specify whether it is a required, optional or ignored input data for their model, using the following terminology:

Required	Data/value that is used at some point and for which the model has no default
Optional	Data/value that is used at some point but for which the model has its own set

[7] VOC – Volatile organic Compounds, TOG – Total Organic Gases

	of default if not user-specified
Not used	Data/value that is not used at any point in the tool's algorithm (ignored)

Table 4: Input data requirement levels

The issue was raised that the requirement level of an input field may depend on the desired precision of output: e.g. wind information is required if dispersion is to be applied to a Local Air Quality computation, although it is not if dispersion is ignored. In such cases, modellers were asked to consider the field as optional, while indicating its link to the output through a comment or footnote to the input data table.

Modellers were also asked to add any required or optional field that was missing from the initial list. Answers from all modellers were then compiled into the table in Appendices E an F.

4.2.3 Output Data Categories

Along with input data, a survey of models' output was carried out. Results of the survey would notably allow a better design of future EEMA modelling exercises, among which the first Euro-Modelling Demo, by ensuring models are capable of computing what they are asked to.

The ten output data categories are listed hereunder:

- Flight trajectory processing
- Pollutants
- Noise metrics
- Groupings
- Local Air Quality regulatory metrics
- Output geographical area
- Grids (emissions)
- Grids (concentrations)
- Contours
- Economics.

Each category was divided into more detailed items: e.g. CO_2, NO_x, H_20, etc. for the *Pollutants* category. For each item, modellers were asked to specify whether their model could calculate the information directly, with some pre- or post-processing, or could not calculate it. The following terminology was used:

Direct	The information is part of the model's output
Post-processing	The information can be obtained by post-processing the model's output
Not available	The information cannot be retrieved by the tool nor by post-processing the model's output
Pre-processing	The information can be obtained in output if extra data is provided in input

Table 5: Output data availability levels

Pre-processing essentially refers to providing the GHG or LAQ models with emission rates for additive pollutant types such as VOC, TOG, PM, etc.

For convenience reasons, all models' outputs were grouped into a single table available in Appendix as well.

4.3 DATA WAREHOUSE CONTENT

The first version of the EEMA Basic System's Data Warehouse was created under an MS Access database. The database was initially populated with a wide range of EUROCONTROL data for environmental modelling, with addition of the Aircraft Noise and Performance (ANP) database and ICAO LTO emission data.

Once feedback was obtained on models' required input data and the scope of the first Euro-Modelling Demo was defined (see next section), the first version of the Data Warehouse was finalised, featuring a set of tables sufficient to have all ten models run. A summary of the warehouse's filled tables is given hereafter:

Category	Table Name	Record #	Data Source
Operations	Flight Operations	4,124,512	GAES-MOVE 2005
	Flight Trajectories	4,124,512	GAES-MOVE 2005
Aircraft & Engines	Aircraft Equivalent	1,214	AEM, ALAQS, ENHANCE
	Aircraft List	704	ALAQS
	Aircraft-Noise Match	122	ANP
	Aerodynamic Coefficients	778	ANP
	Standard LTO Profiles	648	ANP
Airport	Airport Coordinates	8818	GAES-MOVE 2005
	Runway Coordinates	10	AIP (Zurich & Warsaw)
Emissions	LTO Emission Rates	2,012	ICAO Engine Emissions Databank Issue 14
	LTO Times-in-Mode	5	ICAO
Noise	Noise-Power-Distance Data	1,579	ANP
	Spectral Classes	29	ANP

Table 6: Data Warehouse's content description

The detailed list of fields for each table is available in the *Data Warehouse Content Description* document (in Appendix G).

4.4 DATA EXCHANGE PROTOCOL

One key objective of the EEMA Basic System is to harmonise and facilitate the process of data collecting and preparing to European modellers. This includes providing models with the data they need in the format and units they need.

Therefore, once information was obtained about their models' input and output, modellers were asked to provide further information about their preferred data formats and units, so that the *Model Pre-Processing Layer* could be built – essentially MS Access queries and macros to filter the Data Warehouse's content. Feedback was collected from 5 models out of 10 only[8]. The main reason for this low feedback is probably the lack of time given to modellers, since preparing a model input specification document may be time-consuming for those models which do not have one already. Furthermore, some modellers may have feared that the EEMA modelling exercise would turn into a model benchmark. Several of them expressed their preference to perform the input data conversion by themselves. Therefore, it was decided in agreement with EASA to export the Data Warehouse tables in generic data format (such as ASCII files) and units and leave modellers do the necessary conversions for the first Euro-Modelling Demo to be performed as a next – post-processing – step to the project.

An FTP site was created by EUROCONTROL to host the ASCII version of the Data Warehouse and login information was distributed among modellers. In addition to the datasets in Table 6, the FTP features a 'Doc' folder with extra documentation on its content (such as the *Data Warehouse Content Description* document, available in Appendix G) and on the first Euro-Modelling Demo. A specific folder was added for modellers to upload their outputs and run log reports.

4.5 CONCLUSION

The work performed under WP2 Task 2 has set the basis of the EEMA Basic System both in terms of structure and content. A first Data Warehouse has been designed and developed, which serves as a link between existing input data sources and European models. Its role is threefold:

- store all input and output data that may be stored;
- ensure all appropriate data format conversions;
- keep track records of all model runs performed within the EEMA framework and all updates of stored data.

The current MS Access version of the Data Warehouse features input datasets from EUROCONTROL, the ICAO or the Aircraft Noise and Performance (ANP) database. Some additive verification (search for errors), normalisation (removal of duplicate information) and completion efforts would be advised before it can be officially used for pan-European modelling activities. The issue of data confidentiality and/or property should be investigated as well. Further data completion essentially depends on the harmonisation level one wish to achieve between models, e.g.:

- Base Level: Models are provided with traffic data/trajectories; they apply their own aircraft substitutions, aircraft-engine match, performance/emission /noise coefficients.
- Medium Level: Models are provided with traffic data/trajectories, aircraft substitutions and aircraft-engine match; they apply their own performance/ emission/noise coefficients.
- High Level: Models are provided with traffic data/trajectories, aircraft substitutions, aircraft-engine match and performance/emission/noise coefficients.

[8] Feedback supplied by AERO2k, ANCON2, AEM, ALAQS, ENHANCE

Obviously, higher harmonisation levels are more difficult to achieve as it must be demonstrated that this is best practise in order for modellers' to accept that they should modify part of their models' core data. This is a valid aim in order to reduce the differences in outputs from one model to the other, however flexibility should be maintained to constantly review and improve this best practise.

For the first Euro-Modelling Demo described in Section 6, a base/medium harmonisation level was chosen: modellers were provided with traffic and trajectory data (including aircraft-engine matches), as well as noise and emission coefficients. This approach showed good acceptance from modellers and yielded different yet convergent outputs.

Finally, further improvement of the EEMA Basic System should include the design of a web-based user-friendly interface, as well as routines to convert the warehouse's data into formats that are directly readable by models. Whilst this could be a resource intensive exercise to accommodate the needs of all European models, the effort required would depend on the number of models involved and the required harmonisation level between those. Whilst it is simpler from an EEMA development view point if modellers perform the file conversion by themselves, the final choice depends on how much freedom/effort is to be given/asked to modellers in formulating the problem to be modelled.

5 WP2 Specifying the System – Task 3 Selecting the Best

With a significant number of existing models which have the potential to be incorporated into a European Modelling System, there is risk that in seeking to incorporate them all, the system will become over complex and unaffordable. Within the remit of the basic modelling system addressed by this project, these complexity issues have been identified to ensure that the system remains practical whilst retaining enough flexibility to meet foreseeable future policy needs and to incorporate important emerging component tools.

5.1 CRITERIA FOR DOWN-SELECTION

Model down-selection - the exclusion of a model or tool from becoming part of the overall system – might be required due to:

- incompatibility
- fidelity
- relevance
- availability
- confidentiality

5.1.1 Incompatibility

The compatibility of the model and its assumptions with the data exchange protocol developed within this Work Package.

5.1.2 Granularity and accuracy

The ability of the model to produce policy responses adequate for informed policy assessment.

5.1.3 Relevance

The relevance of the model capabilities to European policy modelling needs, including the assumptions used within the model.

5.1.4 Availability

The expected availability of the model to participate in a European Modelling System in an open and timely manner.

5.1.5 Confidentiality

In the case of non-publicly available tools, the modelling organisation's demonstrated ability to conduct confidential studies

5.2 DOWN-SELECTION

The question arises as to how to make the down-selection judgements within the context of the EEMA project – which addresses only a prototype basic modelling system. Beyond EEMA there is expectation of the development of a broader and more capable modelling system with wider scope. Of particular relevance is the data warehouse developed in this work package. The warehouse is essentially flexible and can accommodate additional data in different formats where this is available and is required by particular models.

There are perhaps dozens of other models of varying quality in academic, government and industry within Europe. Data gathering and subsequent fair assessment of all these models is well beyond the scope of this work. The call for models raised with AERONET, XNOISE and European CAEP members brought forward the 10 emissions and noise models described in Table 2 above, all of which are already under assessment by CAEP. Within the context of basic modelling assessment, these models are established within European policy modelling and this process is still ongoing. Whilst there are issues, such as the current non-compliance of the SONDEO noise model with the latest version of Doc29R, none of these issues currently disqualify a model on grounds of "fidelity", accepting that some models will be more suited to some types of policy analysis than others. Any down-selection at this prototype stage appears unnecessary, at least on the technical grounds of fidelity, relevance, availability and confidentiality. The only remaining technical criterion, compatibility, was tested as part of the test sample analysis, described in the next Section. Whilst there are some compatibility issues to be resolved, as described below, there are none which require a model to be eliminated.

In addition to the formal, technical criteria outlined in Section 5.1, there is the issue of cost – of maintenance and of operation of these models. Maintenance and updating of models attracts a cost and the maintenance of multiple models therefore attracts more cost that just a single model. Similarly operation of multiple models attracts extra cost, although in this case there are significant benefits in terms of the quality of the final output when results from different models with different methodologies are available for comparison. Nevertheless, the question still arises as to whether there are grounds for model down selection on the grounds of cost.

At this current prototype stage, there are no direct additional costs incurred by EASA as a result of running the 10 models as part of this EEMA project. For the future, there are wider considerations of the evolution of a European modelling system, including the use of the modelling system by various EC bodies and by individual States. Each may have financial and or technical reasons to select one particular model or to run more than one model. Both of these considerations counsel against down selection at this stage. For the future, should EASA, or any other entity, wish to use the modelling system to carry out specific analyses, there will be the option to choose either one model from of each type (LAQ, GHG and noise) or to run multiple models. In the former case, the selection could be carried out competitively or on any of the down selection criteria outlined in Section 5.1. In neither of these cases will additional costs be incurred compared to those which would have been incurred if down selection had been carried out at this early stage.

As a consequence, no down-selection of the 10 models has been carried out as part of this project.

For the future, as new models emerge, they will need to be assessed, either informally or formally against the outline criteria shown above. In the case of compatibility with the source data, additions can be made to the data warehouse to accommodate emerging models.

6 WP3 Test Sample Analysis

The EEMA prototype basic modelling system – described in Sections 2-5 – has been subjected to a detailed test program as part of work package 3 (WP3) of the EEMA project. The test has been named Euro-Modelling Demo – to avoid confusion with a parallel test in the framework of ICAO/CAEP (called: NOx Sample Problem). The Euro-Modelling Demo was to demonstrate the prototype basic modelling system in operation, especially the linkages between the various models and the EEMA Data Warehouse system. Moreover, it was to tease out problems and to identify any *remaining gaps* in the modelling system. Any such remaining gaps could be all kinds of technical, operational, legal and/or organisational issues arising.

6.1 INTRODUCTION

The setup in European coordination of a basic modelling system – for carrying out policy assessment studies and interdependent modelling of noise, local and global emissions and economics – is unique. The EEMA prototype basic modelling system was therefore subjected to an initial test program, called the Euro-Modelling Demo, to demonstrate the prototype system in operation and to identify gaps.

For the *Euro-Modelling Demo*, the EEMA prototype basic modelling system consisted of the EEMA Data Warehouse system and several ICAO/CAEP candidate models for the calculation of noise, local and global emissions and economic parameters. In case of a relevant gap in the prototype system, a workaround has been developed, whenever and wherever reasonable considering limitations in project budget and time. Other gaps arising - of technical, operational, legal and/or organisational nature – are, e.g., registered in logbooks by modellers and reported in the current report and recommended for future consideration.

The focus of the Euro-Modelling Demo was system demonstration and identification of remaining system gaps. For instance, details and accuracy of input and output data were considered to be of lower priority. Therefore, both the modelling input and output data should be considered as **test data only**.

NLR coordinated the Euro-Modelling Demo which – from start of preparations to end of data analysis and reporting – covered the period February to July 2007. It had full support of the other EEMA team members, Envisa and QinetiQ, and also excellent support was provided by Eurocontrol and European modellers from Anotec Consulting (ES), CERC (UK), Janicke Consulting (DE) and the UK CAA.

The next section (Section 6.2.1) outlines the activities and other relevant matters re the Euro-Modelling Demo. Section 6.2.2 then reports and discusses the modelling results and subsequently in Section 6.2.3 the identified gaps and lessons learned from the Euro-Modelling Demo. This chapter ends with conclusions and recommendations in Section 6.3

6.2 EURO-MODELLING DEMO - INFORMATION AND OUTCOME

This section first addresses all relevant matters concerning the Euro-Modelling Demo and secondly it reports on the outcome of the Euro-Modelling Demo runs.

6.2.1 Euro-Modelling Demo Matters

Demo introduction and activities

As mentioned earlier, in the Euro-Modelling Demo, the EEMA prototype basic modelling system was subjected to initial tests to demonstrate tool linkages in operation and to tease out problems (gaps).

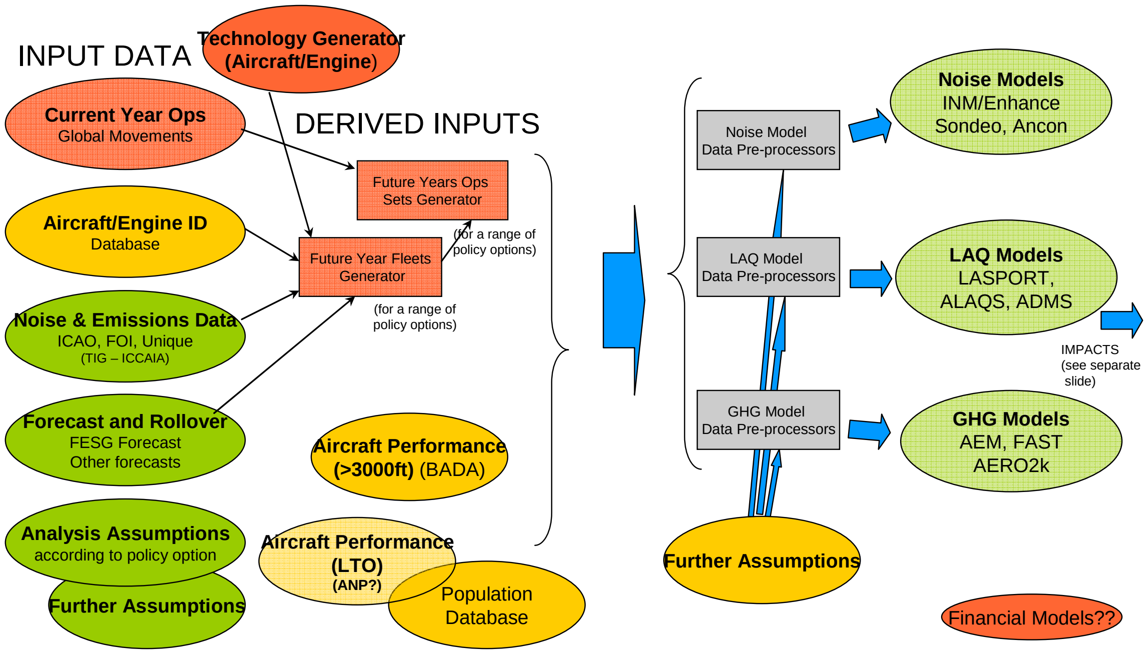


Figure 12: The Basic Modelling System

More specifically, the Euro-Modelling Demo consisted of the assessment of the NOx, fuel and noise effect of the imposition of a change of NOx regulation in ICAO Annex 16. The proposed rule Demo change is (close to the maximum likely CAEP/8 stringency considerations):

- *20% increase in NOx stringency, agreed in 2010, coming into force in 1 January 2013*

The effect of this change has been assessed for the year 2025 (using the ICAO FESG 2020 forecast and assumptions extrapolated to 2025). The NOx stringency itself has been simulated by not delivering engines into the fleet which do not meet the stringency, after 1 January 2013. See Appendix C for details.

The Euro-Modelling Demo took place in the period February to July 2007, starting off with mobilising the involved European modellers, preparation and dissemination of a Euro-Modelling Demo plan and preparation of the actual Demo runs and input data. During the Demo running phase (a couple of weeks in June), two telephone conferences were held for coordination and monitoring progress. At the end, the Demo output data have been analysed and discussed, and the results are presented in Sections 6.2.2 and 6.2.3.

Demo objectives

Basically, the test should demonstrate the feasibility and proper working of the prototype basic modelling system. The test would be successful, albeit for the moment with workarounds, when the whole process could be completed and the system is performing as expected; using input data from the EEMA Data Warehouse, running the various models in parallel and storing relevant output data in the data warehouse. The Euro-Modelling Demo should further identify gaps and subsequent needs for enhancement of (elements of) the prototype basic modelling system including pre- and post-processing modules. Therefore the modellers have been asked to keep a log(book) and note any assumption and/or workaround applied (data or modelling) and any other emerging issue that may concern a technical, operational, organisational and/or legal (IPR/ownership) issue.

Apart from these main test objectives, i.e. demonstrate tool linkages in operation and to tease out problems (gaps), other issues to be tested were:

- Time needed to run the whole process
- Data warehouse:
    - Availability, format/semantics and accessibility of data in the data warehouse and permission to use and store (external) data in the data warehouse
    - Process of adding and removing data
- Workarounds:
    - where needed (identify needs for future updates)
    - how does it affect the outcome, and is there still consistency with similar models
- Obvious system output and response on changes in input data

Demo pre-requisites, pre-conditions and assumptions

The following list provides the main pre-requisites, pre-conditions, assumptions and other remarks which were relevant for the Euro-Modelling Demo:

- The proposed rule change is: a 20% increase in NOx stringency, agreed in 2010, coming into force in 1 January 2013. The effect of this change will be assessed for the year 2025, using extrapolation of the 2002 FESG forecast and an accompanying set of FESG-like assumptions regarding, e.g., rollover and aircraft size.
- For the stringency case, it is assumed that non-compliant engines are replaced by engines which meet the stringency. Where a suitable replacement engine, which is close to the original engine in both thrust and overall pressure ratio and which meets the stringency requirement, can be identified, then that engine is used. Where no suitable replacement engine exists in the current ICAO databank, a new engine is invented, with a representative thrust level and pressure ratio and with a NOx level which meets the stringency by a small margin. To provide an adequate range of engines for the analyses, a total of ten "new" engines have been created. More detailed information on this is provided in Appendix C. (NB: This approach differs from that of previous FESG analyses, where non-compliant engines are assumed to be made compliant by modification.)
- While the main focus of the Euro-modelling demo is on demonstrating the working of the basic modelling system and identifying gaps, details and accuracy of input and output data are of lower priority.
- Use as much as possible and reasonable the input data available in the EEMA Data Warehouse system; if not or in case specific input data (e.g., on taxiing

at an airport) is missing, the “workaround” and reasons behind should be reported in a logbook.

- The output of the Demo runs is mass of emissions and noise contour areas.
- Only one pollutant is considered for the Euro-modelling demo run: NOx, as being one of the main concerns at airports.
- Six (6) weeks of air traffic data (from year 2005 and extrapolated for year 2025) have been used for the modelling; however, to improve presentation and interpretation, this data have been annualised via pre- or post processing.
- Warsaw airport and Zurich airport have been identified as suitable airports to run a case study. For both airports, 2005 traffic data with runway allocation was available. Moreover, Warsaw airport is a typical medium-sized airport in the eastern part of Europe with a fleet of relative small (in size) jet aircraft versus Zurich airport which is a typical larger-sized airport in the western part of Europe with a broad range of jet aircraft in the fleet.
- The focus for input/output of local air quality (LAQ) tools will be on aircraft only –on the ground and in the air – below 1000 ft as well as below 3000 ft altitude. Subsequently, non-aircraft sources are not considered in the Euro-Modelling Demo.

Input and Output Data

Input and output data relevant for the Euro-Modelling Demo are stored in the EEMA Data Warehouse system, which was actually a password-protected ftp site (by courtesy of Eurocontrol Experimental Centre in France); see Section 4 for more details on the EEMA Data Warehouse. The population of the data warehouse has been done by Envisa with support from QinetiQ on fleet data (see Appendix C). For the Euro-Modelling Demo the data included:

- 2005 base year static and dynamic input data
- 2025 forecast/scenario business as usual without stringency measure
- 2025 forecast/scenario with 20% NOx stringency measure.

Basically, six (6) weeks of air traffic movements’ data from year 2005 were used covering approx 4 million of flights globally. For year 2025 – the same 6 weeks – air traffic data has been generated by using extrapolation of the 2002 FESG forecast and an accompanying set of FESG-like assumptions regarding, e.g., rollover and aircraft size (see Appendix C).

For reasons of presentation and interpretation, however, results on an annual basis are preferred. Therefore, via pre- and post-processing, the data are annualised in the following way(s):

- Re GHG emissions modelling: as part of post-processing, GHG-NOx-emissions per day (i.e. 42 days = 6 weeks of air traffic x 7 days per week), have been multiplied with a ‘day multiplier’ and summed
- Re LAQ emissions and noise modelling: two separate airport air traffic files are available – one for Warsaw airport and one for Zurich airport (rigorously having the same flights to/from these airports as in the traffic files used for GHG emissions modelling). These files include a day multiplier for annualisation. Noise modellers need this for pre-processing; LAQ emissions modellers may apply this day multiplier in the pre- or post-processing.

Models and Modellers Involved

The basic modelling methodologies behind the computations of aircraft noise and local and global emissions and aviation economy are addressed in Section 3.

The various models and modellers, actually involved in the Euro-Modelling Demo, were:

- Data Warehouse system – run by ENVISA (FR), and located on a password-protected ftp site by courtesy of Eurocontrol Experimental Centre (FR)
- Local air quality (LAQ) emissions modelling –
    - ADMS run by CERC (UK)
    - ALAQS run by ENVISA (FR)
    - LASPORT run by Janicke Consulting (DE)
- Greenhouse gas (GHG) emissions modelling –
    - AEM run by ENVISA (FR)
    - AERO2K run by QinetiQ (UK)
    - FAST from MMU (UK) [NB: MMU were unable to provide the resources and did not supply results within the period of the contract.]
- Noise modelling –
    - ANCON2 run by UK CAA
    - ENHANCE/INM run by ENVISA (FR)
    - SONDEO run by Anotec Consulting (ES)
- Economic modelling – not available, as explained in Section 3

6.2.2 Results of the Euro-Modelling Demo Runs

The results of the Euro-Modelling Demo runs – for 2005 and for 2025 without and with the 20% NOx stringency measure – are presented in this section. The outcome of the subsequent data analysis is also added. This is done first separately for noise, local emissions and global emissions and then the interdependencies/tradeoffs are considered

In order to get a grip of the number and composition of aircraft movements involved, some input data statistics in round/approx figures are given in the next table and figure [8].

Number of flight operations in 2005	**6 non-successive weeks (round/approx figures)**	**Annual(lised) (round/approx figures)**
Global	4 million	35 million
@ Warsaw airport	12 thousand	110 thousand

@ Zurich airport	19 thousand	175 thousand
Number of flight operations in 2025		
Global	10 million	90 million
@ Warsaw airport	32 thousand	270 thousand
@ Zurich airport	51 thousand	450 thousand

Table 7: Numbers of aircraft movements involved in the Euro-Modelling Demo

NB: At the end of the project, from the analysis of Euro-Modelling Demo data and results and comparing them with data available from the Zurich airport operator, it became apparent that for 2005 only 175 thousand (i.e. 67%) out of the total of (approx) 260 thousand flights at Zurich airport have been processed. This was due to an error in the queries that selected the Zurich airport related flights from the global air traffic database (i.e. Eurocontrol's GAES-MOVE database). This also applies for Warsaw airport, although the proportion of dropped flights is less (about 10%). In general, owing to the variety of dropped aircraft types, the relative development of airport noise and local air quality from one scenario to the other should be very close to the one that would be obtained with total traffic – absolute values are, of course, underestimated. Furthermore, it should be emphasised that this does not harm the objectives of the Euro-Modelling Demo, i.e. system demonstration and identification of remaining system gaps.

Figure 13 provides an indication of the composition of the fleet at Warsaw airport as well as at Zurich airport; i.e. the percentage distribution of different aircraft groups [9e].

[NB: Applied short-cuts mean: large jet (JL); medium jet (JM); small jet (JS); regional jet (JR); business jet (JB); turboprop (TP); propeller (PP)]

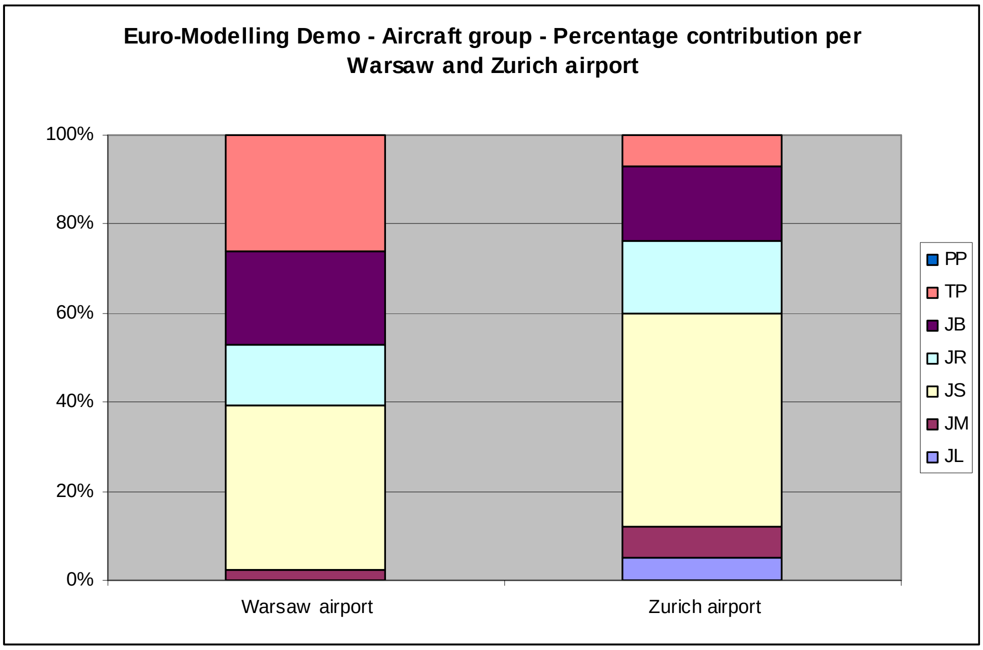


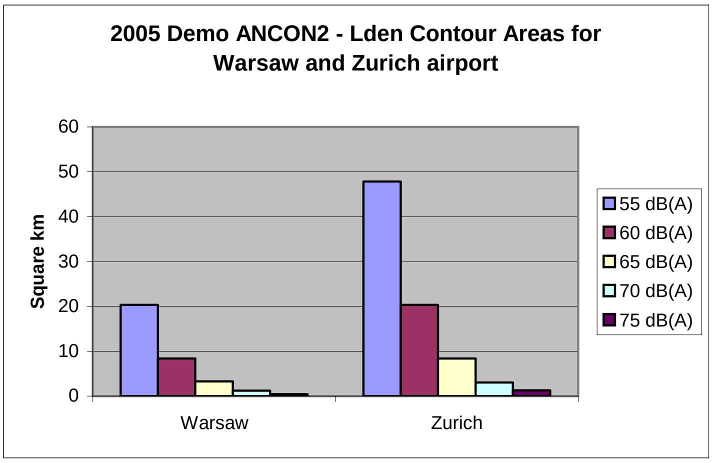
Figure 13: Percentage by Aircraft Category at Warsaw and Zurich Airport

Noise modelling results

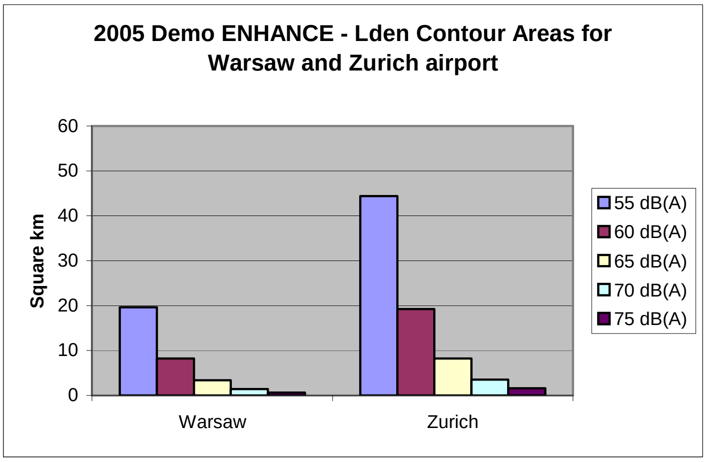
In the Euro-modelling demo exercise, the output parameter for noise modelling has been the size of Lden noise contour areas in square kilometres (Sqkm) (see for modelling and calculation methodology: Section 3, and modellers' log reports [9]). Noise contours of 55, 60, 65, 70 and 75 dB(A) Lden are considered for year 2005 and year 2025 cases at Warsaw airport and at Zurich airport. Actually two 2025 cases are considered: one without a stringency (0% case) and one with a 20% NOx stringency (20% case).

The next three graphs in Figure 14 show the results of noise model runs for year 2005 with respectively the ANCON2, ENHANCE/INM and SONDEO model.

2005 - Lden Contour Areas (Sqkm) ANCON2 model		
dB(A)	Warsaw	Zurich
55	20.34	47.84
60	8.39	20.35
65	3.26	8.37
70	1.25	3.05
75	0.43	1.32



2005 - Lden Contour Areas (Sqkm) ENHANCE/INM		
dB(A)	Warsaw	Zurich
55	19.58	44.39
60	8.22	19.26
65	3.41	8.26
70	1.39	3.52
75	0.61	1.59



2005 - Lden Contour Areas (Sqkm) SONDEO model		
dB(A)	Warsaw	Zurich
55	17.76	41.44
60	7.72	17.97
65	3.21	9.13
70	1.31	3.42
75	0.48	1.16

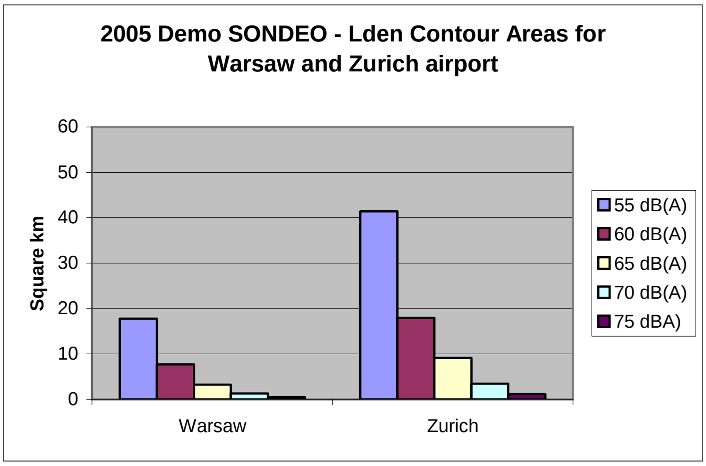


Figure 14: Noise contour results for 2005 base year

In each graph the contour area – in square kilometres (Sqkm) – for each five above-mentioned noise load values (in dB(A) Lden) are given for Warsaw and Zurich airport. These results of the noise modelling are obvious:

- Considering the uncertainties in the detailed modelling, the results of all three noise models are incredibly similar. Area variations are around ±10 percent, which is equivalent to about ±0.5dB. This is really better agreement than could have been anticipated.

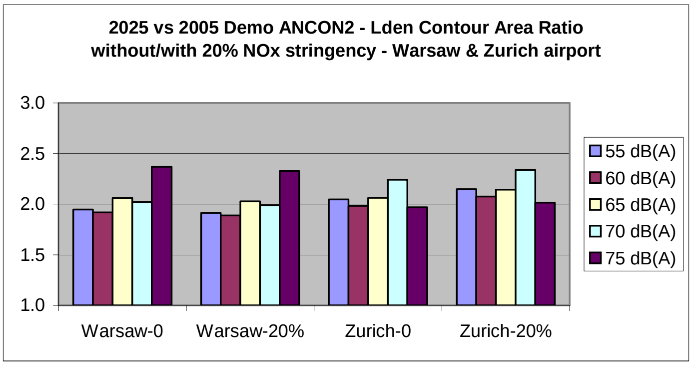
- With increasing noise load level, the Lden contour area becomes smaller.
- The similar Lden contour area is larger for the busiest airport from which relatively larger aircraft operate; i.e. Zurich airport with approx 175 thousand movements of relatively larger aircraft compared to Warsaw airport with approx 110 thousand movements in 2005.

NB: Unfortunately, it was not possible to compare the demo results with Lden contour area information from the airport operators; Switzerland and therefore Zurich airport does not use Lden as a national metric, but uses Lday (6h-22h) and Lnight (22h-23h; 23h-24h; 5h-6h); no information has been received from the Warsaw airport operator. Neither any other (literature) source has been found.

The following 3 pairs of graphs show the 2025 results of noise model runs, again with respectively the ANCON2, ENHANCE/INM and SONDEO model.

Ratio of Lden contour area in 2025 vs 2005
ANCON2 model

dB(A)	Warsaw-0	Warsaw-20%	Zurich-0	Zurich-20%
55	1.95	1.91	2.05	2.15
60	1.92	1.89	1.98	2.07
65	2.06	2.03	2.06	2.14
70	2.02	1.99	2.24	2.34
75	2.37	2.33	1.97	2.01



2025 stringency effect - % change in Lden contour area
in 20% NOx vs no stringency case
ANCON2 model

dB(A)	Warsaw	Zurich
55 dB(A)	-1.68	4.91
60 dB(A)	-1.59	4.62
65 dB(A)	-1.58	3.95
70 dB(A)	-1.66	4.33
75 dB(A)	-1.88	2.28

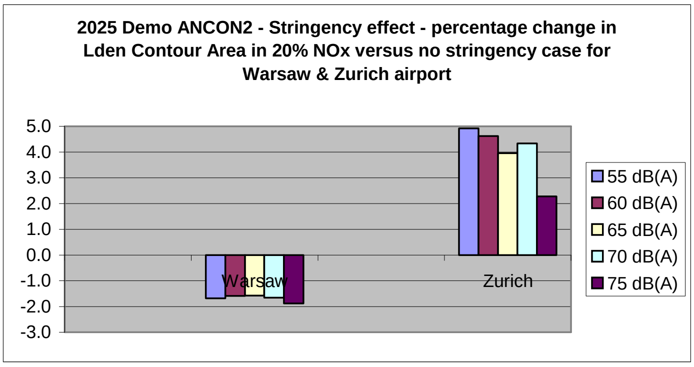
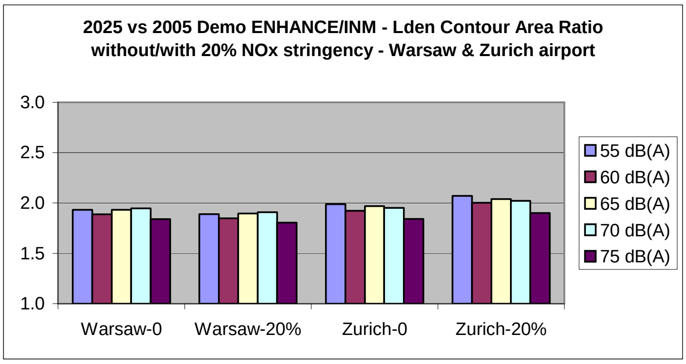


Figure 15: ANCON2 noise contour results – 2025 vs 2005

Ratio of Lden contour area in 2025 vs 2005 ENHANCE/INM model				
dB(A)	Warsaw-0	Warsaw-20%	Zurich-0	Zurich-20%
55	1.93	1.89	1.99	2.07
60	1.89	1.85	1.92	2.00
65	1.93	1.90	1.97	2.04
70	1.95	1.91	1.95	2.02
75	1.84	1.80	1.84	1.90



2025 stringency effect - % change in Lden contour area in 20% NOx vs no stringency case ENHANCE/INM model		
dB(A)	Warsaw	Zurich
55 dB(A)	-2.25	4.20
60 dB(A)	-2.04	4.05
65 dB(A)	-1.84	3.56
70 dB(A)	-1.99	3.62
75 dB(A)	-1.86	3.14

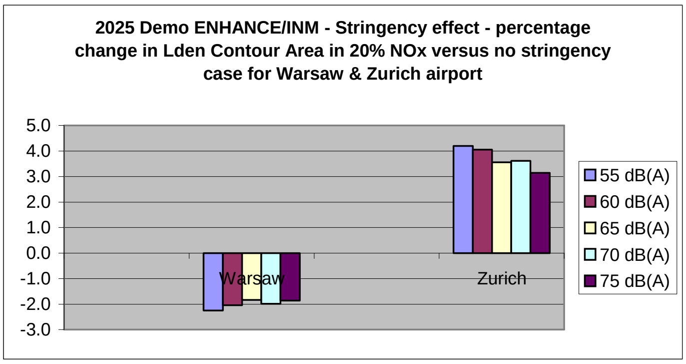
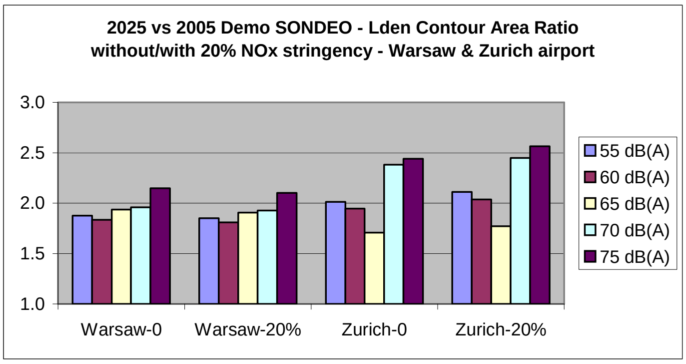


Figure 16: ENHANCE/INM noise contour results – 2025 vs 2005

Ratio of Lden contour area in 2025 vs 2005 SONDEO model				
dB(A)	Warsaw-0	Warsaw-20%	Zurich-0	Zurich-20%
55	1.88	1.85	2.01	2.11
60	1.84	1.81	1.95	2.04
65	1.94	1.91	1.71	1.77
70	1.96	1.93	2.38	2.45
75	2.15	2.10	2.44	2.57



2025 stringency effect - % change in Lden contour area in 20% NOx vs no stringency case SONDEO model		
dB(A)	Warsaw	Zurich
55 dB(A)	-1.43	4.96
60 dB(A)	-1.38	4.57
65 dB(A)	-1.50	3.78
70 dB(A)	-1.68	2.75
75 dB(A)	-2.02	5.16

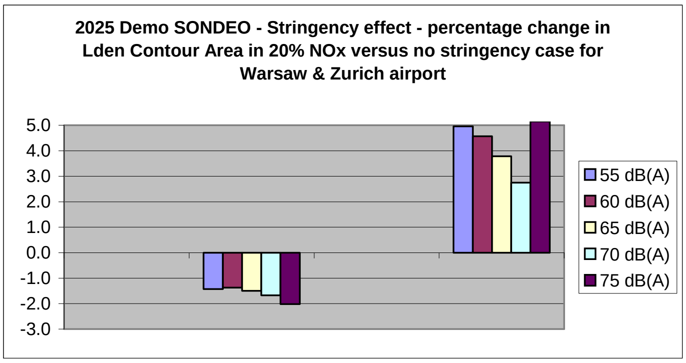


Figure 17: SONDEO noise contour results – 2025 vs 2005

In the first graph of each pair, the ratio of Lden contour area size in 2025 versus 2005 are given for each of the five noise load values for both the non and the 20% NOx stringency case, for Warsaw airport as well as Zurich airport. Some points of discussion re the modelling results are:

- The first graph (of each pair) shows that in general the Lden contour area in 2025 is about twice as big as the 2005 one (following an approx 160% increase in number of movement; i.e. the traffic enhancement factor of approx 2.6). Some observed larger and lower ratios at high noise load levels are related to the small overall contour size (i.e., almost entirely within the airport boundary); a small absolute deviation may result in a big change in ratio. One technical reason will be the grid resolution: the size of the grid, either variable or standard across the entire calculation grid. Furthermore, the alignment of the calculation grid, e.g., with the dominant runway will also affect the calculated contours.
- The second graph (of each pair) shows for Warsaw airport in 2025 a decrease in Lden contour area of 1.4% to 2.3% due to the 20% NOx stringency measure; on the contrary, for Zurich airport it shows an estimated increase in Lden contour area of 2.3% to 5.2%. This opposing stringency effect is linked to the proportion of fleet with aircraft noise adjustment factors other than 1 (one) going from the non-stringency scenario to the 20% NOx stringency scenario for 2025. [NB: this noise adjustment factor is applied to the aircraft movement number; a factor equal to 1 means no noise adjustment, a factor less than 1 account for a less noisy aircraft-engine combination and a factor higher than 1 account for a more noisy combination] Warsaw airport seems to benefit from its large proportion of Boeing 737-300/400/500 aircraft types, which individual noise should be reduced with the stringency. On the contrary, Zurich airport seems to be penalised by its large number of Fokker 100 aircraft types and – to a lower extent – Airbus A320 and A340-300. Individually these aircraft increase noise following the stringency measure.

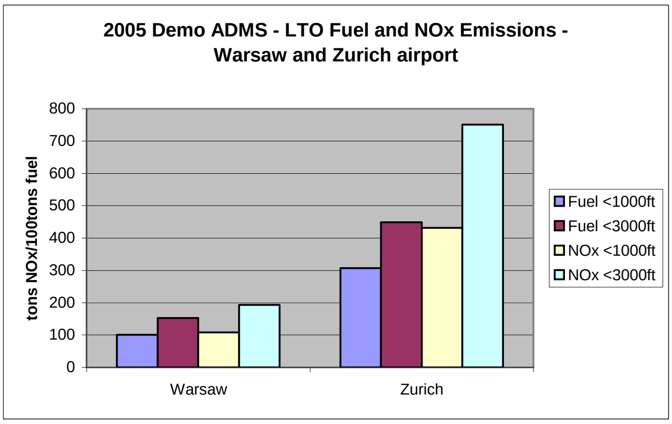
In conclusion, the test criteria related to noise modelling have been fulfilled. With the intuitive results shown above, the noise tool linkages in operation have been demonstrated. A couple of minor problems (gaps), mainly related to input data processing and IT (i.e., posting of output data in EEMA Data Warehouse), have been identified and “worked around”. In more detail, these are reported in the next Section 6.2.3. Finally, the time needed to do the noise modelling including pre- and post processing differed per model: two, four and nine days for ENHANCE/INM, ANCON2 respectively SONDEO; although the latter model needed five days to be adapted in order to accommodate for the way in which flight tracks were defined (especially for arrivals).

LAQ emissions modelling results

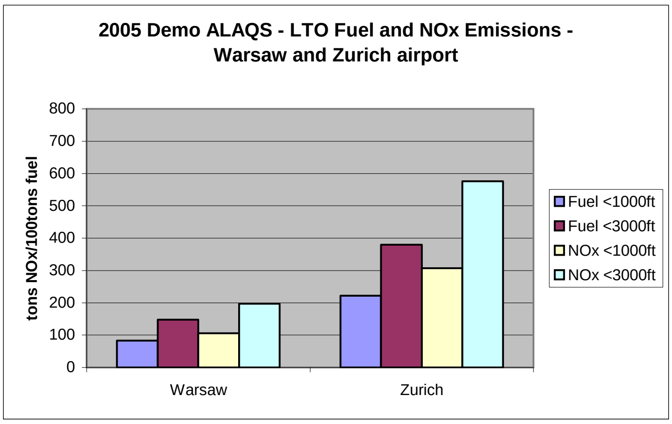
In the Euro-modelling demo exercise, the output parameter for local air quality (LAQ) emissions modelling has been the mass of NOx emissions and fuel used, both in (kilo)grams (see for modelling and calculation methodology: Section 3, and modellers’ log reports [9]). Mass numbers have been computed below 1000ft altitude as well as below 3000ft. As for noise, computations are done for Warsaw airport and Zurich airport for year 2005 and year 2025 – the latter year without and with a 20% NOx stringency measure.

The following three graphs in Figure 18 show the results of LAQ emissions model runs for year 2005 with respectively the ADMS, ALAQS and LASPORT model.

2005 - Mass (NOx: tons; fuel:100 tons)		
	ADMS model	
	Warsaw	Zurich
Fuel <1000ft	100.75	306.70
Fuel <3000ft	152.58	448.88
NOx <1000ft	108.45	431.96
NOx <3000ft	192.96	751.11



2005 - Mass (NOx: tons; fuel:100 tons)		
	ALAQS model	
	Warsaw	Zurich
Fuel <1000ft	83.21	221.72
Fuel <3000ft	147.54	379.74
NOx <1000ft	105.84	306.81
NOx <3000ft	197.16	575.65



2005 - Mass (NOx: tons; fuel:100 tons)		
	LASPORT model	
	Warsaw	Zurich
Fuel <1000ft	129.41	332.71
Fuel <3000ft	201.03	507.44
NOx <1000ft	117.65	344.39
NOx <3000ft	211.28	614.74

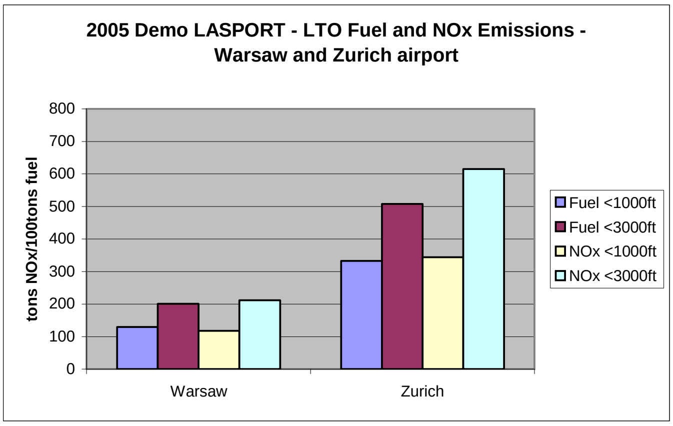


Figure 18: LAQ model fuel and NOx results for 2005 base year

In each graph the landing & takeoff (LTO) cycle NOx emissions and fuel consumption – in metric tonnes respectively 100 metric tonnes – are given for Warsaw and Zurich airport, separately for below 1000ft and below 3000ft. The modelling results are obvious:

- LTO fuel and NOx emissions mass numbers below 3000ft are a factor of 1.5 to 2.0 higher than the mass numbers below 1000ft
- The results of all three LAQ models show similar trends. It needs a further study – not in the EEMA remit – to track down the exact reasons for the observed differences, in absolute numbers. However, they are not due to errors in the EEMA Data Warehouse or data transfer protocols. They seem to originate from each

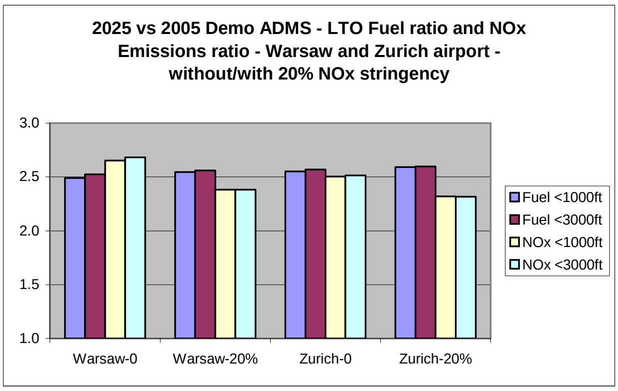
modellers group applying different taxiing assumptions and different flight profile and performance based modelling in the LTO flight phases: i.e. different time-in-mode (TIM), thrust settings and fuel flow calculation schemes. Taxiing assumptions concern assumptions on taxi distance (i.e., choices on taxiways and route network for taxiing), taxi speed and queuing time. All these were not prescribed and/or included in the EEMA Data Warehouse, and do vary between the models. Section 6.2.3 provides recommendations to include these assumptions and prescriptions for future modelling activities.

- The results are of the same order of magnitude as the numbers available in literature. Reference [10] shows that in 2005 approx 267 thousand aircraft movements at Zurich airport caused a NOx emission of 991 tonnes per annum and a fuel consumption of 80 thousand tonnes per annum – derived from CO2 emissions value. The Euro-Modelling Demo results for Zurich airport show for the processed, approx 175 thousand aircraft movements (i.e., 66%) an annual NOx emission ranging from 576 to 751 tonnes (i.e., 58-76%) and an annual fuel consumption ranging from 38 to 51 thousand tonnes (i.e., 48-64%).
- Consultation with the authorities and other data sources (currently not publicly available) shows that the Euro-Modelling Demo for Warsaw airport processed approx 90% of actual aircraft movements with annual NOx emission ranging 87-95% of those estimated by the authorities.

The following 3 pairs of graphs show the 2025 results of LAQ model runs, again with respectively the ADMS, ALAQS and LASPORT model.

Ratio of mass LTO fuel or NOx emissions in 2025 vs 2005
ADMS model

	Warsaw-0	Warsaw-20%	Zurich-0	Zurich-20%
Fuel <1000ft	2.49	2.55	2.55	2.59
Fuel <3000ft	2.52	2.56	2.57	2.60
NOx <1000ft	2.65	2.38	2.50	2.32
NOx <3000ft	2.68	2.38	2.51	2.32



2025 stringency effect-% change in LTO fuel or NOx emissions
in 20% NOx vs no stringency case
ADMS model

		Warsaw		Zurich
Fuel <1000ft	0.00	2.19	0.00	1.53
Fuel <3000ft	0.00	1.43	0.00	1.07
NOx <1000ft	0.00	-10.23	0.00	-7.35
NOx <3000ft	0.00	-11.20	0.00	-7.87

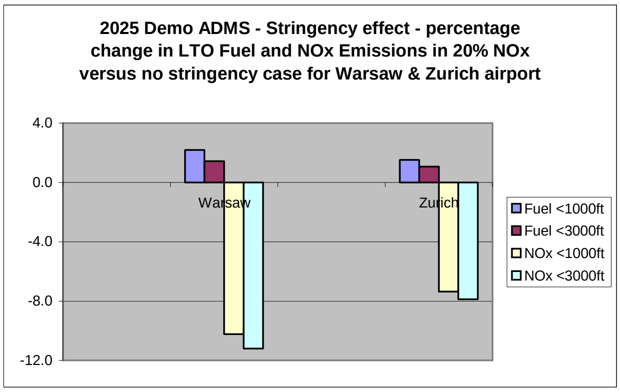
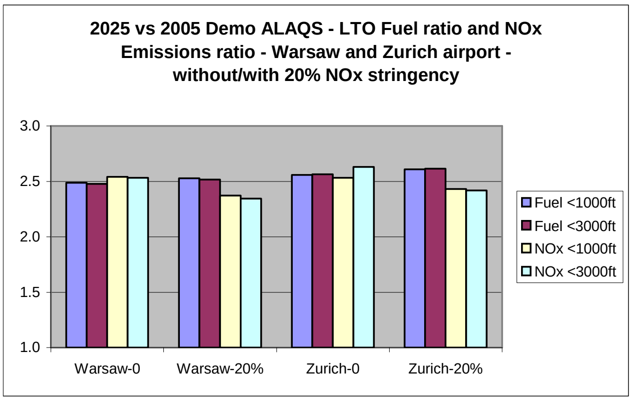


Figure 19: ADMS fuel and NOx results – 2025 vs 2005

Ratio of mass LTO fuel or NOx emissions in 2025 vs 2005 ALAQS model				
	Warsaw-0	Warsaw-20%	Zurich-0	Zurich-20%
Fuel <1000ft	2.49	2.53	2.56	2.61
Fuel <3000ft	2.48	2.52	2.56	2.61
NOx <1000ft	2.54	2.37	2.53	2.43
NOx <3000ft	2.53	2.35	2.63	2.42



2025 stringency effect-% change in LTO fuel or NOx emissions in 20% NOx vs no stringency case ALAQS model				
		Warsaw		Zurich
Fuel <1000ft	0.00	1.62	0.00	2.02
Fuel <3000ft	0.00	1.61	0.00	1.96
NOx <1000ft	0.00	-6.60	0.00	-4.00
NOx <3000ft	0.00	-7.42	0.00	-8.10

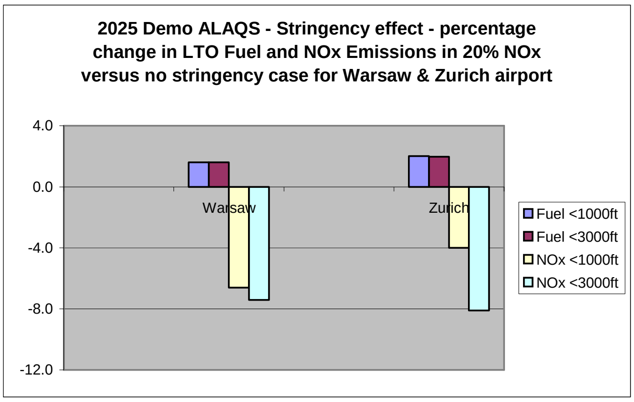
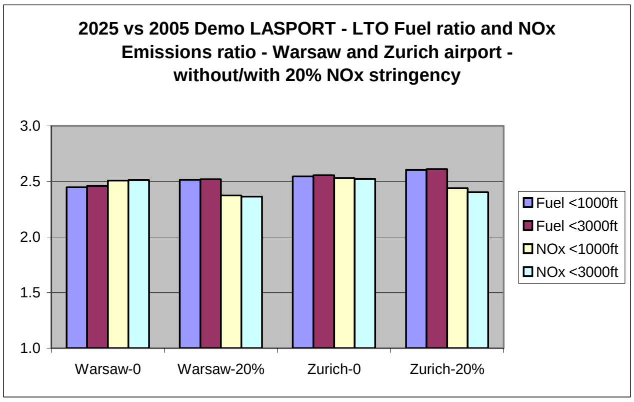


Figure 20: ALAQS fuel and NOx results – 2025 vs 2005

Ratio of mass LTO fuel or NOx emissions in 2025 vs 2005 LASPORT model				
	Warsaw-0	Warsaw-20%	Zurich-0	Zurich-20%
Fuel <1000ft	2.45	2.52	2.55	2.61
Fuel <3000ft	2.46	2.52	2.56	2.61
NOx <1000ft	2.51	2.37	2.53	2.44
NOx <3000ft	2.51	2.36	2.52	2.40



2025 stringency effect-% change in LTO fuel or NOx emissions in 20% NOx vs no stringency case LASPORT model				
		Warsaw		Zurich
Fuel <1000ft	0.00	2.87	0.00	2.33
Fuel <3000ft	0.00	2.41	0.00	2.15
NOx <1000ft	0.00	-5.33	0.00	-3.56
NOx <3000ft	0.00	-5.91	0.00	-4.69

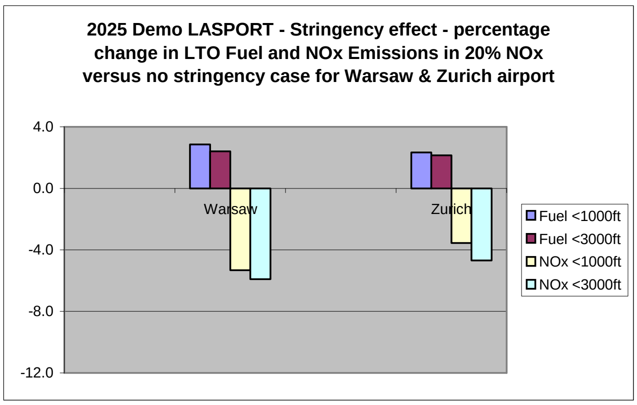


Figure 21: LASPORT fuel and NOx results – 2025 vs 2005

In the first graph of each pair, the ratio of LTO fuel respectively NOx emissions in 2025 versus 2005 are given for below 1000ft and below 3000ft cases for both the non- and 20% stringency case, for Warsaw airport as well as Zurich airport. Some points of discussion re the modelling results are:

- The first graph (of each pair) shows that in general the LTO fuel and NOx emissions in 2025 are a factor of approx 2.5 higher compared to the 2005 numbers (following an approx 160% increase in number of movement; i.e. the traffic enhancement factor of approx 2.6).
- The second graph (of each pair) shows for Warsaw and Zurich airport in 2025 an increase in LTO fuel of 1-3% due to the 20% NOx stringency measure. Concerning NOx emissions, a decrease of between 5 and 11% has been calculated for Warsaw airport, and between 3 and 8% for Zurich airport. The differences in percentages– when comparing Warsaw and Zurich airport numbers – are due to earlier-mentioned differences in fleet mix. And when comparing high and low percentages per airport between models, due to some extremes in NOx emissions levels in the non-stringency case in 2025 versus 2005 (factor higher than 2.6) calculated by the ADMS model in the Warsaw case and the ALAQS model in the Zurich case (below 3000 ft). Again this needs a further study – not in the EEMA remit – to track down the exact reasons for these differences, but they also seem to originate from each group applying non-prescribed and therefore varying taxiing assumptions and different flight profile and performance based modelling in the LTO flight phases.
- In addition to the effect on noise load (i.e., getting much worse at Zurich airport and improving a bit at Warsaw airport), when considering NOx emissions at both airports, the 20% NOx stringency measure has relatively more (positive) impact at Warsaw airport compared to Zurich airport. This means that the fleet at Zurich airport – with relatively larger aircraft – is less affected with respect to LTO NOx emissions, compared to the fleet at Warsaw airport – with relatively smaller aircraft. In the absence of any other effect, the stringency would tend to have larger percentage effects on larger aircraft with engines with higher overall pressure ratio (OPR). However, the dominant effects are the fleet mix and the actual engines replaced during the fleet rollover to future years. Significant further analysis would be required to assess the detail contributions.

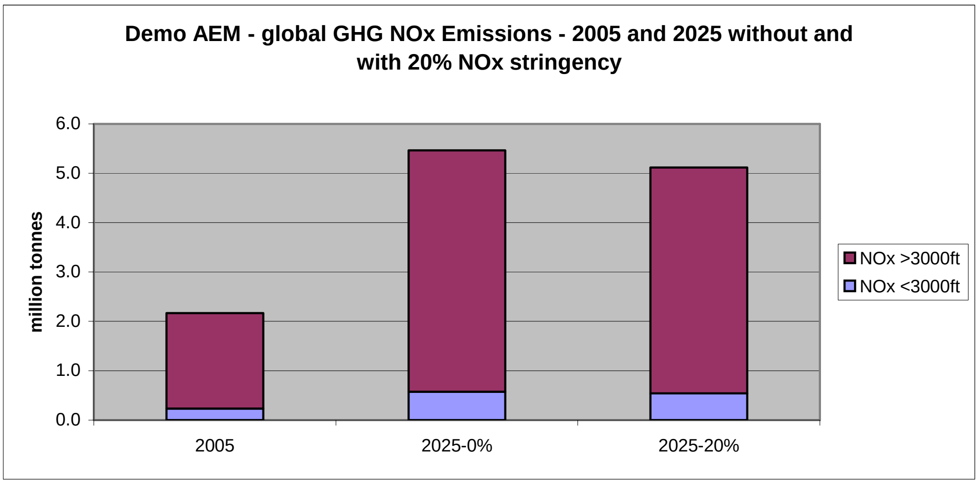
In conclusion, the test criteria related to local air quality (LAQ) emissions modelling have been fulfilled. With the intuitive results shown above, the LAQ emissions tool linkages in operation have been demonstrated. Again, a couple of minor problems (gaps) have been identified and “worked around”; these concern mainly taxiing assumptions and IT (i.e., posting of output data in EEMA Data Warehouse). In more detail, these are reported in the Section 6.2.3. On average, the time needed for the whole LAQ emissions modelling process (e.g., data pre-processing, model construction, model runs and data post-processing) was reported by the modellers as being less than one week in this particular Euro-Modelling Demo case.

GHG emissions modelling results

In the Euro-modelling demo exercise, the output parameter for greenhouse gas (GHG) emissions modelling has been the global mass of GHG NOx emissions in (kilo-)grams and, if available, fuel consumption as well (see for modelling and calculation methodology: Section 3, and modellers’ log reports [9]). Mass numbers have been computed for below 3000ft altitude and separately for above 3000ft (N.B. 3000ft being the standard landing and takeoff – LTO – ceiling). As for noise and LAQ emissions, the GHG NOx emissions computations are done for year 2005 and year 2025 – the latter year without and with a 20% NOx stringency.

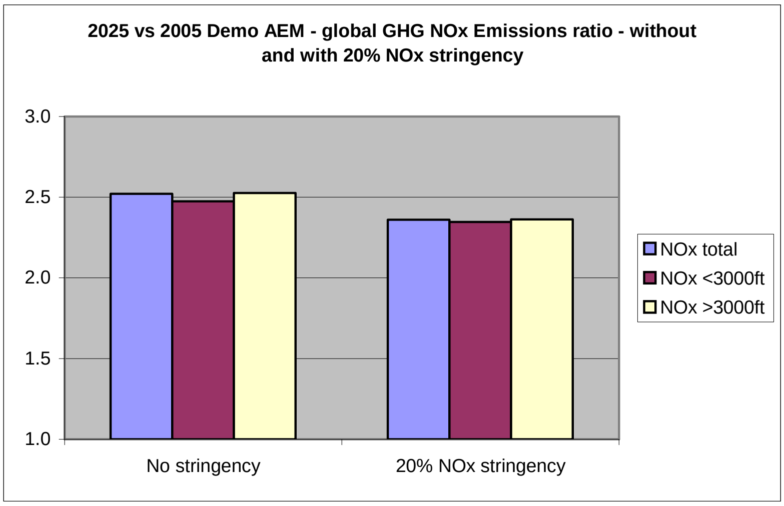
Initially, three GHG emissions calculation models would participate in the Euro-modelling demo: AEM run by Envisa (FR), AERO2K by QinetiQ (UK) and FAST by MMU (UK). In the end, MMU were unable to provide the resources and did not supply FAST results within the period of the contract. While pre-processing AERO2k input data, QinetiQ was faced with errors – related to apparent inconsistencies in flight trajectory data - which require further investigation outside the EEMA remit. Nevertheless, AERO2k data for one day – 8 February – has been prepared to allow results to be compared for the various GHG models. Envisa completed all Euro-Modelling Demo runs with the AEM model. Results from AEM model runs for a full year (2005 or 2025) are shown below as well as results from both AEM and AERO2k model runs for the one day only case – 8 Feb.

Firstly, Figure 22 and Figure 23 show the results of AEM emissions model runs for year 2005 and 2025 without and with a 20% NOx.



GHG NOx Emissions Mass (million tonnes)				
	AEM_Yearly computation			
	2005	2025-0%	2025-20%	Stringency effect in %
NOx total	2.17	5.46	5.12	-6.32
NOx <3000ft	0.23	0.57	0.54	-5.14
NOx >3000ft	1.94	4.89	4.58	-6.45

Figure 22: AEM GHG NOx emissions – 2005 and 2025



Ratio of mass global GHG NOx emissions in 2025 vs 2005			
	AEM_Yearly computation		
	No stringency	20% NOx stringency	Stringency effect in %
NOx total	2.52	2.36	-6.32
NOx <3000ft	2.47	2.35	-5.14
NOx >3000ft	2.53	2.36	-6.45

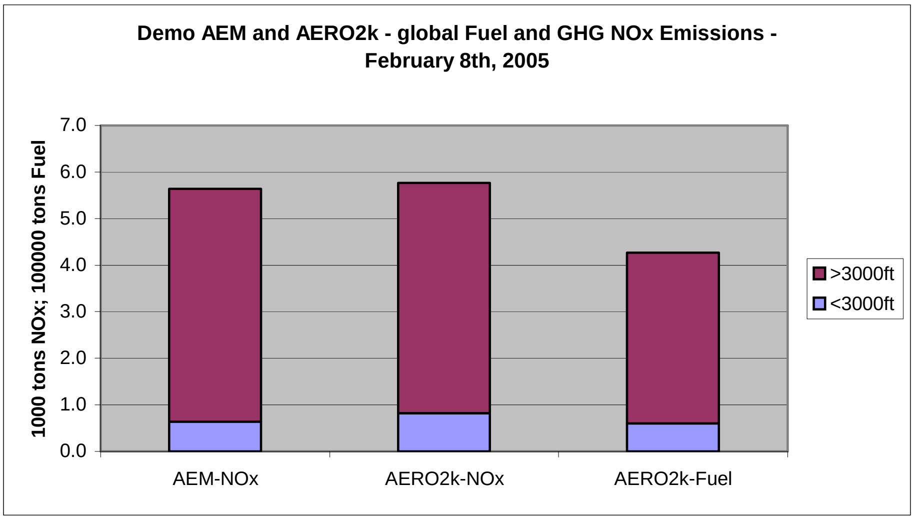
Figure 23: AEM GHG NOx emissions ratios – 2005 and 2025

In Figure 22 the annual mass numbers of global GHG NOx emissions – in million tonnes (i.e. metric tonne = 1000 kg) – are given, calculated with the AEM model. Mass is provided as total annual numbers and separately for below 3000ft and above 3000ft. The modelling results are obvious:

- The results are comparable with the numbers available in literature, at least for 2005. From previous AERO2k studies [11] the global NOx production in 2002 was 2.058 Tg or million tonnes, compared to the 2.17 million tonnes of NOx calculated with AEM. For 2025, previous AERO2k studies estimated a global NOx production of 3.308 million tons compared to the current more than 5 million tons of NOx calculated with AEM in both – non-stringent and stringent – 2025 cases. This difference is most probably due to a significantly more progressive NOx technology roll-over scenario applied in the former AERO2k studies.
- The introduction of a 20% NOx stringency measure has an intuitive impact on the annual mass number of global GHG NOx emissions: in total, it decreases with more than 6 percent (i.e., 6.3%).
- NOx emissions below 3000ft amount to about 10% of the total mass of NOx emissions.

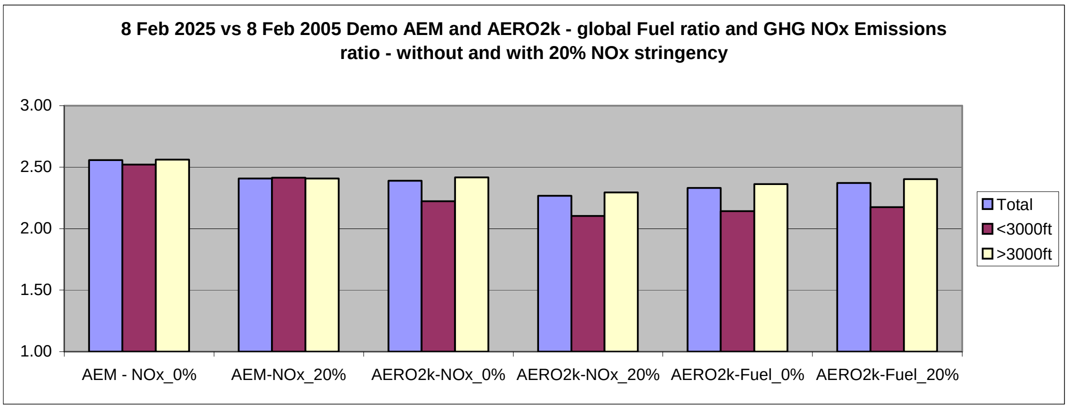
The corresponding Figure 23 clearly shows that the mass ratio of GHG NOx emissions in 2025 versus 2005 is about 2.5 in the non-stringency case. This corresponds quite well to an approx 160% increase in number of movement (i.e. applying the traffic enhancement factor of approx 2.6). Moreover, the NOx mass ratio is about 2.35 in the 20% NOx stringency case. This is subsequent to the 6.3% decrease in annual global NOx emissions due to the stringency measure.

Next, similar graphs as above are shown below, however now for the one day only case (i.e. 8 February) with results from AEM and AERO2k model runs. AERO2k results include global fuel consumption estimates.



GHG NOx emissions & global fuel mass (NOx: 1000 tons; Fuel: 100000 tons) AEM and AERO2k calculations for one day (8 FEB 2005)			
	AEM-NOx	AERO2k-NOx	AERO2k-Fuel
Total	5.64	5.76	4.27
<3000ft	0.64	0.82	0.60
>3000ft	5.00	4.94	3.67

Figure 24: GHG model fuel and NOx results for 8 Feb 2005



Ratio of mass global fuel or GHG NOx emissions on 8 February 2025 vs 8 February 2005 AEM and AERO2k calculations for the one day only case (i.e. 8 February)						
	AEM - NOx_0%	AEM-NOx_20%	AERO2k-NOx_0%	AERO2k-NOx_20%	AERO2k-Fuel_0%	AERO2k-Fuel_20%
Total	2.56	2.41	2.39	2.27	2.33	2.37
<3000ft	2.52	2.41	2.22	2.10	2.14	2.17
>3000ft	2.56	2.41	2.42	2.30	2.36	2.40

Stringency effect (%)			
	AEM - NOx stringency effect in %	AERO2k-NOx stringency effect in %	AERO2k-Fuel stringency effect in %
Total	-5.85	-5.05	1.69
<3000ft	-4.22	-5.42	1.47
>3000ft	-6.06	-4.99	1.73

Figure 25: AEM and AERO2k Fuel and NOx ratios – 8 Feb. 2025 vs 8 Feb. 2005

Figure 24 shows mass numbers of global fuel and GHG NOx emissions – in 100,000 tonnes respectively 1,000 tonnes (i.e. metric tonne = 1000 kg) – calculated with the AEM model (NOx only) and the AERO2k model. Mass is provided as total numbers and separately for below 3000ft and above 3000ft. The modelling results are obvious:

- The NOx emissions results of both GHG emissions models are comparable.

- NOx emissions below 3000ft are about 10-15% of the total mass of NOx emissions on this particular day. Fuel below 3000 ft is approx 14%.

Figure 25 provides results on mass ratio of global fuel and mass ratio of GHG NOx emissions for 8 February 2025 versus 8 February 2005. The results cover both the AEM modelling output and the AERO2K modelling output in the non-stringency case as well as in the 20% NOx stringency measure case (in total and also separately for below 3000ft and above 3000ft). Some points of discussion re the modelling results are:

- The one-day mass ratios calculated with the AEM model are comparable with the annual mass ratios in Figure 23; 2.56 in the non-stringency case and 2.41 in the 20% NOx stringency measure situation subsequent to an approx 6% decrease in one-day global NOx emissions due to the stringency measure.
- The one-day NOx mass ratios calculated with the AERO2k model are approx 0.15 lower; the calculated stringency effect is therefore also about 1% lower but still a decrease of about 5% in one-day global NOx emissions due to the stringency measure.
- The one-day fuel mass ratios calculated with the AERO2k model are comparable with the AERO2k NOx mass ratios in the non-stringency case; however in the 20% NOx stringency case, the fuel mass ratios increases (approx 0.04) subsequent to a negative stringency effect on fuel, i.e. an increase of 1.7%, related to the stringency measure The AERO2k modellers' suggestion for the observed "dips" in fuel and NOx mass ratios is that the increase in fuel burn (as a factor) above 3000ft is greater than that below 3000ft; this could result from greater growth on long-range routes (e.g. Asia-Pacific) than on short-range routes (e.g. US domestic).

In conclusion, the test criteria related to greenhouse gas (GHG) emissions modelling have also been fulfilled. With the (obvious) results shown above, the GHG emissions tool linkages in operation have been demonstrated. Some major problems have been identified and "worked around"; these concern especially flight trajectory data issues. Minor problems as well, e.g., on practical IT level: downloading multi-Mb files, uploading and firewall issue. In more detail, these are reported in the Section 6.2.3. The time needed to do the whole GHG emissions modelling process (i.e. data pre-processing, calculations, data post-processing) was about eight days for AEM and – in case of a successful process – estimated to be of the same amount of days for AERO2k (NB: majority of days spent on actual calculations). However, this would have been between 1 and 2 months if no CAEP material could have been re-used and all scenarios should have been fully run.

Interdependency modelling

The above-mentioned fuel, emissions and noise results from the Euro-Modelling Demo demonstrate not only the effective tool linkages in operation but also interdependency. The (below) summary of results shows that the 20% NOx stringency measure gives a 5-6% NOx reduction at global and a 4-11% NOx reduction at (considered) airport level. This is, however, at the penalty of an increase in Lden noise contour area at Zurich airport of 2-5%. On the contrary, at Warsaw airport the stringency appears to be reducing the Lden noise contour area by around 2%. Another penalty concerns fuel: a 1-3% increase in local (LTO) and global fuel consumption.

In overview and more detail, the 20% NOx stringency measure has the following impacts as calculated / estimated in the framework of the Euro-Modelling Demo:

- Noise:
  - for Warsaw airport, a decrease in Lden contour area of 1.4% to 2.3%
  - for Zurich airport, an increase in Lden contour area of 2.3% to 5.2%
- LAQ emissions:
  - for Warsaw and Zurich airport an increase in LTO fuel of 1-3%
  - concerning NOx emissions, a decrease of 5.9% to 11.2% for Warsaw airport (i.e. below 3000ft; below 1000ft: 5.3% to 10.2%) and a decrease of 4.7% to 8.1% for Zurich airport (i.e. below 3000ft; below 1000ft: 3.6% to 7.4%)
- GHG emissions:
  - annual global GHG NOx emissions decrease with 6.3%
  - a 5-6% decrease in one-day global NOx emissions
  - 1.7% increase in one-day fuel consumption

It is worth noting that no attempt has been made within this project to reconcile the (relatively small) differences between the various models. This aspect is being addressed for the models which took part in this EEMA project as part of the CAEP model evaluation process.

6.2.3 Gaps identified and lessons learned from the Euro-Modelling Demo

Concerning the Euro-Modelling Demo, the model runs demonstrated good results and, above all, interdependency. The work and engagement of the involved European modellers have been good up to excellent. Moreover, a lot of other Euro-Modelling Demo things went (very) well.

Nevertheless, a couple of issues should be highlighted in this gaps and lessons learned section. Following from requested modellers' logbooks [9] and other EEMA project experiences, these issues have been identified; some are resolved already, others are recommended to be resolved in future interdependency modelling activities.

Next, a short list of gaps and lessons learned is provided and subsequently these short-listed issues are discussed in more detail. Short list of gaps and lessons learned:

- Organisational level:
  - available resources
  - IPR and other sensitive data handling
- IT level:
  - limited ftp access
  - downloading multi-Mb files
  - no permission for uploading
- Input data (pre-processing) level:
  - non-automated data pre-processing
  - inconsistencies or missing data
  - mismatch in format and granularity
  - annualisation of air traffic data

- Modelling (processing) level:
  - o ambiguous modelling
  - o workarounds
  - o “selecting the best” model
- Output data (post-processing) level:
  - o non-obvious model output data

Organisational level – available resources

In the time period of running the Euro-Modelling Demo – coincidently – the CAEP NOx Sample Problem took place as well. Both activities required the same resources (i.e., modellers and models) which put an extraordinary pressure on the European modellers’ groups. Better or sufficient flexibility in planning and/or recruitment of more modellers (or models) should be considered and is recommended.

Moreover, the accessibility and attainability – by email or telephone – differs per European modeller. Amongst other things, a strong (communication) network is required to work more efficient and effective in case of interdependency modelling which involves many parties.

Refer to Section 7 for general planning, organisational and management issues related to a European modelling capability.

Organisational level - IPR and other sensitive data handling

The aim of the EEMA Data Warehouse is to provide a central storage area for European data that supports aviation and environmental assessments. It would ideally be populated with non-commercially sensitive data in order to provide a transparent source of information for use in policy assessments, and to facilitate the analysis of trade-offs where multiple modellers are involved. However, some organisations have for instance invested considerable time and money in collating data for airport studies and, as a result, there are intellectual property rights (IPR) issues associated with this information. The inclusion of this data in the EEMA Data Warehouse will be reliant on agreement as to the “accessibility” and “use” of the data in order to preserve IPR.

Although the Warehouse could be sufficiently populated with data required for the Euro-Modelling Demo, IPR issues have been raised by modellers during the EEMA project, e.g.:

- the following statement re the use of data – provided by Eurocontrol – available in the EEMA Data Warehouse (on the ftp site): "Files downloaded from this site are for the explicit purpose of the EEMA project and are not to be reused for any other purpose without the express permission of EUROCONTROL."
- re economic modelling, input data required for running AERO-MS usually have similar conditions for access and use: “- no source codes and databases developed during the AERO-project will be made available to third parties without a written permissions by DGTL”

In order to protect IPR, while also making information available for use in policy assessments, it appears that this will require at least two levels within the Warehouse - one that contains data which is fully transparent and accessible to any modeller for any policy assessment and a second which includes data with associated IPR. Any other restriction like commercially sensitive or proprietary data could introduce another (sub) level. The release of all this data should be carefully controlled.

The following is proposed as a potential way of effectively managing the data (i.e., controlling for instance IPR related data):

i) IPR issues related to specific data should be identified by the supplier when provided to the Warehouse.

ii) Data supplier should clearly state any restrictions with respect to accessibility (e.g. CAEP modellers only) and use (e.g. CAEP use only). Any extension of this would require prior permission of the owner.

Modellers' awareness of this policy should encourage them to do the maximum amount of data contributions to the initial and future versions of the Warehouse.

Furthermore in more detail, the levelled EEMA Data Warehouse approach could be organised as follows:

- Level 1 data: free access and use, e.g. data from the ICAO Engine Exhaust Emissions Database
- Level 2 data: restricted (e.g., password-protected) access and use, and only available when ...
    - paying a – possibly differentiated – fee, every time this data is used; the data supplier will have a certain payback for the time and money it invested in the preparation of the data
    - and/or signing an (bilateral) agreement, every time this data is used; the supplier will keep sight and control of by whom, where and when its (proprietary) data is used
    - and/or ... (any other condition)

Level 2 data transfer will need some kind of registration and charging system, however, this should be possible when considering a future Data Warehouse system: "a true data warehouse with web-based querying and access facilities".

Nevertheless, to ease the operation of a European modelling capability and performing European policy assessment studies, the limitations and provisions related to use, access, intellectual property rights (IPR) and ownership of existing and future data and models should preferably be none, or otherwise at least as practical as possible. Following are a few comments on this.

Ownership and provisions on intellectual property, access and the use of models, tools, databases and modelling results are pertinent questions. Existing models and databases expected to form the basis of a Euro-modelling capability and, where needed, new models and databases will be developed and added. Ownership and intellectual property rights (IPR) of existing models and databases etc. are in most cases already set and usually in the hands of the model maker or the customer who commissioned the model making or both.

Ownership and IPR of yet to be developed models could be made such that these fit better within the Euro-modelling vision. In the case of a mixture of old and new models with different provisions on ownership and IPR, the Euro-modelling system will need to work around it. To facilitate practical access and user conditions/rights, databases and executables of models should be made available royalty-free or subject to a reasonable charge.

The development of new features which are added to an existing model can be done integrally and under contract of the current model and IPR owner, or it can be developed separately as an add-on feature. The latter would require close consultation with the original customer/model makers to ensure an appropriate data exchange protocol. Ownership and IPR of this new feature will either go to the customer or the model feature maker, or both.

In summary, the main Euro-modelling challenge is to encourage model and IPR owners to apply no, or only a minimum set of conditions and charges, for use and access to existing and new models, tools, databases and computational results. A cooperative attitude is essential.

IT level – limited ftp access

Initial problems in accessing the ftp site due to corporate firewall settings. Problem resolved via alternate access available through non-corporate PCs.

IT level – downloading multi-Mb files

Files containing flight trajectories data for GHG emissions modelling are too large for ftp downloading. Problem resolved via making the data available on dvd and dissemination via regular postal mail system, which took two days.

IT level – no permission for uploading

Posting the output data on the EEMA Data Warehouse, i.e. ftp site, requires certain access permissions. This problem is to be resolved in the future.

Input data (pre-processing) level – non-automated data pre-processing

More detailed and complex (interdependency) modelling activities increase the time needed for data pre-processing. In the Euro-Modelling Demo period, this became clear again and was expressed several times by several modellers.

AERO2k was built for a one-off run for 2002. Lack of automation requires visual basic programming in Access for data preparation (i.e., updating airport tables, combining flight and trajectory tables, appending LTO). This is time consuming and should be automated if AERO2k was to be used regularly (not the plan if other models exceed AERO2k performance).

Input data (pre-processing) level – inconsistencies or missing data

The EEMA Data Warehouse should contain – for each airport under consideration – the coordinates of, e.g., runways, gates and taxi ways, in an agreed format. A longer term suggestion made for the data warehouse is the storage of Cartesian data relative to the aerodrome reference point, as well as the lat/long for this reference point. In this case the aerodrome can be located spatially for GIS and also the x-y data is available for modelling. Time was lacking to prepare all this information for this first exercise. It is planned to add them to the warehouse anytime a new study is performed.

Moreover, the EEMA Data Warehouse might contain the airport-specific climbout routes (horizontal paths) which are either required (noise) or at least good to be included for the future (when dispersion is also considered).

For 2005, only 67% of the aircraft movements at Zurich airport have been processed (i.e. 175 thousand of about 260 thousand flights in total). As stated earlier, this was due to an error in the queries that selected the Zurich airport related flights from the global air traffic database (i.e. Eurocontrol's GAES-MOVE database). This also applies for Warsaw airport, although the proportion of dropped flights was less, i.e. about 10%. Fortunately in this case, it didn't harm the objectives of the Euro-Modelling Demo, i.e. system demonstration and identification of remaining system gaps, but errors in queries to select airport related flights should of course be prevented in the future.

For future studies, it may be necessary to ensure that a greater number of the aircraft types in the air traffic movements database (in this Euro-Modelling Demo case: GAES-Move) are identified so as to allow engine types to be allocated. In the Euro-Modelling Demo case, an acceptable level of 96% of the operations has been successfully mapped.

As with the original AERO2k, apparent inconsistencies in the trajectory data are causing error messages in AERO2k data preparation routines. Further investigation is required to ascertain the cause. Initial indications are that a trajectory cleaning module is required – perhaps as part of the warehouse. Consequently, AERO2k running of the remaining 41 days has been suspended until these can be resolved, in order to avoid significant nugatory effort. To allow results to be compared for the various GHG models, data for one day – ie 8 February – has been prepared and posted (less than 1% of the flights were deleted due to above-mentioned problems and about 5% of the flights were not processed because they relate to piston-engined aircraft. Moreover, information was missing on exact departure and arrival points related to the landing and takeoff (LTO) cycle. For instance, AERO2k needs this because routines are written as such to generate required LTO trajectories.

The provided data contained no information on taxi times. Taxi times have therefore been estimated by modellers, e.g., based upon an average taxi velocity, taxiway locations from airport site maps and a runway specific average queue time at departure. The taxiways, i.e. the connection either between arrival runway and gate area or between gate area and departure runway, were set up by best guess as no information on the traffic policy at the airport was provided. In the future, additional data should be included in the EEMA Data Warehouse to fill the data gap and to avoid these inconsistencies.

The emission file in the EEMA Data Warehouse is more or less a copy of the official ICAO engine emission databank, but with different formatting. It should be noted that while the original databank contains fuel flows in kg/s with 3 decimal positions, the initially provided file applied only 2 decimal positions; if the original 3 decimal place data had not been retrieved, this rounding could have lead to differences in emissions, especially for the Idle mode, of up to 10%. PS: In both databases, the Idle fuel flow for UID 1ZM001 was undefined; here, an estimated value of 0.08 kg/s was applied in this study.

Input data (pre-processing) level – mismatch in format and granularity

As was mentioned in Section 2.10, a disadvantage of the basic modelling system concept with a central common data set, is that centralised data such as aircraft performance may not be compatible with individual models. Furthermore, refer to Section 4 for a more detailed discussion on the pros and cons concerning the EEMA Data Warehouse system.

SONDEO (noise) modellers reported the need for format commonality, e.g. similar to the one in use in the CAEP sample problem activity.

Furthermore in LASPORT (LAQ), arrival and departure profiles are specified not for the individual aircraft but for the associated aircraft groups. Background of this simplification is to maintain the close conformance between monitor calculations and scenario calculations (based solely on aircraft groups). The provided traffic file – with individual aircraft specifications – was analysed for each airport and the most-frequent profile of each aircraft group was identified and applied as representative group profile.

Input data (pre-processing) level – annualisation of air traffic data

Air traffic tables were provided – global movements as well as for two airports Zurich and Warsaw – for 6 non-successive weeks distributed over the year 2005. Lengthy discussions took place and confusion arose a couple of times regarding the annualisation process of transforming these six weeks of air traffic into one year – annual – air traffic (see also Appendix C.3). Moreover, the day multiplier – relevant for annualisation – needed careful and different processing when modelling emissions and noise. Time savings in data collection and processing opt for the annualisation process; however, it provides enough room for different (mis-)interpretation. Clear guidelines are needed.

Modelling (processing) level – ambiguous modelling

Ambiguous modelling; a couple of examples:

Outcome of the Fleet Data generation work (see Appendix C) will be three sets of flights (up to six selected weeks), one for 2005 and two equivalent up-to-6-week sets of flights for 2025, one set with and one set without the stringency change. Each flight in each set will have an engine type allocated based on the full range of available certified engine types. How individual modellers use this data will vary model-by-model.

As earlier-mentioned, the provided data contained no information on taxi times. Taxi times have therefore been estimated by modellers with different methods and different taxiing assumptions. Concerning local air quality (LAQ) emissions modelling, the taxiing assumptions made by each group appeared to have significant impacts on results. It would be good if one comprehensive set of taxiing assumptions could be provided beforehand or otherwise if groups could provide results with and without taxiing in the future.

LAQ modellers could use whatever performance based tools they have, or do the trivial calculation by using ICAO figures.

Moreover, different fuel flow calculation schemes have been considered by modellers, e.g.:

a) using fuel flow indices at 100%, 85%, 30% and 7% levels;

b) using percentage thrust levels directly from aircraft profiles with fuel flow indices;

c) using net thrusts and BADA fuel flow method to calculate fuel flow.

Within each of b) and c) there are different options that can be pursued to calculate fuel flow. Further, there are options on calculating the emissions indices from fuel flow. The final choices were made by the modellers themselves. For consistency in future modelling, this could/should be prescribed.

Modelling (processing) level – workarounds

In case gaps were identified which could not be solved within reasonably time and budget, quick & dirty so-called “workarounds” have been created.

The following issues could be considered as relevant workarounds:

- fleet data generation work replacing a required technology modelling (sub) system
- taxi time methodology selected by LAQ emissions modellers replacing missing taxiing assumptions in EEMA Data Warehouse (probably the same holds for the modellers’ selection of fuel flow calculation scheme)
- eliminating flight operations linked to erroneous trajectories causing severe processing errors with GHG emissions modelling.

Regarding technology and economic modelling (sub) systems, please refer to Section3.2. Other workarounds have already been addressed in the current section.

Modelling (processing) level – “selecting the best” model

Please refer to Section 5.

Output data (post-processing) level - non-obvious model output data

GHG emissions modelling: manual data checks showed output for about 10 of the remaining 70000 flights that gave unexpected results (e.g., negative or exceedingly small values) despite passing through AERO2k calculations without problem/error message. Investigation revealed these 10 flights to be a small proportion of the flights with turboprop aircraft with relatively poorly defined flight trajectories above 3000ft. These had no significant effect on the results but need to be investigated.

Output data (post-processing) level - unavoidable post-processing errors

There has been a post-processing problem with the simulation results of one of the LAQ emissions models (case: Warsaw airport, 2025 with stringency, below 1000ft). An updated version of the model results have been provided soon after the error had been detected during Euro-Modelling Demo data analysis.

6.3 CONCLUSIONS AND RECOMMENDATIONS

As part of EEMA WP3, a test program named Euro-Modelling Demo was done and demonstrated the EEMA prototype basic modelling system in operation. Especially the linkages between the noise, local emissions and global emissions models and the EEMA Data Warehouse system – a unique European dataset – have been well tested. Moreover for future consideration, a set of remaining gaps in the modelling system have been identified together with an extensive list of lessons learned. The Euro-Modelling Demo and its valuable outcome had not been possible without the excellent support and contributions of the European modellers involved.

The Euro-Modelling Demo consisted of an assessment of NOx, fuel and noise effects following the imposition of a change of NOx regulation in ICAO Annex 16; i.e. a 20% increase in NOx stringency, agreed in 2010, coming into force in 1 January 2013. The effect of this change has been assessed for the year 2025. The NOx stringency itself has been simulated by not delivering engines into the fleet which do not meet the stringency, after 1 January 2013 and non-compliant engines being replaced by new ones, including a “new design” if no suitable existing replacement existed.

In this section the demo modelling results for 2005 and for 2025 without and with NOx stringency have been presented and discussed:

- global fuel and NOx emissions – involving almost 35 million flights in 2005 and almost 90 million flights in 2025, and
- 55/60/65/70/75 dB(A) Lden noise contour areas and below 1000ft and below 3000ft LTO fuel and NOx emissions – of aircraft only – for two demo airport cases (Warsaw and Zurich) – involving approx 110 respectively 175 thousands flights in 2005 and approx 270 respectively 450 thousands flights in 2025.

In summary, the conclusions after analysis of the demo modelling results are:

- Overall the modelling results are intuitive and comparable with numbers found in literature.
- From inter-model comparisons: overall agreement between models alike; modelling results show similar trends and are comparable in most cases; in a few cases, some larger differences found are argumentative (however, model comparison is out of scope of the EEMA project)
- When generally comparing 2025 results with 2005 ones, it shows that 2025 Lden noise contour areas are twice as big as in 2005, and local and global fuel and NOx emissions show around 150% increase (factor 2.5) in 2025 compared to 2005
- The Euro-Modelling Demo results not only demonstrated the effective tool linkages in operation, but also interdependency (tradeoffs). The effect for the year 2025 of the considered 20% NOx stringency measure is:
    - 5-6% NOx reduction at global level
    - 4-11% NOx reduction at (considered) airport level
    - a reduction of around 2% in Lden noise contour area at Warsaw airport
    - however, at the penalty of an increase in Lden noise contour area at Zurich airport of 2-5%, and
    - at the penalty of an 1-3% increase in local and global fuel consumption.

It should be emphasised that these are **test data only** resulting from modelling runs with test input data.

Overall conclusion is that there is compliance with all test criteria. The fact that obvious modelling results have been produced, demonstrates the well-functioning of linkages in the EEMA prototype basic modelling system including the Data Warehouse system. Moreover, system gaps of technical, operational, legal and organisational nature have been identified and have led to a few so-called “workarounds” plus an extensive list of lessons learned for future consideration (all details in Section 6.2.3).

In a brief overview, the gaps and lessons learned concern:

- @ organisational level, e.g., available resources and IPR/sensitive data handling
- @ general IT level, e.g., limited ftp access, up- and downloading data issues
- @ input data (pre-processing) level, e.g., non-automated data pre-processing, inconsistencies or missing data and mismatches in format and granularity
- @ modelling (processing) level, e.g., ambiguous modelling and workarounds
- @ output data (post-processing) level, e.g., non-obvious model output data

Relevant workarounds applied in the demo are:

- fleet data generation work replacing a required technology modelling (sub) system
- taxi time methodology selected by LAQ emissions modellers replacing missing taxiing assumptions in EEMA Data Warehouse
- eliminating flight operations linked to erroneous trajectories causing severe processing errors with GHG emissions modelling
- no economics calculations replacing a required economic modelling (sub) system.

7 WP4 Management of a European Modelling Capability

A European capability for economic and environmental modelling for aviation and policy assessment studies will consist of one or more sets of models linked to a central database, i.e. the data warehouse system (see Section 4.1). The different models and corresponding data have been or are yet to be developed by various model makers in organisations spread all over Europe (or the World). The technical development of such a European modelling capability is a complex and relevant issue. However, complex and relevant as well – when the capability is under development or *finally* in use for policy assessment studies – are the management and coordination, exploitation, maintenance and further enhancement of the modelling capability. This is a challenging task to do, amongst others, because means and resources are spread all over Europe (or the World) and because of the involvement of many stakeholders with a large range of views and opinions.

This section contains views and recommendations on the management and organisation of a European modelling capability for aviation based on the findings of discussions in recent meetings and interviews.

7.1 INTRODUCTION AND SUMMARY OF FINDINGS

The topic of the current section is a durable modus operandi to mobilise candidate models for the European modelling capability in a coordinated manner to deliver policy-relevant results in policy-relevant timescales. Currently bits and pieces - i.e. models and data – of the required modelling capability are available or under development all over Europe (or the World). Usually the development of models and their use in policy assessment studies is done in isolation, and funded and managed At institutional or national level. In effect this is uncoordinated in a European sense. Moreover, policy-relevant computations of noise, emissions and economic parameters are done separately and quite often based on different sets of data and assumptions; thus, no trace of interdependency modelling.

Therefore, a European interdependency modelling capability and the future management of such a toolset involving lots of means, resources and stakeholders – all with their own requirements and restrictions – will be unique and complex. The composition of a prototype basic modelling system and the organisation of a Euro-modelling demonstration as part of the EASA EEMA study already showed this not to be a trivial activity, despite the relatively limited character and size of the EEMA project. Moreover, funding of the European modelling capability will be a big challenge with the many stakeholders, European member states and organisations involved.

The main question is what can be best recommended on the structure and best practice method to manage such a large, complex and policy-relevant European modelling capability. A range of – sometimes contradictory – requirements needs to be fulfilled and various management skills are needed. NLR, supported by EEMA project team members QinetiQ and Envisa, coordinated and participated in activities required to frame the below-mentioned advice on this relevant management issue.

These activities in the Nov06 to Jul07 time period involved several meetings with EASA, ECAC/ANCAT MITG, AERONET/X3-NOISE/QUANTIFY and bilateral interviews with coordinators of large EU FP6 projects.

7.1.1 Summary of Findings and Advice

In addressing the complex and relevant management issue re a European modelling capability, different scenarios and organisational structures have been considered ranging from business as usual up to a comprehensive network of model makers and stakeholders.

Following desk research and discussions at various recent meetings, the following paragraphs conclude that size, range and quality of the organisation around a European modelling capability depend mainly on the level of collective funding and commitment of stakeholders. Below a certain threshold level of collective funding (and commitment of stakeholders) a business as usual situation will remain. With increasing funding levels and stakeholders commitment a small agency or authority on standardization could be operational and in a next step a “floating” independent European modelling management and coordination group, dubbed EMCG, should be feasible. A durable and comprehensive network of expert modellers and stakeholders (e.g., in a steering or advisory group format) could be arranged at an even higher level of collective funding and commitment of stakeholders. The latter recommendation is similar to the advice from an expert meeting jointly organised by AERONET-III, X3-NOISE and QUANTIFY with support of ECAC/ANCAT MITG.

7.2 ACTIVITIES AND RESULTS

EEMA work package 4 on management of a European modelling capability is relatively small (approx 10% of the 80 person days total). However, due to synergy with parallel activities in EU FP6 projects like AERONET III, the activities and outcome are more extensive.

7.2.1 Main Activities

Main activities, of which the outcome formed the basis for advice on management of a European modelling capability, involved:

- Desk research for input into, and preparation of presentations for meetings and interviews
- Active participation in ECAC/ANCAT Modelling and Interdependencies Task Group meetings (MITG; Nov06, Jan07, Jun07) and EASA EEMA project progress meetings (Nov06, Apr07); all with presentations and lively discussions about the subject of modelling management
- Hosting and chairing an expert meeting (Mar07) on Interdependency Modelling jointly organised by AERONET-III[9] / X3-NOISE[10] / QUANTIFY[11] with support of ECAC/ANCAT MITG; 17 persons from 14 different organisations and 6 different countries attended this meeting at NLR in Amsterdam (NL)

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[9] See also: http://www.aero-net.info
[10] See also: http://www.x-noise.net
[11] See also: http://www.ip-quantify.eu

- Interviews (Jul07) with coordinators of multi-year, multi-million and complex EU FP6 projects, i.e. Integrated Project SILENCE(R)[12] and Network of Excellence ECATS[13].

7.2.2 Management and Organisation of a European Modelling Capability

An effective and efficient, and therefore durable, organisation and management structure should be setup to manage and coordinate activities like promotion, exploitation, maintenance and enhancements of the European modelling capability. From meetings' discussions and interviews, the following points came out as being essential for this:

- Strong management based upon clear project goals
- Well-selected team of players i.e. managers and expert modellers
- Sufficient budget to do more collaboratively than management only
- Well-engaged stakeholders

These four factors are more or less driven by the level of funding and the commitment of stakeholders as will be amplified next.

- **Formation of a team of managers and expert modellers**; an efficient and effective level of coordination and management depends on the existence of a powerful and focused management team, well-organised with respect to authority, representation, (best) quality, number and availability of team members; more (detailed) needs and characteristics of a good management team are provided in an elaborated list on the next page; however, the establishment of such a team will be determined mainly by funding level and stakeholder commitment; in forming a team of managers and/or modellers, the best way to start off is to put together a team which has been working productively together already for some time, of which the parties are familiar with each other and know each other's strengths and weaknesses; in addition, new team members should have proven capabilities and added value to the team; selection to join the "core" team (or not) should be based on a transparent process with clear selection criteria.
- T**erms of references (ToR)**; apart from coordination and management, other work should also be organised and done in a more centralized way in order to raise collaboration and engagement; this would include for instance work on management support, standardization, promotion, exploitation (e.g., actual assessment modelling), policy making, maintenance, research and future enhancements to operate / maintain / attain a comprehensive, high quality and robust European modelling capability; a (virtual) office with one or more staff members and, moreover, a group of expert modellers should then be setup to perform these additional tasks; again size and quality of this collaborative work will depend on funding level and stakeholder commitment in order to get enough personnel with a certain (required) level of expertise
- **Stakeholder engagement;** the engagement and commitment of stakeholders (i.e., model makers, policy makers and others) will be high(er) when giving them clear project goals, good representation and/or responsibility, e.g. policy makers as customers in a steering committee or an advisory board; of course synergy and a win-win situation, when all parties benefit from the work

[12] See also: http://www.snecma.com
[13] See also: http://www.pa.op.dlr.de/ecats

around the European modelling capability, is essential; besides size and quality of the work, dissemination and communication are also very important in this respect; it raises the level of awareness and acceptance of the European modelling capability (and thus its range of application and success):

  - internal communication: transparency and maximising benefits from synergies – between modellers from different European organisations, between policy makers and modellers; adequately dealing with provisions on use, access, IPR and ownership; avoidance of duplication; the introduction, support and maintenance of an internal communication platform is needed ("intranet" like tool)
  - external communication – proactive and effective: promotion of assessment modelling results, improved design and application of legislation, contributions to international agreements on standards, practices and mitigation options

Yet again, the realisation of a win-win situation and an effective communication process involves a certain level of funding and commitment of the people involved.

The need for aviation environmental policy assessment modelling will be permanent; to be successful (i.e. effective & efficient) not only now but also in the longer term, a durable basis for activities regarding the European modelling capability is required; in turn this means a durable funding mechanism and long-lasting stakeholder commitment.

An efficient and effective level of coordination and management depends on the existence of a powerful and focused management team, well-organised with respect to authority, representation, quality and number of team members. Characteristics of the management team (members) have been subject of lengthy discussions in the referred meetings and interviews. Following is a list of views, suggestions and statements, which should be considered in any future management team formation for the European modelling capability:

- Characteristics of a management team (member) should be, amongst other things:
  - Good level of understanding and expertise in the relevant areas of aviation emissions and noise, environmental impact, capacity/ATM, economics and aviation & environmental policy making; multidisciplinary and a well-balanced mix of team members
  - Unprejudiced and reputable person or organisation, with suitable authority and reputation, and a broad acceptance at international level; i.e. stakeholder friendly person
  - Experienced in managing large and complex work programmes; especially the ability to:
    - give momentum to European action, cooperation and affectivity
    - prevent fragmentation, to minimise private interest of model makers and to initiate coordination of all isolated developments at different organisations spread over Europe
    - establish European collaboration in a competitive modelling area

- establish transparency, open access, broad acceptance of models and free data flow
- realise an efficient and effective European modelling capability
- realise continuity/maintenance and future funding
- find compromises, starting with a broad range of views on issues like management, ownership, IPR, model and data access, maintenance and enhancements re the Euro-modelling capability
- meet frequently (with flexibility)
- take tough but substantiated decisions at relevant moments (management with "teeth"); stick to planning and manage on agreed deadlines and milestones

This demanding and broad range of criteria for coordination and management calls for a group rather than for one single person. Basically, the management team should comprise of decisive managers, e.g. from different EU or ECAC member states. In addition, a group of independent senior experts with authority should take part in the management team or act in a separate but closely linked advisory group; i.e. to advise the managers group on certain technical decisions to be taken. It was considered that ECAC/ANCAT (MITG) and established research networks, e.g. AERONET III, X3NOISE and QUANTIFY, could provide this expert level. Other steering and/or advisory groups are needed as well to include views and suggestions from other stakeholder, e.g., policy makers for relevant politics and policy issues. The whole group should preferably operate with an EU mandate and have backup from EU member states and stakeholder organisations like EASA and Eurocontrol.

A management structure will be needed, with a sufficient level of authority and working under suitable agreements and terms of reference. It has been often mentioned that the power is with the ones who are in control of the money. The European capability management, either the management team or steering committee or both, should have the ability to make budgetary decisions. Special agreements are needed with the management's ability to stop counter-productive activities and to initiate alternate or new routes.

Furthermore, the suggestion has been raised to embed the management and coordination of a European modelling capability in an existing European organisation like for instance the EC, EASA or Eurocontrol. Such a decision with far-reaching, obligatory and long-lasting consequences on for instance organisation (ownership), legal and financial commitments, takes some time to evolve.

7.2.3 Example Organisational Structures

The previous section showed that the level of collective funding and the commitment of stakeholders will determine the range and success of activities regarding the European modelling capability. For increasing levels of funding and involvement of stakeholders, Figure 26 provides different sample organisations with growing terms of references (ToRs).

NB: The sample organisations are described in some more detail in Appendix H.

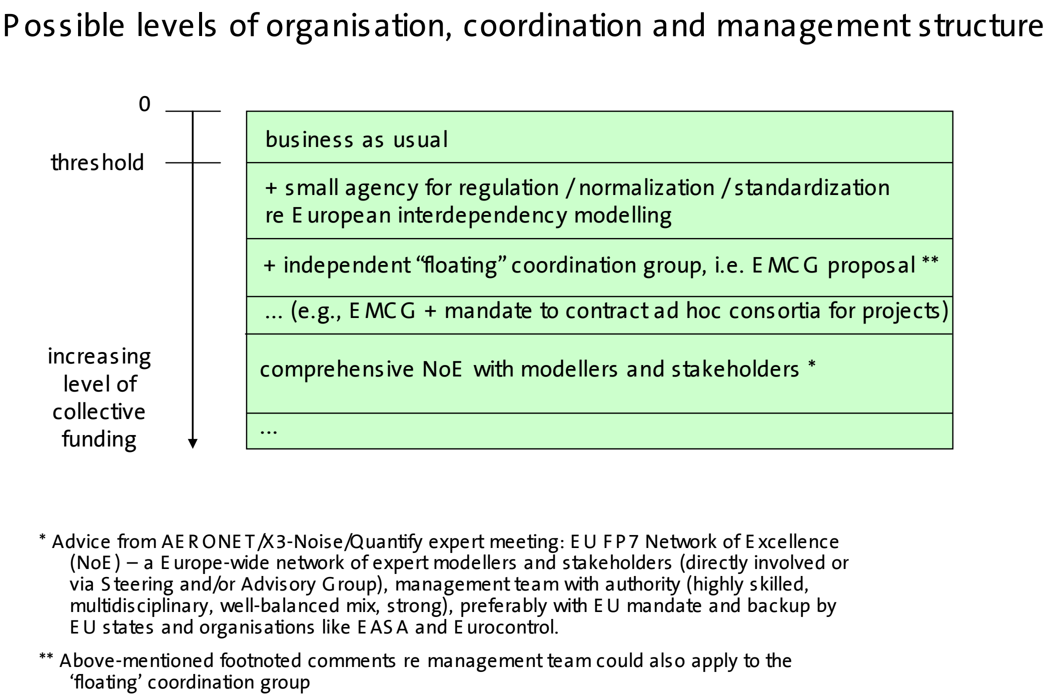

Figure 26: Sample organisations with increasing level of collective funding

Business as usual will continue below a certain threshold level of collective funding. Above a certain threshold level, a small, low-budget and independent agency or authority might be setup to satisfy the basic requirements regarding regulation, normalization and standardization of the European interdependency modelling. With an increasing collective budget – and commitment of stakeholders – it might be possible to install a "floating" independent management and coordination group (called: Euro-Modelling Coordination Group; dubbed: EMCG). This group should satisfy as much as possible – subject to funding – the identified characteristics of a management team (member) as provided in the previous section.

With an even higher level of collective funding and commitment of stakeholders, a comprehensive network of expert modellers and stakeholders – directly involved or via a steering or advisory group – could be setup and operated. The terms of references of such a Europe-wide network, e.g. an EU FP7 network of excellence (NoE), could comprise the whole range of activities like management and coordination, standardization, promotion, exploitation, policy making, maintenance, research and future enhancements to operate, maintain and attain a comprehensive, high quality and robust European modelling capability. The NoE structure has been advised by the earlier-mentioned expert meeting jointly organised by EC thematic research networks of AERONET-III, X3-NOISE and QUANTIFY, with support of ECAC/ANCAT MITG. However, the appropriateness of an NoE in this context would need to be considered and it is uncertain at the present moment whether they will form part of the FP7 work programme in the foreseeable future.

Other organisational structures are of course possible, e.g., an EMCG with a mandate to contract ad hoc consortia for maintenance or enhancements of the European modelling capability as part of a project with limited budget and time. For each of the considered sample organisations with different terms of references (ToRs), the next set of parameters have been evaluated in Table 8:

- **Coordination, management and (stakeholders') steering,** which could be low (zero or limited, e.g., via an MITG as currently ongoing), medium (e.g., specific but limited management and coordination group) or high (e.g., an effective coordination and management team)
- Internal and external **communication** – see section 7.2.2 – which could be low, medium or high in general or deviant on a dedicated topic (e.g., standardization)
- **Assessment modelling** or in other words exploitation and application of the European modelling capability, which could be done externally (i.e. outside the central organisation) or (part) internally
- **Maintenance, research and enhancements** work, re the European modelling capability which could also be done externally (i.e. outside the central organisation) or (part) internally
- **Continuity** of the management activity of the Euro-modelling capability, which could be low (short-term), medium (medium-term) or high (longer-term)
- **Collective funding needs**, which could be zero, low, medium or high.

	Coordination, management and (stakeholders) steering	Communication	Assessment modelling	Maintenance, research and enhancements	Continuity	Collective funding needs
Biz as usual	low (e.g. via MITG)	low (e.g. via MITG)	external	external	low	zero
+ small agency on standardization	low	low; high on mod. standards	external	external	low	low to medium
+ EMCG -"floating" coordination group	medium	medium	external	external	medium	medium
…						
Network/NoE of modellers and stakeholders	high	high	internal / external	internal / external	high	high
…						

Table 8: Values of ToR parameters for different sample organisations

Not surprisingly, the table shows that with increasing levels of collective funding, the levels of coordination and management and communication rise, part of the modelling work and maintenance and enhancements could be done internally, and expectations on continuity are higher. So from a European collaboration perspective, the network of modellers and stakeholders is preferred, however the required level of collective funding is correspondingly high and surrounded, if not threatened, by a high level of uncertainty.

7.3 CONCLUSIONS AND RECOMMENDATIONS

A European capability for economic and environmental modelling for aviation and policy assessment studies will consist of one or more sets of different models linked to the data warehouse system. The different models and corresponding data have been or are yet to be developed by various model makers in organisations spread all over Europe (or world). The technical development as well as the management – in development and exploitation phases – of such a European modelling capability are complex and relevant tasks, amongst others, because means and resources are spread all over Europe (or the World) and because of the involvement of many stakeholders with a large range of views and opinions.

In addressing the complex and relevant management issue regarding a European modelling capability, different scenarios and organisational structures have been considered ranging from business as usual up to a comprehensive network of model makers and stakeholders.

Following desk research and discussions at various recent meetings and interviews, it can be concluded that size, range and quality of the organisation around a European modelling capability depend mainly on the level of collective funding and commitment of stakeholders. Below a certain threshold level of collective funding (and commitment of stakeholders), a business-as-usual situation will remain. With increasing funding levels and stakeholders commitment a small agency or authority on standardization could be operational and in a next step a "floating" independent European modelling management and coordination group, dubbed EMCG, should be feasible. A durable and comprehensive network of expert modellers and stakeholders (e.g., in a steering or advisory group format) could be arranged at an even higher level of collective funding and commitment of stakeholders. The latter recommendation is similar to the advice from an expert meeting jointly organised by AERONET-III, X3-NOISE and QUANTIFY with support of ECAC/ANCAT MITG. The pros and cons of embedding a management and coordination function within an existing European organisation requires consideration of the subsequent organisational, legal and financial implications.

In this section, an extensive list has been provided of necessary characteristics of a management team (member) for the European modelling capability. In this respect, these characteristics are recommended for consideration in a future management team formation.

NB: The management and coordination related matters concerning use, access, intellectual property rights (IPR) and ownership of data and models - required for the European modelling capability - plus any legal provisions in these areas, have already been addressed in the previous Section 6.2.3.

8 WP5 Project Coordination

The EEMA project was a relatively short project with only 3 partners plus a major industrial advisor (Eurocontrol). Whilst more complex than a single-organisation project, coordination issues did not dominate the work carried out.

8.1 WORK PACKAGE STRUCTURE

The work package structure developed in the Project Description proved robust and did not change during the project. Individual WP Leaders took full responsibility for their packages, enlisting the assistance and advice of the partners and of Eurocontrol when needed.

8.2 COMMUNICATIONS

One project meeting was held in Envisa Paris. Otherwise communication was by telecon, held weekly during the key phases of the project. For WP3, the Modelling Demonstration, modellers joined the weekly telecons.

Two meetings were held with EASA. The first on 2 November 2006 covered policy requirements and the project plan; the second on 20 April covered the data warehouse, modelling system and plans for the modelling demonstration.

A consortium agreement has been signed by the three contractors involved in EEMA.

8.3 TIMESCALES

Project timescales were originally set out in the Project Description. A delay in the contractual process resulted in an agreed one month slippage in the project start and all subsequent dates.

During the project, the preparation of the complete set of data needed for the warehouse was found to be dependent upon the model requirements. This caused some delay in the completion of the warehouse and put pressure on the timescale to complete the modelling demonstration, revised to start in mid-March 2007. The CAEP NOx Sample Problem was subsequently set to have data available at the same time – mid-March – which caused some considerable difficulties for the modellers involved in both exercises. Significant efforts were made to keep the EEMA demonstration ahead of the CAEP Sample Problem in order to allow modellers new to NOx stringency to learn first on EEMA rather than the more public CAEP Problem. This was only partially successful with only days between the two exercises.

As a result of the issues described above, an attempt was made to reschedule report writing to recover timescales to deliver the final report by the agreed end-August delivery date. Following discussion with EASA, it was agreed that a preferable course of action was to delay the report delivery by one month. This was confirmed by contract amendment.

8.4 OTHER ISSUES

As stressed in the project proposal, project funding was not adequate to address all the issues arising from the development of a full basic modelling system. Hence this project was focussed on a prototype system, demonstrating the capability but requiring further work before the system can be described as complete. In the circumstances, there were perhaps less workarounds required than expected and as described earlier, some of the workarounds used may be suitable for use in actual policy modelling.

9 Conclusions

The EEMA project has developed a practical and relevant approach to bringing together Europe's aviation environmental modelling capability to meet the policy analysis needs of EU policymakers to address the issue of interdependency modelling. In promoting a practical and relevant approach, the work has focussed on short and medium term priority measures which can be met by a relatively straightforward modelling system – called a basic modelling system. The project has identified the priority policy issues, a set of available and appropriate models, the remaining gaps, the proposed modelling system-of-systems methodology and the outcome of its modelling demonstration. It has also proposed a way in which such a system could be managed within the European framework.

Specifically,

- Aviation environmental policy requirements, for Europe and CAEP have been identified and prioritised and the modelling processes needed to assess those policy options defined
- A basic modelling system to address a number of those policy options has been developed in prototype form to address those policies directly related to regulation. This basic system comprises European and ICAO data sources and models and the links between them, based on a Data Warehouse concept
- In developing the methodology for the basic modelling system, it was identified that whilst there were many component parts available, three were missing. The first, the Data Warehouse, has been developed and implemented under this project. Development of the other two – technology modelling and economics modelling subsystems – was beyond the scope of this project. For the purposes of the EEMA demonstration, technology modelling has been simulated by expert assessment within one of the EEMA partners – a valid process but one which would benefit from wider contribution and, ideally, some technology modelling. The necessary calibration for 2005 of the existing AERO-MS tool or, alternatively, the extraction of standalone economic modules from AERO-MS was considered. However, corresponding time and effort were such that this could not be done in the EEMA remit. The scoping and planning of these updates is now partly underway with initial Netherlands government funding.
- The Data Warehouse concept demonstrated the feasibility and value of collecting and controlling the model input data. Acting as a warehouse for model outputs provides an additional benefit in terms of quality control. Implementation of the warehouse as an ftp site provides a minimal solution with some access problems. Implementation as a password-controlled website would provide a better "feel" and improved access
- Selection of models to define the warehouse data and to take part in the modelling demonstration required no down selection against any of the identified criteria. This is an ongoing issue as other models emerge or as the wider European modelling system is developed
- The demonstration of the prototype system in the *Euro-Modelling Demo* was successful. It showed that the data warehouse and the selected models could

successfully carry out a policy modelling analysis, independent of input from other organisations, using common input data. The actual results of the chosen NOx Stringency analysis are intuitively of the right order and show good agreement between the models. Beyond the scope of EEMA, further results analysis would provide benefits in understanding the model behaviours and differences. A number of relatively minor gaps were identified during the demonstration. These were addressed by workarounds.

- The gaps and lessons learned were:
    - organisational level, e.g., available resources and IPR/sensitive data handling
    - general IT level, e.g., limited ftp access, up- and downloading data issues
    - input data (pre-processing) level, e.g., non-automated data pre-processing, inconsistencies or missing data and mismatches in format and granularity
    - modelling (processing) level, e.g., ambiguous modelling and workarounds
    - output data (post-processing) level, e.g., non-obvious model output data
- Relevant workarounds applied in the demo are:
    - fleet data generation work replacing a required technology modelling (sub) system
    - taxi time methodology selected by LAQ emissions modellers replacing missing taxiing assumptions in EEMA Data Warehouse
    - eliminating flight operations linked to erroneous trajectories causing severe processing errors with GHG emissions modelling
    - no economics calculations replacing a required economic modelling (sub) system.
- These workarounds need to be formalised or replaced with more robust methods.
- The conclusion of research into the subsequent management of the EEMA basic modelling system plus the proposed responsive and aircraft level tools was to make the next step dependent upon the level of collective stakeholder funding and commitment. The formation of a small agency, an independent European Modelling Management Group (dubbed EMCG) or an EC FP7 Network of Excellence are alternatives dependent upon this commitment
- The prototype basic modelling system now requires further development, primarily in the form of filling identified gaps. In addition development of a responsive modelling system, and aircraft level system and impacts and monetisation capability is also required to complete the European aviation environment policy modelling system.

10 Recommendations

This EEMA study has taken forward the “basic modelling system” and as a result of this specific work, the recommendations for further activity are listed below:

- Address the gaps and workarounds identified during the Euro-Modelling Demo and listed in Section 9
- Establish a process for generating robust, transparent and realistic technology assumptions for policy modelling – in the short term through expert opinion, in the longer term through technology modelling
- Establish an economic modelling capability, initially through gathering economic cost data and spreadsheet modelling, latterly through more complex modelling such as that planned for the Netherlands AERO-MS model
- Establish a permanent home and access protocol for the Data Warehouse and add a web-based front end to ease access and downloading issues. Consider ways for standardisation or at least harmonisation of data; e.g., the use of unique aircraft and engine ID types, the use of standard formats and units for data and the removal of equivalent information in separate data files. Improve data pre-processing where this can benefit more than one model. Ensure warehouse data is of sufficient quality and completeness for any given analysis task
- Establish a wider European modelling capability, based on the criteria in this report, which contains some model redundancy in order to provide a robust system fit for purpose
- Carry out further assessment of the results of the *Euro-Modelling Demo* to understand the differences between the models, the reason for the different noise responses between the two chosen airports and to identify the assumptions which drove the results
- Establish links with impacts and monetisation tools
- Entrust the future development and operation of this basic modelling system to a management group based on either a small agency, an independent European Modelling Management Group or an EC FP7 Network of Excellence, dependent upon stakeholder commitment and budget.

Many of the recommendations emerging from EEMA have been presented to the ANCAT-based MITG for consideration in funding future projects. Recommendations from the EFEMTA study regarding the responsive and aircraft-level models still stand.

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b. EEMA – AERO2k Lessons Learned, prepared by QinetiQ, UK, 26 July 2007

LAQ:

c. ADMS – Airport Aircraft Emissions for Euro Modelling Demo, prepared by CERC, UK

d. Euro Modelling Demo: ALAQS-AV Logbook, prepared by Envisa, France, 22/06/2007

e. Euro-Modelling Demo – NOx stringency test case – LASPORT, prepared by Janicke Consulting, Germany, 2007-07-05

Noise:

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A Appendix A - Modelling Requirements Emerging from CAEP/7

The CAEP/8 Work programme contains work items for each working group. The analysis below identifies those items in the work programme which may require modelling

A.1 Probable Modelling Requirements

If they are undertaken, these work items are expected to require modelling effort during the CAEP/8 cycle.

Project No. and Title	Description	Deliverable	Support (names/ organization)	Target (date)	Comment
MOD.02	In support of the model evaluation process, conduct modelling sample problems (including technology response and cost-benefit analysis) to identify gaps in existing tools, to identify potential approaches to displaying interdependencies and to adapt models as necessary. (Note: Results not to be used for actual policy analysis.)	Report on model capabilities and potential enhancements to existing tools. This report will inform MOD.01	ICCAIA, IATA, ACI, Model Owners	CAEP/8/ 2007/SG	SAMPLE PROBLEMS ONLY
MOD.03	To support CAEP environmental goals as stated in the current A35.5, conduct an updated trends assessment, for the baseline case (and forecasts), and various cases which consider technology and operational improvements. As directed by Steering Group, assess the contribution of CAEP policies toward achieving CAEP environmental goals.	Report on noise, emissions and GHG goals	ICCAIA, IATA, ACI, Model Owners	CAEP/8	
MOD.04	Examine how CAEP will directly compare the results of the various modelling tools, including the direct comparison of all aviation environmental impacts and costs versus benefits. This will draw on, as necessary, appropriate technical and scientific expertise from inside and outside CAEP, including a workshop.	Report on assessing aviation environmental impacts and monetisation Report on workshop	ICCAIA, IATA, ACI FAA, ICCAIA, U.K., Italy	Preliminary 2007/SG Final CAEP/8/ 2007/SG	SAMPLE PROBLEMS ONLY
MOD.06	Conduct policy option analyses as requested by CAEP. This effort requires coordinating work including a specific framework and set of assumptions required to support CAEP/8 analyses (WG1/2/3/FESG).	Report on policy option analyses	As required	CAEP/8/ 2007/SG (Framework) CAEP/8 (Results)	Probably covered by other work items
MOD.07	Consider transition to a more comprehensive approach to assess proposed actions. This includes providing cost-benefit information and analyses in the form of sample information.	Progress Report Final Report	U.S.	CAEP/8/ SG CAEP/8	SAMPLE PROBLEMS ONLY
N.28	Taking into account the work of Item N.27 (monitor and report on research) and, in coordination with WG3, provide advice and	Report to WG2	ICCAIA, ACI, IATA	End 2007	TECHNOLOGY MODELLING

Project No. and Title	Description	Deliverable	Support (names/ organization)	Target (date)	Comment
	information on mid and long-term noise reduction technology prospects and future trends.				
N.29	Using the independent expert process, to examine and make recommendations for noise, with respect to aircraft technology and air traffic operational goals in the mid term (10 years) and the long term (20 years).	1) Plan 2) Report	FAA ICCAIA Italy IATA UK	1. First SG 2. CAEP/8	TECHNOLOGY MODELLING
E.03	Technology Advances & Interdependencies 1. Technology advances: Provide assessment of advances in aircraft and engine design technologies for subsonic and supersonic aircraft and the degree to which these technologies could influence gaseous emissions, smoke, particulate matter and fuel consumption; including the potential benefits and trade-offs amongst various emissions and noise, the likely timescales for introduction and appropriate inputs for assessment of the associated economic costs and environmental benefits.	Report	ICCAIA	SG 2009	TECHNOLOGY MODELLING
E.04	Technology goals 1. Using the independent expert process, examine and make recommendations for NOx and fuel burn with respect to aircraft technology and air traffic operational goals in the mid term (10 years) and the long term (20 years). For NOx: .... d) Informing CAEP deliberations on the degree to which NOx technology improvements could influence progress towards achieving CAEP Environmental emission goals.	Report on NOx goals progress		SG 2009 mid 2007	1. TECHNOLOGY MODELLING d) GOAL MODELLING
E.08	Methods & Standards 1. NOx LTO stringency Analyse the technological response to a range of NOx stringency options up to CAEP6 minus 20% at OPR = 30 for application no sooner than 2012.	Report	All WG3	SG 2008	
O.04	Estimate the environmental impact of curfews on destination countries with a case study for a major airport.	Define proposal/report	India	SG meeting / CAEP/8	
O.08	Based on the independent expert process,	Report to CAEP	Italy, Australia,	Third SG	

Project No. and Title	Description	Deliverable	Support (names/ organization)	Target (date)	Comment
	examine and make recommendations for noise, NOx and fuel burn with respect to air traffic operational goals in the mid term (10 years) and the long term (20 years).		UK, US, Eurocontrol, IATA ICCAIA		
O.11	Assess the effect of takeoff thrust and deeper cutback on noise and emissions, fuel consumption (constant weight) and climb-out time. This is an extension of current task on NADP noise and emissions effects.	Technical report	UK, ICCAIA, IATA, IFALPA	Third SG	
O.12	Assess and validate noise and emissions reductions accrued from the use of continuous descent arrival techniques (e.g. CDA). This item, considered as high priority item by TG3, would require definition of continuous descent techniques with other ICAO groups (OCP, OPSP) and is conditional on availability of assessment methods and supporting data.	Technical report	UK, US, Eurocontrol, IATA IFALPA, ICCAIA,	Third SG	
O.13	Review of NAP R&D/implementation projects, including advanced noise abatement departure procedures. This item would provide an analysis of options including the evaluation of tradeoffs of environmental effects.	Technical report and possible recommended practice	UK, Italy, Eurocontrol, IATA, ICCAIA	Third SG	
O.14	Assess benefits of steeper approach. This item should include review of present practice and review of implications for assessment methodologies. Operational and technological feasibility are also considered as part of the assessment.	Technical report	UK, IATA, IFALPA, Eurocontrol, ICCAIA	Third SG	
O.15	Study the noise arising from departing and arriving aircraft at locations 9 to 12 km away from the airport, and if appropriate further away, and investigate whether operational means rather than a change to the certification scheme would be the best way to address problems in these wider areas.	Report to Steering Group	Australia, France, UK, Eurocontrol, IATA, ICCAIA	Second SG	

A.2 Possible Modelling Requirements

Work items in this table, if undertaken, may require modelling. However due to the nature of the work item or uncertainty with the approach which might be taken, the modelling requirement is not certain.

Project No. and Title	Description	Deliverable	Support (names/ organization)	Target (date)
N.08	Monitor, and report on, research to characterize, quantify and measure (including metric) sonic boom signatures, and their acceptability.	Technical report to CAEP	ICCAIA, RFPs, FAA, France Japan	CAEP/8

N.20	Develop further guidance material in case of new certification of an existing aircraft making use of demonstration procedures not used in the original certification or aircraft modification applications (including the use of engine de-rate).	ETM material	FAA, IATA, ICCAIA, France, TC	Last SG before CAEP/8
N.23	Develop guidance for applicants and authorities on deriving certificated noise levels by interpolation between already approved noise/mass values.	ETM material	TC, ICCAIA, IATA, France, FAA	First CAEP/8 SG (Oct. 2007?)
N.24	Provide a report to CAEP 8 on the results of a review and analysis of certification noise levels for transport category jet aircraft to understand the current state-of-the-art of aircraft noise technology.	Report	EASA IATA ICCAIA Italy UK US	CAEP8
N.08	Monitor, and report on, research to characterize, quantify and measure (including metric) sonic boom signatures, and their acceptability.	Technical report to CAEP	ICCAIA, RFPs, FAA, France Japan	CAEP/8
N.20	Develop further guidance material in case of new certification of an existing aircraft making use of demonstration procedures not used in the original certification or aircraft modification applications (including the use of engine de-rate).	ETM material	FAA, IATA, ICCAIA, France, TC	Last SG before CAEP/8
N.23	Develop guidance for applicants and authorities on deriving certificated noise levels by interpolation between already approved noise/mass values.	ETM material	TC, ICCAIA, IATA, France, FAA	First CAEP/8 SG (Oct. 2007?)
N.24	Provide a report to CAEP 8 on the results of a review and analysis of certification noise levels for transport category jet aircraft to understand the current state-of-the-art of aircraft noise technology.	Report	EASA IATA ICCAIA Italy UK US	CAEP8
E.09	**Fuel composition - emissions effects** 1. Review trends in aviation kerosene fuel supply composition. 2. Promote improved understanding of the potential use and emission effects of alternative fuels.	Report Report	ICCAIA	SG 2009

E.10	**Air Quality Guidance** Provide support to WG2, as appropriate, to assist the further development of the Local Air Quality Guidance.	Methodology and data as appropriate	All WG3	
O.05	Examine a case study on the management of "area-wide" aircraft noise.	Report to CAEP	Australia	Third SG
M.04	Examine the potential for emissions offset measures as a further means of mitigating the effects of aviation emissions on local air quality and global climate change.	Report	Australia Canada	CAEP/8

B Appendix B - EASA Policy Analysis Priorities

European policymakers and stakeholders were asked as part of the EFEMTA study "what are the policy measures needing modelling and what are the priorities?". The outcome was tabulated in the EFEMTA report.

These priorities were subsequently discussed with EASA to ascertain which were of particular priority to this EEMA study, which covers "basic" modelling and EASA's particular interest in regulatory impacts

The outcome of the EFEMTA and EASA discussions are tabulated in the following tables:

Air Quality Standards			
PM	Euro requirement. Needs good airport model and data on engine emissions	YES	Can do quantification with basic modelling Use FOA for airports
Emissions caps	Caps for individual airports.	POSS	Need advanced airport modelling tool, common to Europe.
Weighted pollutants analysis		YES	Can (probably) be done by existing tools, if needed
Technology Insertion			
New technology incl. fuels	Depends on measure but some might require analysis	YES	Needs advanced technology tools (technology evaluator or similar)

Source Emission and Noise Regulation			
SSBJ	Various issues including noise and emission regulation, climate impact studies, perhaps ATM	POSS	May need to model specific aircraft (expert modelling of individual aircraft) and then roll these into a fleet (not very difficult). What questions will we need to answer? NOx, climate impact? noise? Assume that we don't need to model these with other policy measures – probably makes the overall modelling too complicated, therefore model separately. NOT BASIC MODELLING
PM	Not a CAEP stringency issue but Euro requirement. Note difficult to model	YES	Can do quantification with basic modelling Use FOA for airports. Need an altitude method (from science – see AERONET work. Also AERO2k method). However, stringency type modelling is a different matter. How to do?? No CAEP guidance
International Agreements			
CO_2 vs other pollutants		YES	Modelling overall climate and noise impact of measures can be crucial in avoiding unforeseen unfortunate consequences (eg NOx flanking measures. This could be a very useful outcome of a system – but does depend on the assumptions about market behaviour
Operational Measures			
Green flight	Contrails, change of operating heights, etc	POSS	GHG only. Not really a common system issue, can be done a variety of ways, each with their own strengths and weaknesses

Economic and Policy Measures			
Taxation		NO(?)	Surprised that it is not a priority as it is now UK government draft policy. Requires RESPONSIVE MODEL or separate demand and technology response assumptions plus BASIC MODEL. That said, responsive model needs separate technology response assumptions
LAQ/GHG charges		YES	Requires RESPONSIVE MODEL or separate demand and technology response assumptions plus BASIC MODEL That said, responsive model needs separate technology response assumptions
Trading		YES	Requires RESPONSIVE MODEL or separate demand and technology response assumptions plus BASIC MODEL That said, responsive model needs separate technology response assumptions
Carbon offsets		YES	Same as trading?
Network effects	Assumed to be modelling of different route structures, hubbing vs point-to-point etc.	YES	Requires revised flight database (normally to achieve the same objective). Interesting area growing in importance given the Boeing view of the world. Again Requires RESPONSIVE MODEL or separate demand and technology response assumptions plus BASIC MODEL That said, responsive model needs separate technology response assumptions
Phaseout rules		YES	Very similar to CAEP modelling – current technology and detail needed
Sustainability assessment		NO(?)	At global level, similar to goals modelling. At airport level, needs an emissions/noise/capacity trade-off
Evolution and goals assessment		NO(?)	Should be possible once we have a basic system in place. Can factor in any set of assumptions.

C Appendix C - Specification for Generation of 2005 and 2025 Fleet Data

C.1 Overall Requirement

The EEMA Sample problem consists of the assessment of the NOx, fuel and noise effect of the imposition of a change of NOx regulation in ICAO Annex 16. Aim of the Sample Problem is to:

(i) demonstrate tool linkages in operation

(ii) tease out problems ("gaps")

The proposed rule Sample Problem change is:

A 20% increase in NOx stringency, agreed in 2010, coming into force in 1 Jan 2013.

The effect of this change will be assessed for the year 2025, using extrapolation of the 2002 FESG forecast and an accompanying set of FESG-like assumptions regarding fleet rollover, aircraft size etc. The NOx stringency itself will be simulated by not delivering engines into the fleet which do not meet the stringency, after 1 Jan 2013.

This document sets out the detail requirements and assumptions needed to generate the 2005 and 2025 fleets. Details will be updated and supplemented as needed during the development and running of the sample problem.

Outcome of this Fleet Data generation work will be a 3 sets of flights (up to six selected weeks to be provided by ENVISA/Eurocontrol), one for 2005 and two equivalent up-to-6-week sets of flights for 2025, one set with and one set without the stringency change. Each flight in each set will have an engine type allocated based on the full range of available certified engine types. How individual modellers use this data will vary model-by-model.

C.2 Detail Specification

C.2.1 Current Year

2005 GAES-MOVE[14] data does not currently contain engine type, tail number or airline data. Hence direct allocation of engine type is not possible on a detail flight basis. This needs to be rectified in future work beyond this contract.

For the purposes of this Sample Problem, engine type data will be simulated for each flight by taking the proportions of each engine type for each aircraft on each route (based on FAA/Wyle data[15]) and allocating these engines amongst the flights by that aircraft type on that route in the GAES-MOVE "movements" table. Airline allocations will not be correctly simulated but route aircraft/engine mix should be.

[14] GAES-MOVE is the Eurocontrol radar-track based movements data, in this case for the year 2005

[15] FAA/Wyle data is current year data originally provided as part of CAEP goals analysis, showing the distribution of engine types on each aircraft-route

Initial investigations, using preliminary data supplied by Envisa, show that there are 8353 airports included with a total of 4124512 operations. Using various mappings between the airport codes in the GAES-Move data and those in the FAA data, it has been possible to cross reference 5830 of the airports in the GAES-Move data, i.e. about 70%. The number of operations which can then be mapped between GAES-Move and the FAA data (in terms of departure/arrival airport pairs) is 4013670, about 97.3% of the total.

A similar approach has then been taken to mapping the aircraft types. The number of aircraft types in the GAES-Move data is 1482, with 851 types in the FAA data. Of these, it has been possible to identify mappings for 481 aircraft types, about 32.5% of the types in GAES-Move. Using both the airport and aircraft mappings then allowed 3948588 of the operations in GAES-Move to be mapped to equivalent operations (departure airport/arrival airport/aircraft type) in the FAA database, representing nearly 96% of the operations in GAES-Move.

For future studies, it may be necessary to ensure that a greater number of the aircraft types in GAES-Move are identified so as to allow engine types to be allocated but, for this sample problem, it is felt that successfully mapping 96% of the operations is acceptable. It is worth noting that some of the 4% of unmatched operations may be inapplicable anyway eg military or GA flights.

The remaining task for the 2005 baseline data will be, for each airport pair/aircraft combination that has been mapped successfully, to identify the engine types (and their proportion) in the FAA operations data and then to map these engine types onto the GAES-Move operations. This will allow an engine type to be defined for each of the GAES-Move operations to be included in the output. For the future year scenarios, each engine type in the 2005 data will be mapped to an engine satisfying the future scenario requirements and then mapped back to the operations data.

The output from this process, therefore, will be a Microsoft Access database containing three tables. Each table will contain the same number of flight definitions. The columns will be:

ID Departure_Airport Arrival_Airport Aircraft_Type Engine_Type Ops_Factor

The ID will be the same flight ID as in the supplied GAES-Move 2005 operations data (or will be created if it does not exist already), as will the departure and arrival airports and the aircraft type. The engine type will be allocated by QinetiQ as described above. The Ops_Factor will be used to define the growth in the number of operations between 2005 and 2025 and will be calculated on a regional basis as described below (the factors for 2005 will all be 1.0).

C.2.2 Future Year (2025) – Base Case (No stringency change)

Each flight in the 2005 movements data will be “grown” to represent the traffic increase, the increase in average aircraft size and the rollover of aircraft using the following assumptions:

- 2002 FESG traffic forecast for 2020, will be extrapolated to 2025 with an assumption of constant growth rate expressed as a factor (or percentage growth rate) (ie 2020-2025 annual growth rates same as FESG 2016-2020 annual growth rates). The FESG forecasts use global “routes”, so each airport pair will be mapped to these FESG routes to allow the relevant growth value to be applied.

- Fleet rollover assumptions in accordance with FESG 2002
- New and replacement aircraft/engines have been selected from the WG1 best practice and WG3 in-production databases used in the CAEP/7 ICAO Environmental Goals work, using existing aircraft/engine combinations meeting CAEP/5 noise and CAEP/6 NOx standards. For the stringency case, it is assumed that non-compliant engines are replaced by engines which meet the stringency. Where a suitable replacement engine, which is close to the original engine in both thrust and overall pressure ratio and which meets the stringency requirement, can be identified, then that engine is used. Where no suitable replacement engine exists in the current ICAO databank, a new engine is invented, with a representative thrust level and pressure ratio and with a NOx level which meets the stringency by a small margin. Note that this approach differs from that of previous FESG analyses, where non-compliant engines are assumed to be made compliant by modification. A list of engine replacements and the characteristics of new engines are provided in Tables C1 to C3.
- Outcome of the above assumptions will be a set of factors applicable on flight-by-flight basis to the 2005 movements data
- New large aircraft (>500 seats) will be simulated by B747s. No A380s will be included in this exercise
- There will be no new routes or improvement/worsening due to ATM changes

Output is a (6-week) set of 2025 movements with engines types and Ops Factors (see above) allocated. Each 2005 movement will have been replaced by:

- A movement with the same engine as for 2005 – with a revised Ops Factor (eg 0.65) representing the number of 2025 flights by that aircraft/engine type compared to the one flight in 2005
- One or more movements with one or more different engines (representing new deliveries since 2005) – with a revised frequency factor (eg 1.74)

The new movements will retain the flight profile data from the original 2005 movement.

C.2.3 Future Year (2025) – Stringency Case (20% stringency change)

Stringency revision is defined by a 20% reduction in Dp/Foo at an OPR of 30, that difference value maintained for engines above OPR30. For engines below OPR 30, a 20% reduction on CAEP/6 values is applied. For the purposes of this analysis, this stringency is applied to all certificateable engines (ie >26.7kN).

Each flight in the 2005 movements data will be "grown" using:

Application to 6 weeks flight profile data as for 2025 Base Case

C.3 Annualisation of air traffic movements data

As mentioned in the previous paragraphs, the Fleet Data generation work provides three sets of flights – one for 2005 and two for 2025 – each one with six selected weeks of air traffic movements.

For reasons of presentation and interpretation, however, results on an annual basis are preferred. Therefore, via pre- and post-processing, the data are annualised in the following way(s):

- Re GHG emissions modelling: as part of post-processing, GHG-NOx-emissions per day (i.e. 42 days = 6 weeks of air traffic x 7 days per week), have been multiplied with a 'day multiplier' (available in the EEMA Data Warehouse) and summed
- Re LAQ emissions and noise modelling: two separate airport air traffic files are available – one for Warsaw airport and one for Zurich airport (rigorously having the same flights to/from these airports as in the traffic files used for GHG emissions modelling). These files include a day multiplier for annualisation. Noise modellers need this for pre-processing; LAQ emissions modellers may apply this day multiplier in the pre- or post-processing.

2005 Engine	CAEP/6 Engine	2005 Engine	CAEP/6 Engine	2005 Engine	CAEP/6 Engine	2005 Engine	CAEP/6 Engine	2005 Engine	CAEP/6 Engine	2005 Engine	CAEP/6 Engine
1AS001	1AS001	3CM027	3CM027	2GE045	2GE045	4PW069	3CM030	1RR011	4RR037	PT6A4R	PT6A4R
1AS002	1AS002	2CM019	4CM036	2GE042	2GE037	4PW070	3CM030	4RR037	4RR037	PT6A50	PT6A50
4AL003	4AL002	3CM022	3CM022	2GE046	2GE037	4PW071	7PW083	1RR012	5RR038	PT6A60	PT6A60
4AL002	4AL002	3CM028	3CM028	2GE043	2GE036	1PW005	4BR009	5RR038	5RR038	PT6A6A	PT6A6A
6AL006	6AL006	6CM044	6CM044	2GE047	2GE036	1PW007	4BR009	5RR039	5RR038	PT6A6B	PT6A6B
6AL007	6AL007	7CM048	7CM048	3GE057	3GE057	1PW033	2GE037	1RR016	6GE093	PT6A6R	PT6A6R
6AL012	6AL012	1CM010	7CM047	2GE044	2GE048	1PW034	2GE037	1RR018	5GE084	PW118	PW118
6AL013	6AL013	1CM011	7CM047	2GE048	2GE048	1PW021	1PW054	1RR019	4BR009	PW119B	PW119B
6AL015	6AL015	2CM015	7CM047	2GE055	2GE055	1PW023	1PW054	1RR020	4BR009	PW120	PW120
6AL018	6AL013	7CM047	7CM047	3GE058	2GE055	1PW024	1PW054	1RR021	4BR009	PW120A	PW120A
6AL020	6AL015	3CM030	3CM030	2GE049	2GE055	1PW025	1PW054	6RR041	6RR041	PW121	PW121
6AL022	6AL022	3CM031	4CM036	2GE051	2GE051	1PW026	1PW054	3RR029	3RR029	PW123	PW123
1AA001	4BR009	3CM032	1CM008	5GE085	4GE081	1PW027	1PW054	3RR030	3RR030	PW123B	PW123B
1AA002	3CM026	3CM033	3CM026	4GE081	4GE081	1PW028	1PW054	2RR024	2RR024	PW123D	PW123D
1AA003	1CM008	3CM034	3CM026	3GE060	6GE090	1PW029	2GE045	2RR026	2RR026	PW124B	PW124B
1AA004	4CM036	1GE034	1GE034	3GE061	6GE090	1PW030	2GE045	2RR027	2RR027	PW125B	PW125B
1AA005	4PW072	1GE035	1GE035	6GE091	6GE090	1PW039	4PW072	5RR040	5RR040	PW127A	PW127A
4BR008	4BR008	5GE083	5GE083	7GE099	7GE099	4PW072	4PW072	1TL001	6AL008	PW127E	PW127E
4BR005	3CM029	6GE092	6GE092	1IA001	1CM008	1PW040	4PW072	1TL002	7PW079	R1820	R1820
4BR007	7CM048	6GE094	6GE094	3IA006	3CM028	7PW080	7PW080	1TL003	7PW080	RDA10	RDA10
1CM003	4CM035	3GE068	1PW054	3IA007	1CM008	1PW042	2GE045	1TL004	7PW080	RDA7	RDA7
1CM004	4CM035	3GE070	2GE037	1IA002	1CM008	1PW043	2GE055	1ZM001	4BR009	T56-1	T56-1
1CM005	4CM035	3GE073	2GE037	1IA003	1CM008	2PW061	2PW061	501D22	501D22	TFE731	TFE731
1CM007	4CM036	3GE074	2GE037	1IA004	3CM026	2PW062	6GE088	CF700D	CF700D	TIO540	TIO540
1CM008	1CM008	3GE078	2GE037	1IA005	3CM020	3PW065	6GE088	CJ6102	CJ6102	TPE10	TPE10
1CM009	1CM009	3GE072	2GE037	3IA008	4CM038	3PW066	3GE064	CJ6106	CJ6106	TPE12	TPE12
4CM035	4CM035	3GE077	2GE037	1KK003	3CM020	5PW076	5RR040	CT7-5	CT7-5	TPE14	TPE14
4CM036	4CM036	1GE001	5RR038	1PW035	1AS002	1PW045	1PW054	IO320	IO320	TPE2	TPE2
2CM012	3CM020	1GE002	5RR038	1PW036	1AS002	1PW047	2GE045	IO360	IO360	TPE3	TPE3
2CM016	3CM020	1GE003	5RR038	1PW037	1AS002	1PW048	5PW074	PT67B	PT67B	TSIO36	TSIO36
3CM020	3CM020	1GE010	1PW054	1PW001	3CM029	1PW049	5PW075	PT67D	PT67D		
3CM023	3CM020	1GE012	1PW054	1PW003	3CM029	5PW075	5PW075	PT6A14	PT6A14		
2CM013	7CM045	1GE013	1PW054	1PW008	4BR009	4PW067	5PW075	PT6A20	PT6A20		
3CM024	7CM045	2GE036	2GE036	1PW010	4BR009	1PW052	1PW057	PT6A27	PT6A27		
4CM038	4CM038	2GE037	2GE037	1PW011	4BR009	1RR002	4RR036	PT6A28	PT6A28		
3CM025	4CM038	2GE038	2GE038	1PW013	4BR009	1RR005	4RR036	PT6A34	PT6A34		
2CM014	3CM026	2GE039	2GE039	1PW014	4BR009	1RR006	4RR036	PT6A36	PT6A36		
2CM018	3CM026	3GE056	3GE056	1PW016	3CM029	1RR008	4RR036	PT6A42	PT6A42		
3CM021	3CM021	2GE040	2GE040	1PW017	3CM029	1RR010	4RR036	PT6A45	PT6A45		
3CM026	3CM026	2GE041	4RR036	4PW068	3CM030	4RR036	4RR036	PT6A4A	PT6A4A		

Table C1: 2005 Engine Maps to meet CAEP/6

2005 Engine	Stringency Engine	2005 Engine	Stringency Engine	2005 Engine	Stringency Engine	2005 Engine	Stringency Engine	2005 Engine	Stringency Engine	2005 Engine	Stringency Engine
1AS001	1AS001	3CM027	7PW083	2GE045	4RR036A	4PW069	7PW083	1RR011	3GE056	PT6A4R	PT6A4R
1AS002	1AS001	2CM019	3CM022	2GE042	2GE037	4PW070	7PW083	4RR037	3GE056	PT6A50	PT6A50
4AL003	6AL013	3CM022	3CM022	2GE046	2GE037	4PW071	7PW083	1RR012	4PW072A	PT6A60	PT6A60
4AL002	6AL013	3CM028	3CM022	2GE043	4RR036A	1PW005	6GE095	5RR038	5RR038A	PT6A6A	PT6A6A
6AL006	6AL007	6CM044	4CM043	2GE047	4RR036A	1PW007	6GE095	5RR039	5RR038A	PT6A6B	PT6A6B
6AL007	6AL007	7CM048	7PW083	3GE057	3GE056	1PW033	2GE037	1RR016	6GE093	PT6A6R	PT6A6R
6AL012	6AL013	1CM010	4CM038	2GE044	3GE056	1PW034	2GE037	1RR018	5GE084	PW118	PW118
6AL013	6AL013	1CM011	4CM038	2GE048	3GE056	1PW021	2GE037	1RR019	6GE095	PW119B	PW119B
6AL015	6AL007	2CM015	4CM038	2GE055	3GE056	1PW023	2GE037	1RR020	6GE095	PW120	PW120
6AL018	6AL013	7CM047	4CM038	3GE058	3GE056	1PW024	2GE037	1RR021	6GE095	PW120A	PW120A
6AL020	6AL007	3CM030	4CM039	2GE049	3GE056	1PW025	2GE037	6RR041	3GE056	PW121	PW121
6AL022	6AL022	3CM031	3CM022	2GE051	2GE051	1PW026	2GE037	3RR029	4GE081	PW123	PW123
1AA001	6GE095	3CM032	4CM041	5GE085	4GE081	1PW027	2GE037	3RR030	3RR030A	PW123B	PW123B
1AA002	3CM021	3CM033	4CM042	4GE081	4GE081	1PW028	2GE037	2RR024	2RR024	PW123D	PW123D
1AA003	4CM042	3CM034	4CM043	3GE060	5RR040A	1PW029	4RR036A	2RR026	2RR026A	PW124B	PW124B
1AA004	4CM041	1GE034	1GE034	3GE061	6GE091A	1PW030	4RR036A	2RR027	5RR040A	PW125B	PW125B
1AA005	4CM038	1GE035	1GE035	6GE091	6GE091A	1PW039	4PW072A	5RR040	5RR040A	PW127A	PW127A
4BR008	6GE095	5GE083	5GE083	7GE099	7GE099A	4PW072	4PW072A	1TL001	6AL008	PW127E	PW127E
4BR005	4CM039	6GE092	6GE092	1IA001	4CM042	1PW040	5RR038A	1TL002	7PW079	R1820	R1820
4BR007	7PW083	6GE094	6GE094	3IA006	3CM022	7PW080	7PW080	1TL003	7PW080	RDA10	RDA10
1CM003	7PW083	3GE068	2GE037	3IA007	4CM042	1PW042	4RR036A	1TL004	7PW080	RDA7	RDA7
1CM004	4CM039	3GE070	2GE037	1IA002	4CM042	1PW043	3GE056	1ZM001	6GE095	T56-1	T56-1
1CM005	7PW083	3GE073	2GE037	1IA003	4CM042	2PW061	2RR024	501D22	501D22	TFE731	TFE731
1CM007	3CM022	3GE074	2GE037	1IA004	3CM020	2PW062	3PW065A	CF700D	CF700D	TIO540	TIO540
1CM008	4CM041	3GE078	2GE037	1IA005	3CM020	3PW065	3PW065A	CJ6102	CJ6102	TPE10	TPE10
1CM009	4CM042	3GE072	2GE037	3IA008	4CM038	3PW066	2RR026A	CJ6106	CJ6106	TPE12	TPE12
4CM035	7PW083	3GE077	2GE037	1KK003	3CM020	5PW076	6GE091A	CT7-5	CT7-5	TPE14	TPE14
4CM036	4CM041	1GE001	5RR038A	1PW035	1AS002	1PW045	2GE037	IO320	IO320	TPE2	TPE2
2CM012	3CM020	1GE002	5RR038A	1PW036	1AS002	1PW047	4RR036A	IO360	IO360	TPE3	TPE3
2CM016	3CM020	1GE003	5RR038A	1PW037	1AS002	1PW048	4RR036A	PT67B	PT67B	TSIO36	TSIO36
3CM020	3CM020	1GE010	2GE037	1PW001	4CM039	1PW049	2GE051	PT67D	PT67D		
3CM023	3CM020	1GE012	2GE037	1PW003	4CM039	5PW075	4GE081	PT6A14	PT6A14		
2CM013	4CM038	1GE013	2GE037	1PW008	6GE095	4PW067	4GE081	PT6A20	PT6A20		
3CM024	4CM038	2GE036	4RR036A	1PW010	4BR009A	1PW052	3GE056	PT6A27	PT6A27		
4CM038	4CM038	2GE037	2GE037	1PW011	4BR009A	1RR002	5RR038A	PT6A28	PT6A28		
3CM025	4CM038	2GE038	3GE056	1PW013	4BR009A	1RR005	2GE037	PT6A34	PT6A34		
2CM014	4CM042	2GE039	3GE056	1PW014	4BR009A	1RR006	2GE037	PT6A36	PT6A36		
2CM018	4CM042	3GE056	3GE056	1PW016	4BR009A	1RR008	2GE037	PT6A42	PT6A42		
3CM021	3CM021	2GE040	4RR036A	1PW017	4CM039	1RR010	4RR036A	PT6A45	PT6A45		
3CM026	3CM021	2GE041	4RR036A	4PW068	7PW083	4RR036	4RR036A	PT6A4A	PT6A4A		

Table C2: 2005 Engine Maps to meet CAEP/6-20% stringency

UID No	Engine Identification	Combustor Description	Eng Type	B/P Ratio	Press Ratio	Rated Output (kN)	EI NOx T/O (g/kg)	C/O	App	Idle
4BR009A	BR700-710A2-20 - stringency		TF	4.19	24.16	65.61	17.54	14.07	7.18	4.37
4PW072A	PW2037 - stringency		TF	5.71	26.7	166.35	23.56	19.19	7.83	3.28
5RR038A	RB211-535E4 - stringency	Phase 5	MTF	4.1	26.0	178.4	19.45	15.31	7.3	3.84
4RR036A	RB211-524G-T - stringency		MTF	4.25	32.1	253	25.24	19.35	8.59	3.55
3RR030A	Trent 772 - stringency	Improved traverse	TF	5.03	35.8	316.3	30.63	23.56	9.18	4.2
3PW065A	PW4084D - stringency		TF	6.3	36.36	369.6	37.6	27.99	9.01	2.89
2RR026A	Trent 884 - stringency		TF	5.87	38.96	390.10	38.39	29.36	10.61	4.83
5RR040A	Trent 895 - stringency		TF	5.7	41.52	413.05	42.26	30.32	10.07	4.52
6GE091A	GE90-94B - stringency	DAC II	TF	8.33	40.53	432.8	45.81	33.90	14.11	4.95
7GE099A	GE90-115B - stringency	DAC	TF	7.08	42.24	513.9	45.37	32.43	14.87	4.68

Table C3: Data for "new" engines required to meet stringency case

D Appendix D - Summary of AERO-MS Economic and Environmental Modelling Capabilities

The AERO Modelling System (AERO-MS) is a policy-testing tool for quantifying the environmental and economic consequences of measures that it is anticipated would curb emissions from aircraft. The AERO-MS can analyse a wide range of such measures – economic, regulatory, technological and operational – in the context of alternative future "business-as-usual" economic and technological scenarios for the aviation sector.

Some basic information

The AERO-MS comprehensively integrates the relevant economic, commercial, technological and environmental reactions to a policy measure (or a package of measures). Figure D.1 illustrates the sequence of computational steps and interactions in the AERO-MS that model these reactions when a measure is being tested.

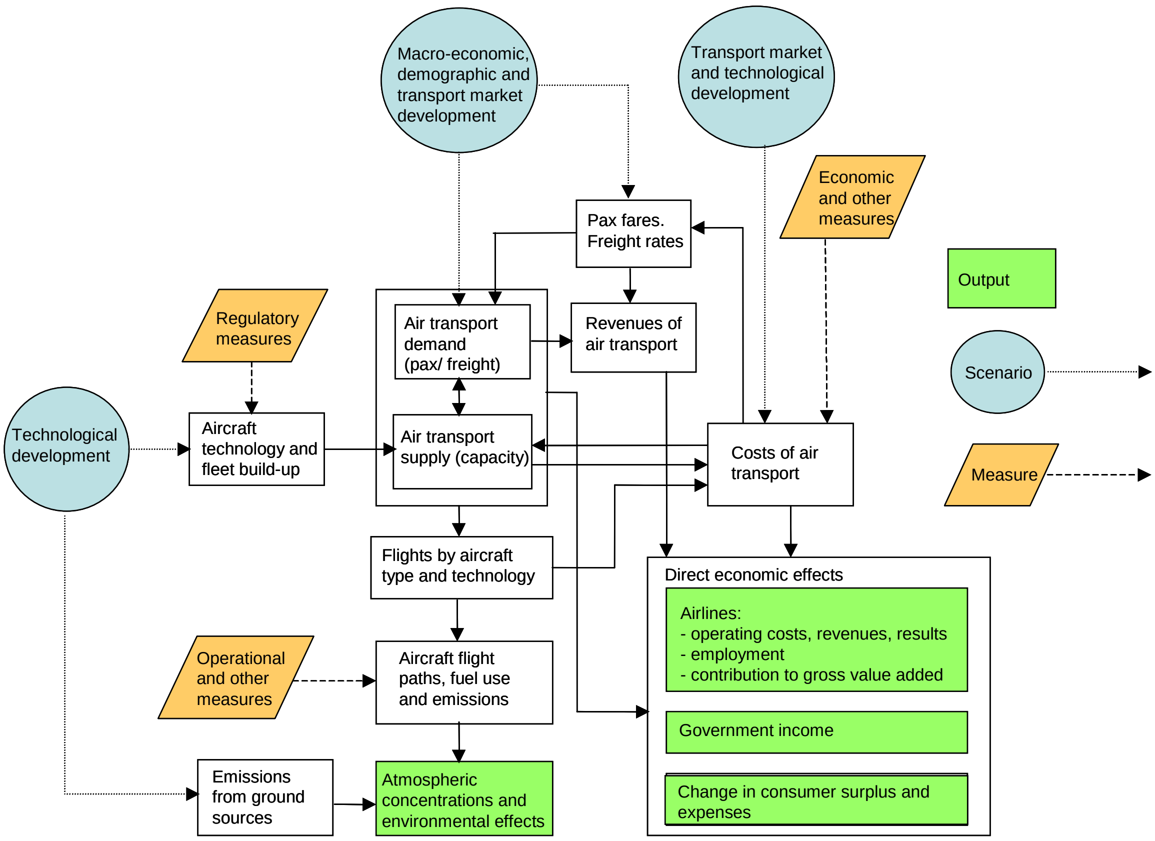

Figure D1: Modelling policy measures with the AERO-MS

The AERO-MS is global in coverage, but functions at a highly disaggregate level in several "dimensions":

- Spatially, the system processes individually some 19,000 city-pair 'flight stages'. These account for 85% of scheduled passenger-km, the remaining city-pairs being included as a series of aggregate groups defined by route length and geographic location;

- Air service demand is split between three classes of passenger traffic, with different fare elasticities, and air cargo;
- Air service supply is represented by ten generic aircraft types with different combinations of seating (or cargo) capacity and range capability;
- Aircraft technology related to fuel efficiency distinguishes between "current" and "older" designs, the former having been certificated within the 12 years previous to the forecast year;
- Competitive forces are represented by the world region of ownership of the different carriers on each flight stage, and by the alternative of surface transport where relevant.

These dimensions are captured in the AERO-MS "Unified Database". For the system's Base Year (originally 1992, and subsequently updated to 1997), each explicit flight stage is described in terms of its passenger and cargo demand, and the number of flights performed by each generic aircraft type, split into "current" and "older" technology and by carrier. Fares, freight charges and costs for different carriers and routes and aircraft types are included. Good quality data on aircraft engine fuel burn, modelling the combustion process and the resulting emissions were also secured.

Assembled at the disaggregate level, the Base Year data were shown to validate well in aggregate, in terms of airline costs and revenues, passenger-km and aircraft-km, the distribution of the aircraft fleet among generic types, and fuel use. This provides the sound basis from which projections can be made into the future.

System outputs

The AERO-MS produces extensive outputs consistent with the comprehensive scope of the modelling undertaken. The main output categories are:

- Air transport volumes:
  - Passenger demand by class and cargo demand;
  - Flights and aircraft-km by generic aircraft type;
  - Available seat capacity and available seat-km;
  - Fleet size by generic aircraft type;
  - Load factors;
- Economic impacts on airlines, consumers and economies:
  - Airline costs and revenues;
  - Consumer surplus;
  - Taxation revenues;
  - Gross value-added of aviation sector;
  - Airline-related employment;
- Environment:
  - Aviation fuel use;
  - Aviation emissions by substance (CO2, CO, CxHy, H2O, NOx, SO2);

- Effect on surface emissions due to transfer of demand to ground transport;
- Changes in radiative forcing and effective ultraviolet doses.

Results for individual flight stages can be aggregated to 196 region-pairs, based on 14 regions derived from IATA definitions. Emissions and atmospheric concentrations are computed by the AERO-MS in three-dimensional space, based on a – variable – global geographical grid (default: 5° by 5° (longitude/latitude)) and – variable – altitude bands (default: 15 equidistant bands of 1 km). The inventory of emissions from ground sources is based on a global geographical grid of 1° by 1°.

Future year assessments

In the AERO-MS, measures are tested against expectations of potential future developments in the air transport sector in the absence of measures: the "business-as-usual" scenario. Starting from the base year, the effects of such developments become manifest in changes in the fuel-use and emission characteristics and purchase prices of aircraft; air transport demand (passenger and freight), fares and freight rates; and aircraft flights by flight stage, aircraft type and technology level. Consequently, the computation of all economic and environmental effects needs to be updated, prior to testing the measures of interest. For the business-as-usual scenario, assumptions have to be input concerning:

- the growth in the air transport demand;
- the rate of change in the underlying fuel use of newly-available aircraft, and the potential trade-offs in technological development between considerations of aircraft noise, CO2 and NOx emissions;
- the development of the commercial aviation sector in terms of costs, fares, load factors and profitability.

In generating the business-as-usual scenario, the AERO-MS user has responsibility to ensure that there is consistency between the changes in costs, fares, demand, capacity and technology inputs, though a number of pre-packaged business-as-usual scenarios have previously been agreed by the ICAO Forecasting and Economic Analysis Support Group (FESG).

The "Policy case" in which measures are tested is based on the business-as-usual scenario situation with the measures (or policies) to be evaluated superimposed upon it. For market-based measures, the AERO-MS models, e.g., the responses and interactions of air service consumers and carriers to arrive at a revised equilibrium of demand and supply, with associated operating cost and fare (and freight charge) levels. This position also modifies the forecast of aircraft emissions compared with the business-as-usual scenario. The essence of the AERO-MS approach is to compare the situations with and without measures as two distinct lines of future development from the Base position, from which the economic and environmental impacts of introducing the measures can be quantified.

Individual models in AERO-MS

The AERO-MS contains the following individual models:

- **Aircraft Technology Model (ATEC)**: computes fuel use and emission characteristics by aircraft types and technology level, and for future cases with or without measure(s), it computes, in addition, aircraft purchase prices due to price developments or possible measures

- **Air Transport Demand and Traffic Model (ADEM)**: processes base year data on air transport demand and flights, and assesses passengers and freight transported, flights by aircraft type and technology level, fares and freight rates; for future cases, it translates economic, demographic and fare developments into air transport demand (passengers and freight) forecast and subsequently into aircraft flights by flight stage, aircraft type and technology level; for future cases with measure(s), it translates changes in costs into changes in fares to produce revised air transport demand forecast, plus final changes in unit composite costs and final forecast of aircraft flights by flight stage, aircraft type and technology level
- **Aviation Operating Cost Model (ACOS)**: computes aircraft operating costs (e.g., fuel, crew and aircraft finance costs) by aircraft type, technology level and flight stage; for future cases, ditto, however, per region pair (in stead of flight stage) plus unit operating costs – per passenger and kg freight – by aircraft type, technology level and flight stage; for future cases with measure, ditto and in addition – due to a possible measure – a change in unit operating costs and a change in unit composite costs by flight stage
- Economic impact models:
    - **Direct Economic Impact Model (DECI)**: for base and future cases, it calculates airline operating costs and revenues, airline related employment, airline contribution to gross value added, extent and composition of airline fleets (by carrier group and IATA region); in future cases with measure(s), it calculates in addition the government income from charges (if applicable) and changes in consumer surplus and consumer expenses (by carrier group and IATA region)
    - **Macro-Economic Impact Model for the Netherlands (MECI)**: computes the contribution to employment and gross value added related to air transport to and from the Netherlands
- **Flights and Emissions Model (FLEM)**: calculates fuel use and emissions (CO_2, NO_x, SO_2, C_xH_y, CO and H_2O) in 3D grid
- Atmospheric impact models:
    - **Other Atmospheric Immissions Model (OATI)**: calculates emissions of CO_2, NO_x, SO_2, C_xH_y, CO and N_2O of other sources of emissions in the atmosphere
    - **Atmospheric Processes Dispersion Model (APDI)** (also called: **Chemical Tracer Model KNMI (CTMK)**): calculates concentrations of CO_2, NO_x and O_3 in a 3D grid
    - **Environmental Impact Model (ENVI)**: calculates the effective UV radiation and in future cases, in addition, the change in global warming potential

Application of AERO-MS

The AERO-MS has formed a key part of a number of international studies where the results from model tests have provided a clearly quantified basis on which policy judgements may be made.

Between 2000 and 2004 the AERO-MS was used extensively to evaluate the potential for market-based measures (notably taxes, charges and emission trading) for the International Civil Aviation Organisation (ICAO) Committee on Aviation Environmental Protection (CAEP). In a further study for the Dutch government a wider range of global, regional and local policy options were evaluated, with specific attention being paid to the impact on the Netherlands. Recently, an EC study made use of the AERO-MS to explore the environmental, government, consumer and industry impacts of a wide range of consistent technology, regulatory, demographic, social and economic scenarios.

In 1997 the modelling system was employed on behalf of the EC to examine the effects of lifting the exemption of civil aviation kerosene from taxation. During 2000 the Dutch Civil Aviation Authority commissioned a study to facilitate the debate on the national allocation of CO2 between the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the UN Framework Convention on Climate Change (UNFCCC) and ICAO CAEP.

The AERO-MS has also been used to examine the impacts of liberalisation of European Air Transport (1996), to undertake a global analysis of emission charges and taxes for CAEP's "Focal Point on Charges" (FPC, 1998).

Information sources (references)

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- AERO-team (2002). AVIATION EMISSIONS AND EVALUATION OF REDUCTION OPTIONS – AERO – Main Report. Published by: Directorate General for Civil Aviation, Ministry of Transport, Public Works and Water Management of the Kingdom of the Netherlands, The Hague, Netherlands. July 2002.

E Appendix E - EEMA Models' Input

Tables	Description / Sample data	GHG tools				LAQ tools			Noise tools			Economics
		AEM	AERO2K	FAST	AERO-MS (FLEM)	LASPORT	ALAQS-AV (+ LASAT)	ADMS	SONDEO	ANCON2	ENHANCE / INM	AERO-MS (ADEM+ACOS +DECI)
Operations												
Traffic												
FlightID	Unique ID	Required	Required	Required	Optional	Not used	Optional	Not used	Optional	Required	Required	Required
On-block time		Not used	Not used	Optional	Not used	Required (3)	Optional	Optional	Not used	Required	Not used	Required
Landing time		Not used	Not used	Optional	Not used	Required (3)	Required	Not used	Not used	Not used	Not used	Not used
Roll-off time		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Off-block time		Optional	Not used	Not used	Not used	Required (3)	Required	Not used	Optional	Optional	Optional	Not used
Take-off time		Required	Required	Optional	Not used	Required (3)	Optional	Optional	Optional	Optional	Optional	Required
Call sign		Optional	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Airline		Optional	Not used	Optional	Optional	Not used	Not used	Optional	Not used	Not used	Not used	Optional
Departure airport	ICAO or IATA code	Required	Required	Required	Required	Not used	Not used	Optional	Required	Not used	Not used	Required
Destination airport	ICAO or IATA code	Required	Required	Required	Required	Not used	Not used	Optional	Optional	Not used	Not used	Required
Operation type	Departure or Arrival (LAQ / noise)	Not used	Not used	Optional	Not used	Not used	Required	Required	Required	Required	Required	Not used
Aircraft type	ICAO code	Required	Required	Required	Required	Required (3)	Required	Required	Required	Required	Required	Required
Engine type		Optional	Optional	Optional	Optional	Not used	Optional	Required	Optional	Required	Not used	Optional
Nb of engines		Optional	Optional	Optional	Optional	Not used	Optional	Required	Optional	Required	Not used	Optional
Aircraft registration number		Optional	Not used	Not used	Not used	Not used	Optional	Not used	Not used	Optional	Not used	Not used
Number of seats		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Age		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Load factor		Not used	Not used	Optional	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Required
Flight category	Pax, Cargo, Combi	Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Required
Take-off weight		Not used	Optional	Optional	Optional	Not used	Optional	Optional	Optional	Required	Optional	Required
Landing weight		Not used	Not used	Not used	Optional	Not used	Optional	Not used	Optional	Required	Optional	Required
Fuel weight	maximum, reserve	Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Required
Take-off runway		Not used	Not used	Not used	Not used	Required (3)	Required	Required	Optional	Required	Required	Not used
Landing runway		Not used	Not used	Not used	Not used	Required (3)	Required	Required	Optional	Required	Required	Not used
Gate		Not used	Not used	Not used	Not used	Required (3)	Required	Required	Not used	Not used	Not used	Not used
Flight trajectory												
FlightID	If individual flight trajectories available	Required	Required	Required	Optional	Not used	Optional	Not used	Optional	Required	Required	Required
Event time		Required	Required	Required	Optional	Not used	Not used	Optional	Required	Optional	Optional	Optional
Attitude	climb, cruise, descent	Optional	Not used	Optional	Optional	Not used	Optional	Optional	Optional	Not used	Not used	Not used
Ground speed		Optional	Required	Not used	Optional	Not used	Not used	Optional	Optional	Required	Optional	Optional
True airspeed		Not used	Not used	Not used	Optional	Not used	Optional	Not used	Optional	Required	Optional	Optional
Climb-descent rate		Optional	Not used	Not used	Optional	Not used	Not used	Optional	Optional	Not used	Not used	Not used
Latitude		Required	Required	Required	Optional	Not used	Optional	Not used	Optional	Required (2)	Required	Not used
Longitude		Required	Required	Required	Optional	Not used	Optional	Not used	Optional	Required (2)	Required	Not used
FL (AFL)		Required	Required	Required	Optional	Not used	Optional	Not used	Not used	Required	Required	Not used
Great circle distance		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Detour factor		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Thrust setting		Not used	Not used	Not used	Optional	Not used	Optional	Optional	Optional	Required	Optional	Optional
Taxi distance		Not used	Not used	Not used	Optional	Not used	Optional	Optional	Optional	Not used	Not used	Optional
Taxi route used between runway / gate		Not used	Not used	Not used	Not used	Required (7/4)	Optional	Optional	Optional	Not used	Not used	Not used
Taxi speed or Taxi time		Not used	Not used	Not used	Optional	Required (7/4)	Required	Required	Optional	Not used	Not used	Optional
Runway rolling distance		Not used	Not used	Not used	Not used	Required (7/4)	Required	Required	Optional	Required	Optional	Not used
Start/Touchdown point	displace start-roll / touchdown threshold	Not used	Not used	Not used	Not used	Required (7/4)	Required	Required	Optional	Required	Optional	Not used
Reverse thrust usage		Not used	Not used	Not used	Not used	Optional (7)	Not used	Optional	Optional	Required	Not used	Optional
Weight		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Optional	Required	Not used	Optional

Tables	Description / Sample data	GHG tools				LAQ tools			Noise tools			Economics
		AEM	AERO2K	FAST	AERO-MS (FLEM)	LASPORT	ALAQS-AV (+ LASAT)	ADMS	SONDEO	ANCON2	ENHANCE / INM	AERO-MS (ADEM+ACOS +DECI)
Aircraft & Engine												
Aircraft equivalent												
Aircraft type	A/c type in source data (e.g. A321-111)	Required	Required	Required	Required	Not used	Required	Required	Required	Required	Required	Required
Equivalent aircraft type	in the model's a/c dtb (e.g. A321)	Required	Optional	Optional	Required	Required (8)	Required	Required	Required	Required	Required	Required
Aircraft list												
Aircraft type		Required	Required	Required	Required	Optional (10)	Required	Required	Required	Required	Required	Required
Equivalent aircraft	BADA, PIANO, …	Required	Required	Required	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Average/Max seat capacity		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Max take-off weight		Not used	Not used	Not used	Optional	Optional (10)	Required	Required	Required	Not used	Required	Optional
Max landing weight		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Required	Not used	Required	Optional
Max landing distance		Not used	Not used	Not used	Not used	Not used	Required	Required	Required	Not used	Required	Not used
Design range		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Description		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional	Not used	Optional	Not used
VOC TOG Class	commercial, air taxi, general aviation	Required	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Average age of the fleet		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Launching date of the model		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Manufacturer		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Aircraft / engine match												
Aircraft type		Required	Required	Required	Required	Optional (10)	Required	Required	Required	Required	Required	Optional
Aircraft registration number		Not used	Not used	Not used	Not used	Not used	Optional	Not used	Not used	Required	Not used	Not used
Engine type		Optional	Required	Optional	Optional	Not used	Not used	Optional	Required	Required	Required	Optional
Fleet %	% of fleet equiped with this engine	Not used	Not used	Optional	Not used	Optional (10)	Required	Optional	Optional	Not used	Not used	Not used
Nb of engines		Required	Required	Optional	Optional	Optional (10)	Required	Optional	Required	Required	Required	Optional
ICAO Unique engine ID (UID)		Not used	Required	Optional	Optional	Optional (10)	Optional	Optional	Required	Required	Not used	Optional
Engine list												
Engine type		Required	Not used	Not used	Optional	Not used	Required	Required	Required	Required	Required	Optional
Manufacturer		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Static thrust		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Required	Required	Required	Optional
Noise Id		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Required	Required	Required	Optional
Chapter category		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Performance coefficients												
Aircraft type		Not used	Not used	Not used	Required	Not used	Not used	Optional	Required	Required	Optional	Optional
Aerodynamic coefficients	drag over lift, polar coefficients, etc.	Not used	Not used	Not used	Optional	Not used	Not used	Optional	Required	Required	Optional	Not used
Wing surface		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Optional	Optional
Engine coefficients	used to derive thrust	Not used	Not used	Not used	Optional	Not used	Not used	Optional	Required	Required	Optional	Not used
Standard LTO profiles												
Aircraft type		Not used	Not used	Not used	Optional	Required (8)	Required	Required	Required	Not used	Optional	Optional
Standard Landing and Take-Off Profiles	altitude, TAS and thrust	Not used	Not used	Not used	Optional	Optional	Required	Required	Required	Not used	Optional	Optional

Tables	Description / Sample data	GHG tools				LAQ tools			Noise tools			Economics
		AEM	AERO2K	FAST	AERO-MS (FLEM)	LASPORT	ALAQS-AV (+ LASAT)	ADMS	SONDEO	ANCON2	ENHANCE / INM	AERO-MS (ADEM+ACOS +DECI)
Airport												
Airport infrastructure												
ICAO Code		Required	Required	Required	Required	Not used	Required	Optional	Optional	Optional	Optional	Required
IATA Code		Required	Required	Required	Required	Not used	Required	Optional	Required	Optional	Optional	Required
Latitude	reference point	Required	Required	Required	Optional	Optional	Required	Optional	Required	Required	Required	Optional
Longitude	reference point	Required	Required	Required	Optional	Optional	Required	Optional	Required	Required	Required	Optional
Altitude	reference point	Optional	Not used	Optional	Optional	Optional	Required	Optional	Required	Required	Required	Not used
City		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Not used	Not used	Not used	Not used
Airport name		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Not used	Not used	Not used
Country		Not used	Not used	Optional	Optional	Not used	Required	Optional	Required	Not used	Not used	Optional
World region		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Not used	Not used	Optional
Taxi-In average duration		Optional	Optional	Optional	Optional	Optional	Not used	Optional	Optional	Not used	Not used	Optional
Taxi-Out average duration		Optional	Optional	Optional	Optional	Optional	Not used	Optional	Optional	Not used	Not used	Optional
Taxi speed (can be taxiway specific)		Not used	Not used	Not used	Not used	Optional	Required	Required	Optional	Not used	Not used	Optional
Number of runways		Not used	Not used	Not used	Not used	Required (4)	Required	Required	Required	Not used	Not used	Not used
Runway coordinates	Id / lat / long / alt	Not used	Not used	Not used	Not used	Required (4)	Required	Required	Required	Required (2)	Required	Not used
Horizontal Climbout routes		Not used	Not used	Not used	Not used	Optional	Optional	Optional	Required	Not used	Optional	Not used
Apron coordinates	Id / lat / long / alt	Not used	Not used	Not used	Not used	Required (4)	Optional	Optional	Not used	Not used	Not used	Not used
Taxiway coordinates	Id / lat / long / alt	Not used	Not used	Not used	Not used	Required (4)	Optional	Optional	Not used	Not used	Not used	Not used
Operational hours	e.g. no movement at night	Not used	Not used	Not used	Optional	Optional (5)	Not used	Optional	Optional	Not used	Not used	Optional
Main activity	passengers, cargo, business, etc.	Not used	Not used	Not used	Not used	not used	Not used	Not used	Not used	Not used	Not used	Not used
Roughness length		Not used	Not used	Not used	Not used	Optional (1)	Required (1)	Required	Not used	Not used	Not used	Not used
Map		Not used	Not used	Not used	Not used	Optional	Required	Required	Optional	Not used	Not used	Not used
Terrain / population												
Terrain Elevation data		Not used	Not used	Not used	Not used	Optional (1)	Optional	Optional	Optional	Optional	Optional	Not used
Census Data		Not used	Not used	Not used	Not used	Not used	Optional	Optional	Required	Required	Optional	Not used
Fuel, Emission & Noise												
En-Route fuel flows												
Equivalent aircraft type	BADA, PIANO, …	Required	Not used	Required	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Attitude	climb, cruise, descent	Required	Not used	Required	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Not used
WeightCategory	low, high, nominal	Required	Not used	Required	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Level	FL	Required	Not used	Required	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Fuel burn rate		Required	Not used	Required	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
LTO emissions												
Engine type		Required	Not used	Required	Required	not used	Required	Required	Not used	Not used	Not used	Optional
Pollutant	fuel, NOx, CO, HC	Required	Not used	Required	Required	Optional (6)	Required	Required	Not used	Not used	Not used	Optional
Mode	take-off, climb-out, approach, idle	Required	Not used	Required	Required	Optional (6)	Required	Required	Not used	Not used	Not used	Optional
Emission index		Required	Not used	Required	Required	Optional (6)	Required	Required	Not used	Not used	Not used	Optional
Time in mode		Required	Not used	Required	Required	Optional (9)	Not used	Optional	Not used	Not used	Not used	Optional
Test date		Optional	Not used	Optional	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Source	ICAO, FAA, FOI, ANP, FOCA, etc.	Optional	Not used	Optional	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
VOC / TOG class constants												
VOC TOG Class		Required	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Pollutant	Benzene, Toluene, etc.	Required	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
value		Required	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Noise-Power-Distance data												
Noise Id		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Required	Required	Required	Optional
Noise-Power-Distance data		Not used	Not used	Not used	Optional	Not used	Not used	Not used	Required	Required	Required	Optional

Tables	Description / Sample data	GHG tools				LAQ tools			Noise tools			Economics
		AEM	AERO2K	FAST	AERO-MS (FLEM)	LASPORT	ALAQS-AV (+ LASAT)	ADMS	SONDEO	ANCON2	ENHANCE / INM	AERO-MS (ADEM+ACOS +DECI)
Meteorological Data												
Standard atmosphere data												
Altitude		Required	Not used	Not used	Required	Not used	Not used	Not used	Not used	Not used	Not used	Required
Temperature		Required	Not used	Not used	Optional	Not used	Not used	Optional	Not used	Not used	Not used	Optional
Pressure		Required	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Sound velocity		Required	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Density of air		Required	Not used	Not used	Optional	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Density of H2O		Required	Not used	Not used	not used	Not used	Not used	Not used	Not used	Not used	Not used	not used
Relative humidity		Required	Not used	Not used	Required	Not used	Not used	Optional	Not used	Not used	Not used	Required
Relative humidity	yearly evolution											
Month		Not used	Not used	Not used	Optional	Not used	Not used	Optional	Not used	Not used	Not used	Not used
Latitude		Not used	Not used	Not used	Optional	Not used	Not used	Optional	Not used	Not used	Not used	Not used
Height		Not used	Not used	Not used	Optional	Not used	Not used	Optional	Not used	Not used	Not used	Not used
Humidity		Not used	Not used	Not used	Optional	Not used	Not used	Optional	Not used	Not used	Not used	Not used
Airport meteorological data												
Day / time		Not used	Not used	Not used	Optional	Required (1)	Required (1)	Required	Optional	Optional	Optional	Not used
Measurement point position	lat, long, alt	Not used	Not used	Not used	Optional	Required (1)	Required (1)	Required	Optional	Optional	Optional	Not used
Wind speed		Not used	Not used	Not used	Optional	Required (1)	Required (1)	Required	Optional	Optional	Optional	Not used
Wind direction		Not used	Not used	Not used	Optional	Required (1)	Required (1)	Required	Optional	Optional	Optional	Not used
Atmospheric stability	Monin-Obukhov length, Klug-Manier class	Not used	Not used	Not used	Optional	Required (1)	Required (1)	Optional	Not used	Not used	Not used	Not used
Temperature		Not used	Not used	Not used	Optional	Not used	Optional (1)	Optional	Optional	Optional	Optional	Not used
Pressure		Not used	Not used	Not used	Optional	Not used	Optional (1)	Optional	Optional	Optional	Optional	Not used
Humidity		Not used	Not used	Not used	Optional	Not used	Optional (1)	Optional	Optional	Optional	Optional	Not used
Traffic Forecast												
Future fleet												
Aircraft type		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Required	Not used	Optional
Base year		Not used	Not used	Required	Required	Not used	Not used	Optional	Optional	Required	Not used	Required
Replacement year		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Required	Not used	Optional
Replacement rate		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Required	Not used	Optional
Efficiency improvement		Not used	Not used	Required	Required	Not used	Not used	Optional	Optional	Required	Not used	Required
Future operations												
Aircraft type		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Required	Not used	Optional
Aircraft seat category		Not used	Not used	Optional	Optional	Not used	Not used	Not used	Not used	Required	Not used	Optional
World region		Not used	Not used	Optional	Optional	Not used	Not used	Not used	Optional	Required	Not used	Optional
Aircraft category	commercial, cargo, business, etc.	Not used	Not used	Optional	Optional	Not used	Not used	Not used	Optional	Required	Not used	Optional
baseline year		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Required	Not used	Optional
Forecast year		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Required	Not used	Optional
% traffic growth		Not used	Not used	Optional	Optional	Not used	Not used	Optional	Optional	Required	Not used	Optional

Tables	Description / Sample data	GHG tools				LAQ tools			Noise tools			Economics
		AEM	AERO2K	FAST	AERO-MS (FLEM)	LASPORT	ALAQS-AV (+ LASAT)	ADMS	SONDEO	ANCON2	ENHANCE / INM	AERO-MS (ADEM+ACOS +DECI)
Economics												
Price of emissions												
Pollutant		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Year / month		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Altitude band	ground, troposphere, etc.	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Minimum price		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Maximum price		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Average / most realistic price		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Air transport data												
Pax and/or freight transported		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Required
Revenue tonne kilometres (RTK) performed		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Required
Actual aircraft/passenger/freight-km		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Required
Available tonne/seat/cargo-km		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Required
Different variable operating costs	per km, block-hour or cycle	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional
Pax fares and freight rates		Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Not used	Optional

(1) Used for dispersion calculations with LASAT.
(2) Needed in catesian coordinates, not polar coordinates (lat/lon).
(3) For a monitor calculation.
(4) Emission calculations can be carried out as well without this information but with user-defined times-in-mode.
(5) For a scenario calculation: specification of average day (distinct for arrivals and departures) / week / month courses for each aircraft group.
(6) Fuel flows and emission indices for the modes idle, approach, climbout, and takeoff are required for each aircraft group and can be specified as well individually to each aircraft (monitor calculation).
Any trace substance can be defined. Default emission values are provided for NOX, CO, HC, and Benzene.
(7) Not specified on the basis of individual aircraft.
(8) Aircraft are pooled in aircraft groups. Default groups are provided, user-defined groups can also be applied.
(9) Used for a separate emission calculation with user-defined times in-mode.
(10) Optional for the next major Lasport release. Presently, emissions are either explicitly given for each aircraft/aircraft group or they are derived from the provided data data base by assigning a technology mixture to each group.

F Appendix F - EEMA Models' Output

Category	Item	GHG tools				LAQ tools			Noise tools			Economics
		AEM	AERO2K	FAST	AERO-MS (FLEM)	LASPORT	ALAQS-AV (+ LASAT)	ADMS	SONDEO	ANCON2	ENHANCE / INM	AERO-MS (ADEM+ACOS +DECI)
Flight trajectory proc	Completion of missing flight segments	Direct	Direct	Pre-proc	Direct	Not available	Not available	Not available	Direct	Direct	Not available	Not available
	Radar data smoothing	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct	Direct	Not available
Pollutants	Fuel burn	Direct	Direct	Direct	Direct	Pre-proc	Direct	Post-proc	Not available	Not available	Not available	Direct
	CO2	Direct	Direct	Direct	Direct	Pre-proc	Post-proc	Pre-proc	Not available	Not available	Not available	Not available
	H2O	Direct	Direct	Direct	Direct	Pre-proc	Post-proc	Pre-proc	Not available	Not available	Not available	Not available
	SOx	Direct	Not available	Not available	Direct	Pre-proc	Direct	Direct	Not available	Not available	Not available	Not available
	NOx	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Not available	Not available	Not available	Not available
	CO	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Not available	Not available	Not available	Not available
	HC	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Not available	Not available	Not available	Not available
	VOC	Direct	Not available	Not available	Direct	Pre-proc	Post-proc	Direct	Not available	Not available	Not available	Not available
	TOG	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	Acetaldehyde	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	Acrolein	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	POM16PAH	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	POM7PAH	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	Styrene	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	1-3Butadiene	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Direct	Not available	Not available	Not available	Not available
	Benzene	Direct	Not available	Not available	Not available	Direct	Post-proc	Direct	Not available	Not available	Not available	Not available
	Ethylbenzene	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	Formaldehyde	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	Propianaldehyde	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	Toluene	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	Xylene	Direct	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
	PM10	Not available	Direct	Post-proc	Not available (2)	Pre-proc	Direct	Direct	Not available	Not available	Not available	Not available
	User-defined pollutant	Not available	Not available	Not available	Not available	Pre-proc	Pre-proc	Pre-proc	Not available	Not available	Not available	Not available
Noise metrics	SEL	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct	Direct	Direct	Not available
	Lden	Not available	Not available	Not available	Not available (2)	Not available	Not available	Not available	Direct	Direct	Direct	Not available
	Ln	Not available	Not available	Not available	Not available (2)	Not available	Not available	Not available	Direct	Direct	Direct	Not available
	LAmax	Not available	Not available	Not available	Not available (2)	Not available	Not available	Not available	Direct	Direct	Direct	Not available
	Number Above metrics (e.g. N70)	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct	Direct	Post-proc	Not available
Groupings	By flight leg	Direct	Direct	Direct	Direct	Not available	Not available	Not available	Post-proc	Not available	Not available	Direct
	By flight phase	Direct	Direct	Direct	Direct	Direct	Post-proc	Pre-proc	Post-proc	Not available	Not available	Direct
	By flight	Direct	Direct	Direct	Direct	Not available	Post-proc	Pre-proc	Post-proc	Direct	Direct	Direct
	By aircraft type	Post-proc	Post-proc	Direct	Direct	Direct (3)	Post-proc	Pre-proc	Post-proc	Direct	Direct	Direct
	By time	Post-proc	Post-proc	Not available	Not available	Not available (4)	Direct	Direct	Post-proc	Direct	Direct	Not available
	By case / scenario	Post-proc	Post-proc	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
	By world region	Post-proc	Post-proc	Direct	Direct	Post-proc	Not available	Pre-proc	Post-proc	Not available	Not available	Direct

Category	Item	GHG tools				LAQ tools			Noise tools			Economics
		AEM	AERO2K	FAST	AERO-MS (FLEM)	LASPORT	ALAQS-AV (+ LASAT)	ADMS	SONDEO	ANCON2	ENHANCE / INM	AERO-MS (ADEM+ACOS +DECI)
Local Air Quality regulatory metrics	Annual means	Post-proc	Post-proc	Not available	Not available	Direct	Post-proc	Post-proc	Not available	Not available	Not available	Not available
	Short-time means (EU Directives)	Post-proc	Post-proc	Not available	Not available	Direct	Post-proc	Post-proc	Not available	Not available	Not available	Not available
Output geographical area	Rectangular	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Not available
	Polygonal	Direct	Post-proc	Direct	Direct	Post-proc	Not available	Not available	Direct	Not available	Not available	Not available
Output grids (emissions)	2D grids	Direct	Direct	Direct	Direct	Not available	Direct	Direct	Direct	Direct	Direct	Post-proc
	3D grids	Direct	Direct	Direct	Direct	Not available	Direct	Direct	Not available	Not available	Not available	Not available
	4D grids (3D + time)	Direct	Direct	Direct	Not available	Not available	Post-proc	Direct (24h)	Not available	Not available	Not available	Not available
Output grids (concentrations)	2D grids	Not available	Not available	Not available	Not available	Direct	Direct (1)	Direct	Direct	Direct	Direct	Not available
	3D grids	Not available	Not available	Not available	Not available	Direct	Direct (1)	Direct	Not available	Not available	Not available	Not available
	4D grids (3D + time)	Not available	Not available	Not available	Not available	Direct	Post-proc (1)	Post-proc	Not available	Not available	Not available	Not available
Contours	Contour plot	Post-proc	Post-proc	Post-proc	Post-proc	Direct	Post-proc (1)	Direct	Direct	Direct	Direct	Not available
	Contour area	Post-proc	Post-proc	Post-proc	Post-proc	Direct	Post-proc (1)	Post-proc	Direct	Direct	Direct	Not available
	Population count	Post-proc	Not available	Not available	Not available	Post-proc	Post-proc (1)	Post-proc	Post-proc	Direct	Direct	Not available
Economics	Flight crew and cabin crew costs	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Maintenance costs	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Fuel costs	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Capital costs and finance charges	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Route and landing costs	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Total and other variable operating costs	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Volume related costs	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Total operating revenues/costs/results	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Air transport efficiency indicators	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Employment and contribution to gross value added	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Change in consumer surplus/expenses	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Change in airline revenues/costs/results	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Government income from charges	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct
	Government cost of subsidy and scrapping	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Not available	Direct

(1) after dispersion calculations with LASAT
(2) in development
(3) by aircraft group
(4) for the total time period studied

G Appendix G - Warehouse Content Description

This section describes the EEMA Data Warehouse's structure and field content for each individual table as they were for the first Euro-Modelling Demo (June 2007).

Foreword to modellers: *It should be noted that the warehouse's content is **not definitive** and should not be seen as a reference for any environmental modelling activity for aviation other than the present EEMA exercise. In addition, data are not to be reused without the express permission of EUROCONTROL. The database may include fields of no direct use for the first Euro-Modelling Demo.*

Aircraft & Engines

ACFT – Aircraft list

Data sources: ICAO, INM, ALAQS, AzB
Note: Not of direct use for this first Euro-Modelling Demo since aircraft, engine and profiles are available on a flight-by-flight basis in the Flight Operations database. The BADA equivalent aircraft, if required, should be read from the 'ACFT – Aircraft equivalent' table.

OID	Aircraft unique identifier
ICAO	Aircraft code (not necessarily 4-letter!)
AC_GRPCODE	AzB classification
AC_GROUP	AzB classification
MANUFACTURER	
NAME	
CLASS	
MTOW	Maximum take-off weight (lb)
ENG_COUNT	Number of engines
ENGINE	Most commonly fitted engine type
DEP_PROF	Average INM departure profile
ARR_PROF	Average INM arrival profile
BADA_ID	BADA equivalent aircraft code (to be ignored)
WAKE_CAT	

ACFT – Aircraft equivalent

Data sources: BADA, AEM, ALAQS, ENHANCE, INM
Note: Provides aircraft substitution suggestions for GHG, LAQ and noise modellers separately.

Aircraft type	Aircraft code from all types of sources
BADA Equiv	BADA equivalent aircraft code suggestion
ALAQS Equiv	ALAQS equivalent aircraft code suggestion
INM Equiv	INM/ANP equivalent aircraft code suggestion

ACFT – Aircraft-noise match

Data source: ANP + EEMA specific adding
Note: To be used by noise modellers to derive the noise category (NPD_ID) and spectral class of an aircraft-engine combination.

ACFT_ID	INM/ANP aircraft code
Description	
Source of data	
Engine type	
Number of engines	
Weight class	
Owner category	
Max gross takeoff weight	(lb)
Max gross landing weight	(lb)
Max landing distance	(ft)
Max sea level static thrust	(lb)
Noise chapter	
NPD_ID	To be linked to the 'NOISE – NPD data' table
Power parameter	
Approach spectral class ID	To be linked to the 'NOISE – Spectral classes'
Departure spectral class ID	table
Lateral Directivity Identifier	To be linked to the 'NOISE – Spectral classes'
	table

ACFT – Standard LTO profiles

Source: INM, ANP, ALAQS
Note: To be used by LAQ and noise modellers to derive landing and take-off profiles associated with the 'Profile' field in the airport traffic tables. A Profile Id consists of the INM/ANP equivalent aircraft code followed by the operation type (A or D) and stage length.

OID	Profile point unique identifier
PROF_ID	To be linked to 'Profile' field in 'OPS – [arpt name] traffic'
ARR_DEP	tables
STAGE	Operation type (A or D)
POINT	Integer increasing with stage length (starts 1)
WEIGHT_LBS	Profile point #
HORIZ_FT	Profile weight (lb)
VERT_FT	Distance from start roll / to touchdown point (ft)
TAS_FTS	Aircraft elevation over the runway (ft)
WEIGHT_KG	Aircraft true airspeed (ft/s)
HORIZ_M	Profile weight (kg)
VERT_M	Distance from start roll / to touchdown point (m)
TAS_MS	Aircraft elevation over the runway (m)
POWER	Aircraft true airspeed (m/s)
MODE	Engine power (% of static thrust in 'ACFT – Aircraft-noise
SOURCE	match')
	Operational mode (Take-Off, Climb, Approach)

ACFT – Aerodynamic coefficients

Source: ANP
Note: Not of direct use for this first Euro-Modelling Demo since fixed-point profiles (elevation, true airspeed and thrust) are used.

ACFT_ID	INM/ANP aircraft code
Op type	Operation type (A or D)
Flap_ID	Flap / landing gear setting
B	Take-off distance coefficient (ft/lb)
C	Calibrated airspeed coefficient C (kt/lb^0.5)
D	Calibrated airspeed coefficient D (kt/lb^0.5)
R	Drag-over-lift ratio

Airport

ARPT – Airport coordinates

Source: GAES-MOVE
Note: Provides a list of reference point coordinates for global airports.

AIRPORT	Airport code from all types of sources
IATA_CODE	3-letter code
ICAO_CODE	4-letter code
ETMS_CODE	
LATITUDE	(decimal degrees, positive North)
LONGITUDE	(decimal degrees, positive East)
APT_ELEVATION_FT	Airport elevation (ft)
NAME	
CITY	
STATE_CODE	
COUNTRY_CODE	
CountryName	
TIME_ZONE	
SAGE Region	

ARPT – Runway coordinates

Source: AIP
Note: Provides runway threshold coordinates for LAQ and noise modelling airports.

Airport	Airport ICAO code
Runway	Runway threshold Id
lat	Runway threshold latitude (decimal degrees, positive North)
lon	Runway threshold longitude (decimal degrees, positive East)
elevation (ft)	Runway threshold elevation (ft)

Emissions

EMI – LTO emission rates

Source: ICAO Engine Emissions Databank, EPA, Pratt & Whitney, EEMA specific emission rates, etc.
Note: To be used by GHG and LAQ modellers to derive fuel flow and emission rates associated with engine types in the Flight Operations database.

OID	Unique identifier
ICAO_UID	ICAO unique engine Id
ENG_TYPE	
ENG_NAME	
THRUST	ICAO engine mode power level (% of static thrust)
MODE	(Take-Off, Climb, Approach, Taxi/Idle)
FUEL_KG_S	Fuel flow (kg/s)
CO_EI	CO emission index (g/kg fuel)
HC_EI	HC emission index (g/kg fuel)
NOX_EI	NO_x emission index (g/kg fuel)
SOX_EI	SO_x emission index (g/kg fuel)
PM10_EI	PM10 emission index (g/kg fuel)
SN	Smoke number
SN_MAX	Maximum smoke number
FUEL_TYPE	Fuel specification
MANUFACTURER	
SOURCE	
REMARK	
ENG_NAME_TYPE	

EMI – LTO times in mode

Source: ICAO
Note: Provides the ICAO time for each of the following LTO modes: Approach, Taxi In, Taxi Out, Take-Off, Climb.

Mode	(Approach, Taxi In, Taxi Out, Take-Off, Climb)
Time_s	Time in mode (seconds)

Flight Operations

OPS – 2005 Baseline flights with engines
OPS – 2025 flights with CAEP6 engines
OPS – 2025 flights with stringency engines

Source: EUROCONTROL GAES-MOVE 2005, FESG, Wyle, FAA
Note: Provides a list of global flight operations for 6 representative weeks for each of the following scenarios: 2005, 2025 no stringency, 2025 NO_X stringency. To be used by GHG modellers only. The 'OpsFactor' is a multiplier used to represent the evolution

of global traffic and fleet between 2005 and 2025 (it is set to 1 in the 2005 traffic table).

FlightID	Unique flight identifier
DepartureTime	
DepartureAirport	Departure airport code
DepartureRegion	
ArrivalTime	
ArrivalAirport	Arrival airport code
ArrivalRegion	
AircraftID	Aircraft type code
OpsFactor	Multiplier used to derive 2025 operations (= 1 in 2005 table)
WyleEngineID	ICAO unique engine Id

OPS – Warsaw traffic
OPS – Zurich traffic

Source: EUROCONTROL GAES-MOVE 2005, FESG, Wyle, FAA
Note: Subset of the above global flight operations limited to Warsaw and Zurich airports respectively. Provides information on take-off/landing runway, profiles, routes, gates. To be used by LAQ and noise modellers. The ‘OpsFactor’ is a multiplier used to represent the evolution of global traffic and fleet between 2005 and 2025.

FlightID	Unique flight identifier
AircraftID	Aircraft type code
OpsTime	Take-off / landing time
OpsType	(A or D)
Gate	
Rwy	Runway threshold Id
Route	Route Id
Profile	Profile Id
2005_Eng	2005 ICAO unique engine Id
2025_Eng_CAEP	2025 no stringency ICAO unique engine Id
2025_Eng_Stringe	2025 NO_x stringency ICAO unique engine Id
2005_OpsFactor	(1)
2025_OpsFactor	Multiplier used to derive 2025 operations
Day Multiplier	Multiplier used to derive yearly operations from the 6 representative weeks (same as in ‘OPS – Day multipliers’ table)
ANP A/C ID	Equivalent ANP aircraft Id (for noise modelling)
Day Period	Operation’s day period: day (D), evening (E), night (N)
2005_Adj_Factor	Operation adjustment factor for the 2005 a/c-engine combination
2025_CAEP_Adj_Factor	Operation adjustment factor for the ‘2025 CAEP’ a/c-engine combination
2025_String_Adj_Factor	Operation adjustment factor for the ‘2025 Stringency’ a/c-engine combination.

OPS – Warsaw ground tracks
OPS – Zurich ground tracks

Source: AIP
Note: Point-by-point coordinates of departure and arrival ground tracks for each runway end and route in the traffic files, in both X/Y (nm) and Lat/Lon (decimal degrees) units.

Rwy	Runway threshold Id
OpsType	Operation type
Route	Route Id – to be linked with the one in traffic table
Pt_Num	Trajectory point number (integer starting 1)
X_nm	Point's X value in nautical miles (0 for the airport reference point)
Y_nm	Point's Y value in nautical miles (0 for the airport reference point)
Lat	Point's latitude (decimal degrees)
Lon	Point's longitude (decimal degrees)

OPS – Day multipliers

Source: EUROCONTROL GAES-MOVE 2005, OAG
Note: 42 day-by-day multipliers used to derive yearly traffic/emissions from the 6 representative weeks in the Flight Operations database.

Day DayTraf Sum Multiplier	To be linked to flight's departure date (yyyymmdd) Number of OAG operations on that day Number of OAG operations on all similar weekdays of the year period 'Sum / DayTraf' ratio

Noise

NOISE – NPD data

Source: ANP
Note: Used to derive Noise-Power-Distance data of each aircraft-engine combination.

NPD_ID Noise metric Op type Power setting L_200ft ... L_25000ft	Same as in 'ACFT – Aircraft-noise match' table (EPNL, L_{Amax}, SEL, ...) (A or D) (lb or % of static thrust) Noise level (dB) at 200 ft distance ... Noise level (dB) at 25000 ft distance

NOISE – Spectral classes

Source: ANP
Note: Used to derive spectral classes of each aircraft-engine combination.

Spectral class ID	Same as in 'ACFT – Aircraft-noise match' table

Op type Description L_50Hz ... L_10000Hz	(A or D) Engine configuration Noise level (dB) at 50 Hz frequency ... Noise level (dB) at 10000 Hz frequency

H Appendix H - Example Organisational Structures

In the next four figures, each of the four organisational structures is graphically shown. In order to highlight differences between the organisational structures, the associated project management aspects, i.e. time, budget, quality, information and organisation, are also valued for each structure.

Business as usual case:

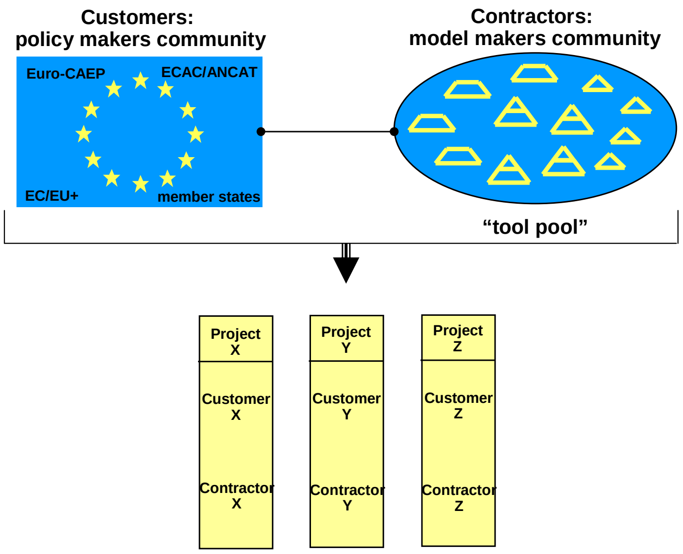
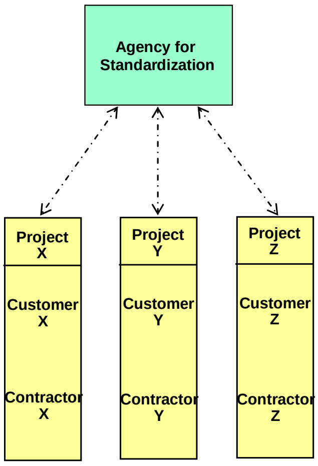


Figure H.1: Business as usual case

Figure H.1 shows the small agency for standardization re interdependency modelling in addition to the business as usual case. This will still lead to individual, unlinked projects as in the business as usual case, but with high(er) quality output:

- Time: durable agency; time-limited projects
- Budget: @ agency level: ToR dependent; @ projects level: external
- Quality: high(er) compared to biz as usual
- Information: project dependent / variable
- Organisation: individual unlinked projects each with usual project organisation

Small agency for standardization re interdependency modelling in addition to business as usual case:



FigureH.2: Agency for standardization

Figure H.2 shows the small agency for standardization re interdependency modelling in addition to the business as usual case. This will still lead to individual, unlinked projects as in the business as usual case, but with high(er) quality output:

- Time: durable agency; time-limited projects
- Budget: @ agency level: ToR dependent; @ projects level: external
- Quality: high(er) compared to biz as usual
- Information: project dependent / variable
- Organisation: individual unlinked projects each with usual project organisation

Independent "floating" coordination group
inclusive of standardization agency activities in addition to the business as usual case:

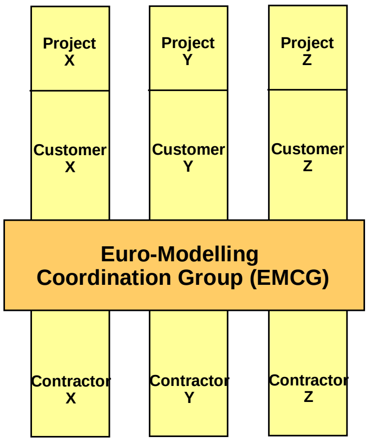


Figure H.3: Euro-Modelling Coordination Group (EMCG)

Figure H.3 shows the Euro-Modelling Group (EMCG), which will lead to a set of coordinated projects:

- Time: durable EMCG; time-limited projects
- Budget: @ EMCG level: ToR dependent; @ projects level: external
- Quality: high(er) compared to biz as usual
- Information: better exchange due to coordination
- Organisation: individual projects with usual project organisation and in addition coordination / steering by EMC

Comprehensive network of excellence (NoE) of modellers and stakeholders:

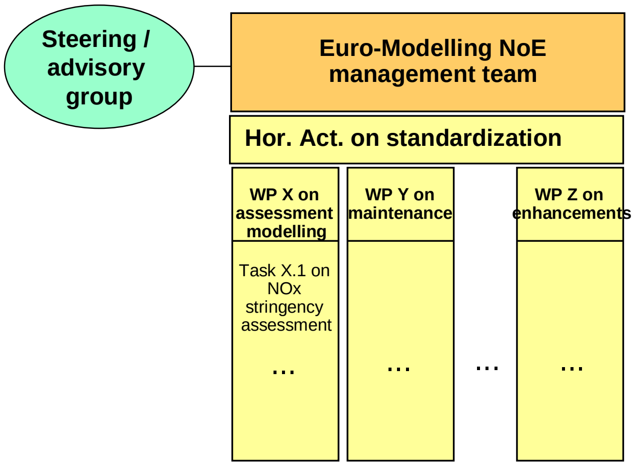


Figure H.4: Euro-modelling network of modellers and stakeholders

Figure H.4 shows the Euro-modelling network of modellers and stakeholders, which will lead to one comprehensive project:

- Time: durable project
- Budget: ToR dependent
- Quality: high(er)
- Information: coordinated
- Organisation: one project including, e.g., management team, steering / advisory group, secretariat, work packages (on different areas like assessment modelling, maintenance, enhancements) and tasks (similar to previous projects).

Initial distribution list

External
EASA – Willem Franken
EASA – Steve Arrowsmith
Eurocontrol – Ted Elliff
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Envisa – Ayce Celikel
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