ASSESSING TRENDS IN AVIATION NOISE AND EMISSIONS IN EUROPE USING ADVANCED MODELLING CAPABILITIES

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Abstract. In 2013, IMPACT and the Aircraft Assignment Tool (AAT) were introduced at 1st ECATS Conference as two new major tools of the European aviation environmental modelling tool suite. Both tools are based on the experience gained during more than 15 years of environmental modelling development in support of European and ICAO Committee on Aviation Environmental Protection (CAEP) environmental assessments.

IMPACT is a web-based modelling platform which constitutes a significant improvement towards achieving robust trade-off assessments between noise and fuel burn and/or gaseous emissions. IMPACT combines the Advanced Emissions Model (AEM) and the multi-airport noise model STAPES into a common modelling platform, with a goal to provide these environmental models with common input data in terms of aircraft trajectories (along with other flight parameters of relevance for environmental modelling purposes). A key component of IMPACT is a new aircraft trajectory calculator, which computes complete aircraft trajectories from the departure airport to the arrival airport, along with engine thrust and fuel flow information.

AAT is a generic tool that takes as input an existing demand and fleet forecast and converts it into a forecast of movements by particular aircraft type on specific airport pairs. The geographical scope is dependent on the forecast, and can range from a single airport pair to full global operations. The output of AAT can be used as input to environmental models such as IMPACT and to assess the evolution of the aircraft fleet for future planning and policy purposes.

AAT combined with IMPACT made it possible to assess trends in noise and emissions in Europe until 2035, under various traffic forecasts and aircraft technology scenarios, for the European Aviation Environmental Report 2016.

Keywords: noise, fuel burn, emissions, aircraft performance, forecast.

INTRODUCTION

In 2013, IMPACT and the Aircraft Assignment Tool (AAT) were presented at 1st ECATS Conference as two new major tools of the European aviation environmental modelling tool suite. Both tools are based on the experience gained during more than 15 years of environmental modelling development in support of European and ICAO Committee on Aviation Environmental Protection (CAEP) environmental assessments.

IMPACT

The IMPACT modelling tool was first introduced at the 2013 CAEP Steering Group meeting as a successor to two models already approved by CAEP: the Advanced Emissions Model (AEM) and the SysTem for AirPort noise Exposure Studies (STAPES).

AEM is a EUROCONTROL model that can determine the amount of fuel burned by a specific aircraft type equipped with a specific type of engine, flying a specific 4D trajectory. It can also determine the precise by-products of burning that fuel such as: carbon dioxide (CO_2), water vapour (H_2O), oxides of sulphur (SO_x), oxides of nitrogen (NO_x), unburnt hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM), and some volatile organic compounds (VOCs) such as benzene and acetaldehyde. The core emission calculation engine of AEM implements the Boeing Fuel Flow Method 2 (BFFM2), which is described in the Aerospace Information Report 5715 (SAE International, 2009).

STAPES is a multi-airport noise model that is the result of successful collaboration by the European Commission (EC), the European Aviation Safety Agency (EASA) and EUROCONTROL. STAPES consists of a noise modelling software, hosted and maintained by EUROCONTROL, which is compliant with the calculation method recommended in the ICAO Doc 9911 (ICAO, 2008) and ECAC Doc. 29 (ECAC, 2005) guidance documents, combined with an airport database that provides information on runway and route layouts, along with statistics on their usage (i.e. distribution of aircraft operations). The STAPES airport database, jointly maintained by EASA and EUROCONTROL, currently covers 45 European airports that are representative in terms of their noise impact on the surrounding population (i.e. number of people within the L_{den} 55 dB noise contours). Population estimates are based on the population database supplied by the European Environment Agency (EEA), complemented with local census data when available. STAPES is a CAEP-approved noise model that has contributed to CAEP's noise trends assessment and future stringency analyses since 2009.

The introduction of IMPACT constitutes a significant improvement towards achieving robust trade-off assessments between noise and fuel burn and/or gaseous emissions. IMPACT integrates the core emission calculation engine of AEM and a reengineered and enhanced version of the core noise calculation module of STAPES into a common modelling platform, with a goal to provide these environmental models with common input data in terms of aircraft trajectories (along with other flight parameters of relevance for environmental modelling purposes).

A key component of IMPACT is a new aircraft trajectory calculator, which computes complete aircraft trajectories from the departing airport to the destination point, along with engine thrust and fuel flow information. This common trajectory data is then exported to the core engine of AEM and the core noise calculation module of STAPES to calculate emissions and noise. With this modelling approach, consistent assessments of trade-offs between noise and fuel burn and/or gaseous emissions are enabled over the portion of the trajectories within the Terminal Manoeuvring Area (TMA). The IMPACT trajectory calculator relies on the Aircraft Noise and Performance (ANP) database and the latest release of EUROCONTROL's Base of Aircraft Data (BADA 4). The ANP database provides the noise and performance characteristics of a wide range of civil aircraft types, which are required to compute noise contours around civil airports using the calculation method described in ICAO Doc 9911 (ICAO, 2008) and ECAC Doc. 29 (ECAC, 2005). BADA (Base of Aircraft Data) is an aircraft performance model developed and maintained by EUROCONTROL, in cooperation with aircraft manufacturers and operating airlines. BADA is based on a kinetic approach to aircraft performance modelling, which enables the accurate prediction of aircraft trajectories and the associated fuel consumption (EUROCONTROL, 2010). The latest BADA 4 family constitutes a major improvement in terms of aircraft performance modelling accuracy (Gallo ***et al., 2006***).

The complete trajectory computed by the IMPACT aircraft trajectory calculator is illustrated in Figure 1.

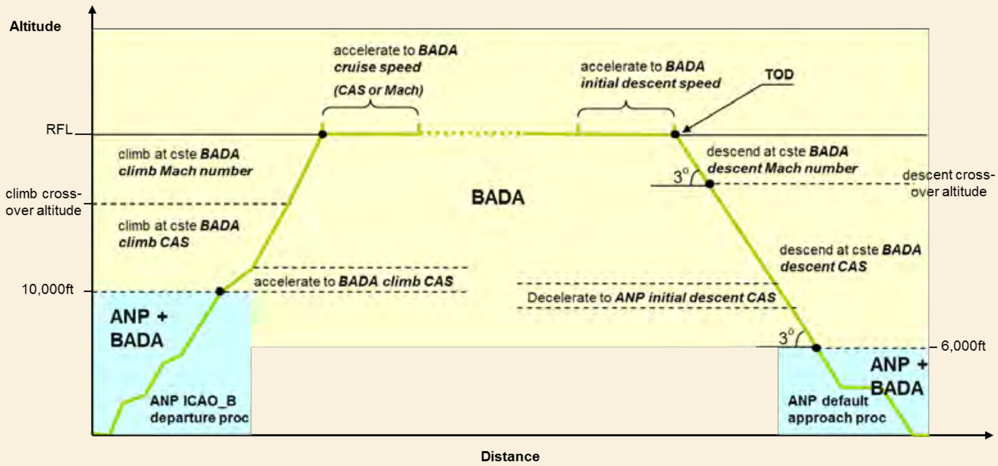


Figure 1. IMPACT full flight procedure.

Another key characteristic of IMPACT is that it is a web-based modelling platform remotely accessible by the users, via a dedicated and secured portal (Figure 2). All calculations are performed on dedicated servers hosted by EUROCONTROL. In particular, users do not need to install any specific software on their machines; they only need a web browser to connect to the IMPACT web portal, upload their input data, launch calculations, visualise, and download the results. This web-based approach enables easy update of the different databases used by IMPACT, without the need to redistribute a new software package, and provides the flexibility to select the database versions to be used in a study. Another major advantage is that it secures sensitive aircraft reference data such as the BADA data.

IMPACT supports different types of input data, which can be retrieved from various sources (i.e. real-time and arithmetic model-based simulations, real data, or more theoretical definitions of flight procedures). The main results produced by IMPACT include noise contour shapefiles, surface and population count using the European Environment Agency (EEA) population database, fuel burn and emissions of a wide range of pollutants, gridded (i.e. geo-referenced) emission inventories within the LTO portion; as an introduction to further – more detailed – Local Air Quality (LAQ) assessments.

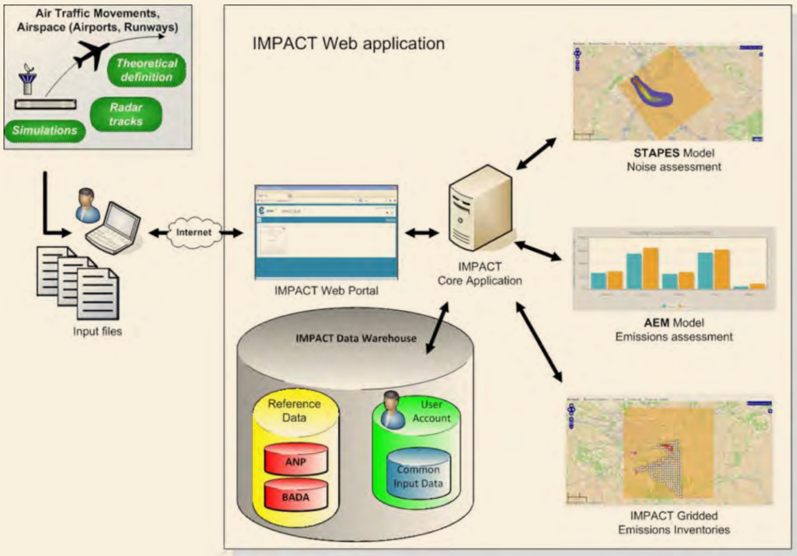


Figure 2. IMPACT Web-based Modelling Platform.

During the CAEP/10 work programme, IMPACT was thoroughly reviewed against other CAEP-approved models and contributed to the CO_2 Standard analysis as well as the greenhouse gas and LAQ trends assessment. While meeting CAEP assessment needs, IMPACT was also developed to comply with the Single European Sky ATM Research (SESAR) environmental assessment requirements and is the recommended assessment tool for this European ATM research programme.

THE AIRCRAFT ASSIGNMENT TOOL (AAT)

To meet European needs and as part of their support of CAEP, the European Commission, EASA and EUROCONTROL have developed a fleet and operations forecasting capability called the Aircraft Assignment Tool (AAT). The AAT is a generic tool that takes as input an existing demand and fleet forecast, such as that from CAEP's Forecasting and Economic Analysis Support Group (FESG), and converts it into a forecast of movements by particular aircraft types on specific airport pairs. The geographical scope is dependent on the forecast, and can range from a single airport pair to full global operations. The output of the AAT can be used as input to environmental models such as IMPACT. Such information can also be used to assess the evolution of the aircraft fleet for future planning and policy purposes.

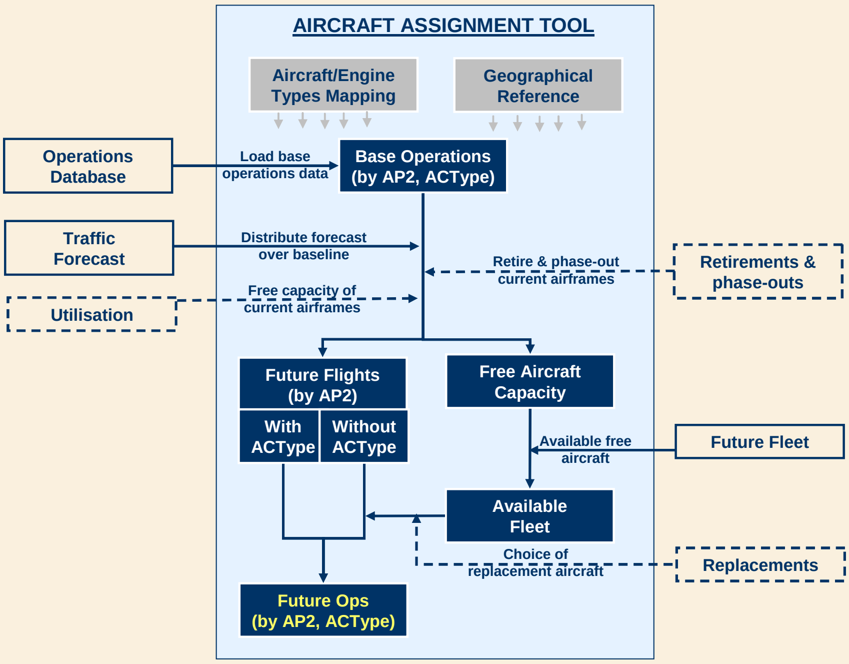
The typical AAT input data consists of: a demand forecast; a set of base year operations (e.g. the Common Operations Database for CAEP applications); aircraft retirement curves; a set of in-production aircraft over the forecast period (future fleet) along with their respective transport capability (seats/tonnes), maximum range and their market shares in the group they belong to (shares may vary in time). The AAT can also handle user-defined phase-out functions for specific aircraft types.

Aircraft types in AAT are typically grouped by user-defined categories based on their transport and range capability.

Within a particular category, each aircraft type is assigned a specific market share. Market shares are specified by the user, which allows the application of various calculation methods including: equal market shares (all aircraft in a bin have the same share); market-driven market shares (shares are derived from the relative operating costs of each aircraft, e.g. using a multinomial logit); and historical market shares (shares are derived from past aircraft deliveries). If the demand forecast is expressed in available seat-kilometres (ASK) or available tonne-kilometres (ATK) for freighters, the AAT adjusts the number of movements on a given route to the size of the aircraft assigned to this route and their respective market shares.

The AAT was developed following four key non-functional requirements:

- Flexibility: With a variety of possible uses, the AAT is flexible enough to process input data from different sources and deliver output data fit for various modelling tools.
- Speed: To allow regular updates within strict deadlines and with limited resources (e.g. EUROCONTROL forecasting process), the AAT architecture allows relatively easy operation and fast run-times.
- Openness: In order to be transparent, the AAT does not develop its own assumptions (based on historical data patterns or the like). Instead the assumptions are formulated, and the input data constructed, by the user outside the AAT. This allows the AAT to be used for analysis of scenarios and "what-ifs" following different "stories" as defined and specified in the inputs by the user.
- Accessibility: The AAT is accessible via a web portal and therefore only requires a web browser and an internet connection to be run.



(AP2 = Airport pair; ACType = Aircraft type)

Figure 3. Aircraft Assignment Tool (AAT) design.

During the CAEP/10 cycle, the AAT was reviewed by the Forecasting and Economic Analysis Support Group (FESG) and was used in the CO_2 standard's cost-effectiveness analysis.

USING IMPACT AND AAT FOR THE EUROPEAN AVIATION ENVIRONMENTAL REPORT 2016

AAT was integrated into the EUROCONTROL/STATFOR 20-year forecast toolset for the passenger market segment. Combined with IMPACT, it made it possible to assess trends in noise and emissions in Europe until 2035 under various traffic forecasts and aircraft technology scenarios for the European Aviation Environmental Report 2016 (EASA *et al.* (2016)). Figures 4 and 5 present respectively the estimated L_{den} 55 dB population exposure and full-flight CO_2 trends from 2005 to 2035.

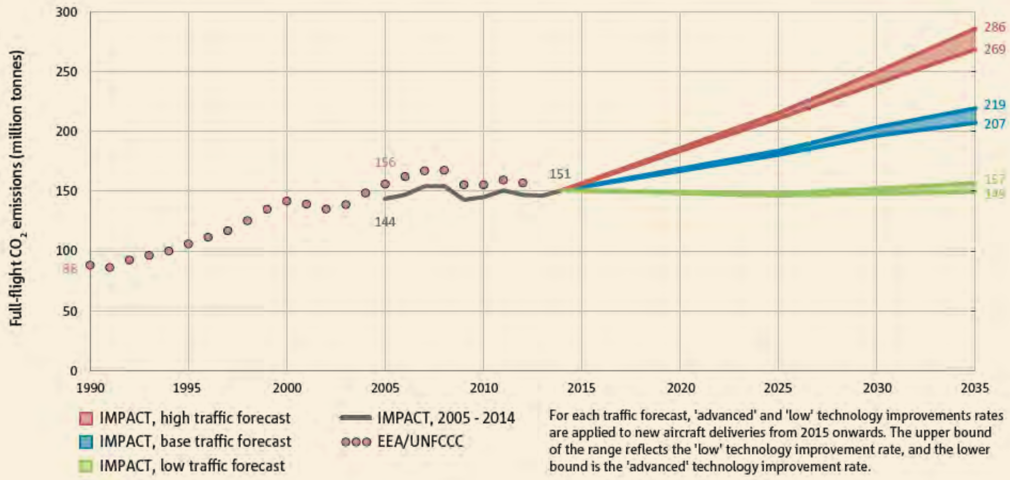


Figure 4. EAEr 2016 – L_{den} 55 dB population exposure at 45 STAPES airports

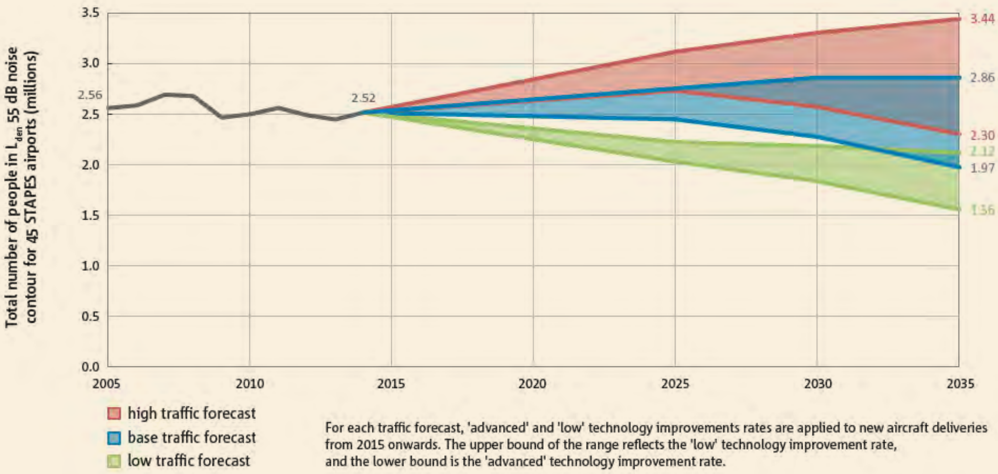


Figure 5. EAEr 2016 – Full-flight CO_2 emissions for all departures from EU+EFTA

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