STUDY ON THE VARIATION IN THE FUEL CONSUMED AND EMISSIONS PRODUCED BY AIRCRAFT IN THE AIRSPACE MANAGED BY ASECNA

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In the framework of the cooperation between ICAO and the Agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA) towards the achievement of ICAO's global goal of reducing the impact of aviation on the environment through a reduction in aircraft CO_2 emissions, an initial joint study was conducted in 2012 to estimate the variation in the fuel consumed and emissions produced by aircraft in the airspace managed by ASECNA between the 2005 and 2011.

The results of this study found a substantial reduction in unit fuel burn and CO_2 emissions by flight in 2011 compared to 2005 leading to the conclusion that operational improvements implemented during that period resulted in fuel savings and emissions reductions.

As part of its "Plan, Do, Check, Act" approach, and in order to assess its contribution to the achievement of ICAO's global environmental goals, ASECNA initiated a second study in 2015 covering the period 2011-2014 in order to estimate the difference in fuel burn and CO_2 emissions by aircraft during the cruise phase in the airspace managed by ASECNA.

The aim of this second study is to determine whether the technological and operational improvement measures implemented through the Services and Facilities Plan (SFP) 2011-2014 have continued to produce environmental and economic benefits for airspace users. These results may also be used by ASECNA Member States in the preparation of action plans to reduce CO_2 emission from international aviation.

How the Project Contributes to Reducing the Environmental Footprint of the Sector

The study was conducted using real traffic data during the cruise phase, registered in the airspace managed by ASECNA in 2011 and 2014. This airspace covers about 16.1 million km^2 and is composed of 6 Flight Information Regions (FIRs) extending from the Atlantic Ocean to the Indian Ocean, and crossing both West and Central Africa (Dakar continental, Dakar oceanic, Niamey, N'Djamena, Brazzaville and Antananarivo).

The data used in the study was composed of about a million records/rows containing raw data of the traffic managed by the 13 ASECNA ATS Centres responsible for providing en-route air traffic services. The raw data was subject to a preliminary filtering leading to data that is pertinent to the study and that are in the format required for use in ICAO's ATFEET/IFSET tool. As a consequence, the study does not take into consideration the following: flights of piston aircraft, helicopters, military and VFR flights. The range of flight levels taken into consideration spans from FL100 to FL410, inclusive, most commonly used by commercial flights. An aggregation phase of the various flight segments registered by ATS centres has allowed the reconstitution of each flight within the airspace managed by ASECNA.

Using the ICAO ATFEET/IFSET tool, the unit fuel burn (in kg per second) was estimated for each flight taking into account the aircraft category, the flight level, the distance flown and the flight time. The total fuel burn for each flight was obtained by multiplying the unit fuel burn by the flight time in the airspace managed by ASECNA.

The variation in total fuel burn from 2011 to 2014 may be explained by four possible factors: traffic growth (increase in the number of flights crossing the airspace managed by ASECNA) and/or a change in airline networks (change in the origin-destination pairs) and/or a change in aircraft category and/or a change in air navigation operational conditions (optimum flight levels, direct and/or shortened routes, etc.).

Thus, a two-step approach was adopted. In the first step, an overall analysis was performed to assess the variation in fuel burn due to all four factors above. In the second step, a more focused analysis was performed in order to isolate the impact of ATM improvements only.

Associated Quantitative/Qualitative Benefits

Results of the overall analysis covering all flights for 2011 and 2014

Between 2011 and 2014, the equivalent of about 341 million kg of CO_2 emissions was avoided

The overall analysis covered all the flights, in both years, on which the following estimations were made:

- The total fuel burn for each year: which is the sum of the fuel burn of all individual flights in the airspace managed by ASECNA in the given year.
- The average fuel burn per flight for each year: which is the ratio of the total fuel burn by the total number of flights in the given year.
- The gap in the average fuel burn per flight between 2014 and 2011: which represents the average fuel savings per flight and is estimated at 351 Kg
- The total fuel savings achieved for all flights in 2014: which is obtained by multiplying the average fuel savings per flight by the total number of flights in 2014.

The number of flights crossing the airspace managed by ASECNA increased by 14.2% in 2014 compared to 2011, while the total annual fuel burn increased by 7.6%: the rate of increase in fuel burn is **twice lower** than the rate of increase in traffic. Similarly, the average fuel burn per flight has declined by **5.8%** in 2014 as compared to 2011, representing an average fuel savings of about 351 kg per flight.

The total fuel savings of about 108 million kg represent an environmental benefit equivalent to about 341 million kg of CO_2 emissions avoided (1 kg fuel generating 3.157 kg of CO_2). In terms of operating expenses, this is equivalent to about USD 48.6 million savings in aircraft operators' fuel costs (considering an average fuel price of USD 0.45 per kg in 2014).

These fuel savings cover all flights registered during both years 2011 and 2014 including in particular, the new flights introduced after 2011 and those existing in 2011, but for which the operated aircraft category has changed, as well as the 2011 flights that ceased to exist in 2014.

The observed fuel savings result from the combined effects of the three following factors: the changes in aircraft operated on certain routes, the changes in operators' networks (due to the opening of new routes and the closing of existing ones), and the changes in air navigation operational conditions linked to ATM (due to the introduction of new Communication, Navigation, Surveillance - CNS-ATM equipment, services and procedures). The first two factors are controlled by the air carrier, whereas the third one is under the control of the Air Navigation Service Provider.

In order to evaluate the environmental impact of ASECNA's initiatives, a more detailed analysis was performed in order to focus only on the ATM factor.

Results of the detailed analysis covering the common flights for 2011 and 2014

The detailed analysis covered a total of 247,281 flights operated from the same origin to the same destination with an aircraft in the same ATFEET/IFSET category in the years 2011 and 2014. Focusing only on those flights eliminates the impact of changes in aircraft in operation and in operators' networks.

- Using the total fuel burn data per flight, an average fuel burn (AFB) per flight per combination "Origin - Destination - ATFEET/IFSET aircraft category" is estimated for both years: 2011 and 2014.
- The 2014 total fuel burn for the 247,281 common flights may be obtained either by summing up the fuel burn of individual flights

	Total number of flights	Total Fuel Burn (Kg)	Average Fuel Burn per Flight (Kg)	Total Distance Travelled (Km)	Average Distance per Flight (Km)	Total Flight Time (hours)	Average Time per Flight (hours)	Average FL
2011	269 373	1 629 699 365	6050	143 489 845	533	365 919	1.36	300
2014	307 712	1 753 797 731	5 699	158 487 092	515	402 686	1.31	300
Gap: 2014-2011	38 339	124 098 366	351	14 997 247	-18	36 767	-0.05	
Growth rate	14.2%	7.6%	-5.8%	10.5%	-3.4%	10%	-3.7%	

The fuel savings for all flights in 2014, on the basis of average fuel savings per flight, amounted to: 108,006,912 Kg.

Table 1. Results of the overall analysis covering all flights for 2011 and 2014.

or by using the corresponding 2014 AFB per flight instead.

- The 2014 total fuel burn for the 247,281 common flights assuming that operational conditions were identical to those in 2011, may be estimated by replacing the fuel burn of individual flights with the corresponding 2011 AFB per flight before calculating the sum.

The 247,281 common flights operated in 2014 had a total fuel burn lower by 0.5%, compared to the total quantity of fuel consumed had the air navigation operational conditions remained the same as in 2011. This corresponds to fuel savings of about 7 million kg of fuel.

Furthermore, it is worth noting that the distance travelled and time spent in the airspace managed by ASECNA were also reduced by 2.7% and 4.5%, respectively. These results indicate greater efficiency of flights in 2014 due to ATM improvements. These fuel savings lead to an environmental benefit equivalent to about 22,464 tons of CO_2 emissions avoided. In addition, this represents savings of about USD 3.2 million in fuel costs for aircraft operators.

The detailed analysis highlights the contribution of air navigation operational conditions (ATM improvements) in the reduction in fuel burn in 2014. This contribution results from the improvements introduced by ASECNA in the provision of air navigation services (CNS and ATM) in this airspace between 2011 and 2014, in particular the extension since September 2012 of the Atlantic Ocean Random Routing Area (AORRA) to Latitude 4° North; the implementation of several additional 10 Require Navigation Performance routes on a permanent basis in the continental and oceanic airspace in the FIRs of Dakar, Niamey, N'Djamena et Brazzaville, from April 2011 to October 2012; the introduction of flexible routes (iFLEX) in the Brazzaville FIR since March 2012 in order to facilitate and improve the transit to and from the AORRA airspace; the implementation of new surveillance Radar and Automatic Dependent Surveillance/Contract systems, as well as Controller Pilot Data Link Communications in the FIRs of N'Djamena and Brazzaville since April 2012 after the Dakar et Niamey FIRs in 2010. All these improvements have allowed aircraft operators to use more direct routes and have offered them an increased flexibility in the selection of more efficient flight levels.

Project Evolution and Outlook: 3 Years and Beyond

In general, tools developed by ICAO, including IFSET, and made available to States and Air Navigation Service Providers are suitable to pursue such studies to measure the environmental benefits, as well as economic gains associated with air navigation operational improvements.

For ASECNA, it is planned in the short term to prepare a similar study on the 2005-2015 period to take into account the implementation of its SFP over the same period. In the medium term, it is envisaged to also prepare a third study covering the period 2015-2017, following the completion of the ongoing project aiming to extend the current surveillance capabilities which includes the equipment of 11 additional ATS Centres of ASECNA with surveillance facilities (RADAR Secondary Surveillance Radar and ADS-C) and implementation of CPDLC communications. A fourth study will be conducted at the end of the planned coverage of all airspace managed by ASECNA by ADS-Broadcast. Similarly, at the end of the implementation of the modules of Block 0 ASBU, including PBN procedures and CCO and CDO at all airports, a fifth study will be prepared regarding the traffic in terminal phase of flights (arrivals and departures).

These studies will provide ASECNA with indicators enabling it to measure the environmental and economic performance, and relevance of its investment efforts in CNS-ATM.

End Notes:

ATFEET/IFSET: Air Traffic Fuel Efficiency Estimation Tool/ ICAO Fuel Savings Estimation Tool.

	Total Fuel Burn (Kg)	Total Distance (Nm)	Total Flight Time (hour)
2011	1 295 621 342	124 595 714	328 285
2014	1 288 505 858	121 246 075	312 894
Gap: 2014-2011	-7 115 484	-3 349 639	-15 391
Growth rate	-0, 5%	-2.7%	-4.7%

The savings of fuel achieved in 2014 based on the flights that are common to both 2011 and 2014 amount to: 7 115 484 Kg

Table 2. Results of the detailed analysis covering the common flights for 2011 and 2014