COMPARATIVE ANALYSIS OF OPERATIONS IN LANDING-TAKE OFF CYCLES AT DIFFERENT AIRPORTS IN THE EUROPEAN UNION.

Alejandro Di Bernardi[1], Juan Ignacio D'Iorio[1], Matias Coppa[1], Juan Pedro Monteagudo[1], Nahuel Tomassini[1]

[1]Grupo de Transporte Aéreo (GTA) – Departamento de Aeronáutica, Facultad de Ingeniería, Universidad Nacional de La Plata, Argentina

Abstract: it is known that the International Civil Aviation Organization (ICAO) has standard times, power settings and velocities for LTO cycles. Those parameters do not contemplate aircraft type, engine, airport configuration and specific operation conditions. The aim of this paper is to make a comparison among those parameters in ten different and significant airports around the European Union, to develop an alternative for the ICAO standards.

The variation of parameters are related to operational times and fuel consumptions, and as a consequence different amounts of emissions are produced: unburned hydrocarbons (HC), Nitrogen Oxides (NO_X) , Carbon Monoxide (CO) and Carbon Dioxide (CO_2), *inter alia*. The difference between take off times, speeds, distances and power settings, and the standards values allow the development of indicators, which is the main goal of this study.

Equivalent aircraft mixes and different operative scenarios were used in each airport, emphasizing the minimum and maximum conditions in "Taxi In" and "Taxi Out" situations.

From the comparison, differences between the standard parameters and issues related to the operative strategy in each airport were observed.

Keywords: airports, operations, engines, LTO cycle.

1. Introduction

A worldwide consensus exists regarding the reduction of emissions. There are different organizations that intend to define actions according to each activity and its prognosis. Examples are the Intergovernmental Panel on Climate Change (IPCC), established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), and the United Nations Framework Convention on Climate Change (UNFCCC). Main concerns are related to greenhouse gases (GHGs): water vapour (H2O), CO2, CH4, NOX, O3, CFCs, among others.

The aeronautical industry is not unaware of this situation and has taken an active role on it. The Group on International Aviation and Climate Change (GIACC), dependent on ICAO, was formed on 2007. This group develops, spreads and recommends an action plan with economical efficient and technological feasible strategies, as well as initiatives to reduce GHGs emissions for the Member States. Technological improvements, use of alternative fuels, efficient energy use and operational upgrades are examples to be mentioned. In 2010, the 190 Member States of ICAO agreed to reach a neutral emissions growth in international aviation by 2020.

The International Air Transport Association (IATA) states that will be an increment from 2400 millions of passengers in 2010, to 16000 millions in 2050. That is why a reduction in emissions is a main goal for all the organizations involved.

Emissions characterization is done in different scales, from the local one, i.e. immediate airport surroundings (30 km radius from a point of reference), to the global, i.e. through atmospheric circulation (thousands of kilometres). According to this, the study is focused in the local scale, in order to define the uses of the soil.

ICAO has developed a method to determine the environmental impact in the airport and its surroundings, but it has its limitations, since the times of approach, taxi in, taxi out and take-off are established and the same for all studies and airports.

This method is used by many international organisms (ICAO, IPCC, EEA, Environmental European Agency) to calculate emissions. The assessment of time periods involved in different conditions will show the differences with the established method.

[1] Alejandro Di Bernardi: cadibern@ing.unlp.edu.ar

2. Development

ICAO has defined times and power settings used in each LTO cycle phase, and are the same for each airport-aircraft combination. Phases are:

- Landing: the operations from 3000 ft. over the airport until the aircraft reaches the runway.
- Taxiing: manoeuvres that the aircraft performs until the block-on position, and those ones from block-off until reaches the runway threshold.
- Take-off: from the runway threshold until rotation of the aircraft.
- Climb out: from the rotation until the aircraft reaches 3000 ft.

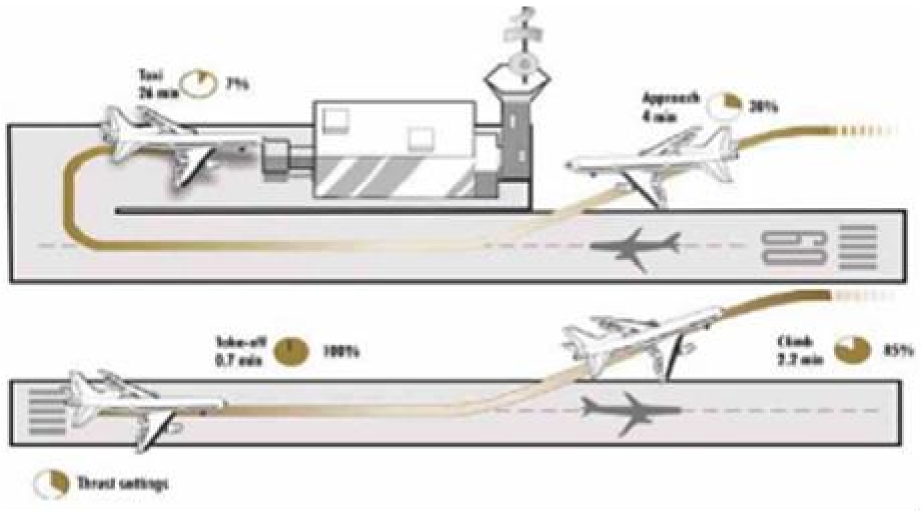


Fig. 1
Landing Take-off cycle.
Source: ICAO 2013 Environmental Report.

Table 1
Time and power setting in each LTO cycle phase

Phase	***Time (min)***	***Power (%)***
Approach	4	30
Taxi	26	7
Take – off	0,7	100
Climb out	2,2	85

Source: ICAO 2013 Environmental Report.

ICAO yearly presents information concerning more than 500 airliner's engines, regarding fuel consumption, unburned hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NO_X).

Emissions from an engine are function of many variables; some are: fuel type, mixture conditions, engine type, combustor type, maintenance levels, time of usage, etc. Theoretical equation for a combustion of a C_aH_b fuel type is presented:

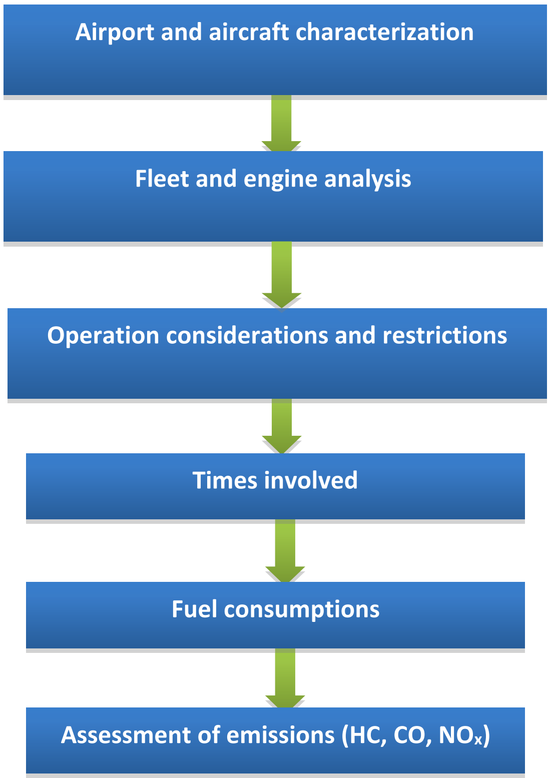
$$C_aH_b + \left(a + \frac{b}{4}\right)(O_2 + 3{,}773N_2) = _{(1)} \; aCO_2 + \frac{b}{2}H_2 + 3{,}773\left(a + \frac{b}{4}\right)N_2 \; _{(2)}$$

where (1) represents the reactives and (2) the products for a stoichiometric fuel burn. If the reaction is produced with less than the necessary air, the oxygen is not enough to produce the total fuel burn, producing the emissions quoted.

The values depend on the operation time of the engine in each phase; generally, only 10% of emissions are produced during the LTO cycle.

The logical method for the assessment is presented in the following figure.

Fig. 2
Logical method applied.
Source: GTA.



After studying air operators, share market and frequencies in Europe, a typical fleet was chosen to be analysed:

Table 2
Aircraft and engines considered

Aircraft	*Engines*
Boeing 737-800	*CFM56-7B*
Boeing 737-800	*CFM56-5B; V2527-A*
Boeing 767-300	*CF6-80C2B, PW4060*
Airbus A320-200	*CFM56-7B*

Source:Airfleets.es.

The parameters that were used, for an actual condition for each aircraft and airport, to obtain times and fuel consumptions for each phase are:

Approach:
- Reference speed (Vreff).
- Approach speed (Vapp).
- Landing distance available (LDA).
- Descent slope.
- Taxiing speed.

Taxiing (in and out):
- Minimum and maximum distances to apron.

- Taxiing speeds (min. and max.).

Take-off and climb out:

- Climb speed.
- Climb angle.
- Rotation speed.
- Margin (remaining distance to the end of the runway).

The airports chosen to be included in the study are included below. With the assessment of times in each airport and the aircraft considered it is possible to obtain the differences with the ICAO model. In the same way, the values obtained for the emissions vary with respect to those obtained with the standard LTO cycle.

Table 3
Airports considered

Name	City, Country
Stansted Airport	Essex, England
John Lennon Airport	Liverpool, England
Girona-Costa Brava Airport	Gerona, Spain
Frankfurt-Hahn Airport	Frankfurt, Germany
Ciampino Airport	Rome, Italy
Luton Airport	London, England
East Midlands Airport	East Midlands, England
Shannon Airport	Shannon, Ireland
Orio al Serio Airport	Bergamo, Italy
Dublin Airport	Dublin, Ireland

Fig. 3
Minimum and maximum distances in Girona Airport.

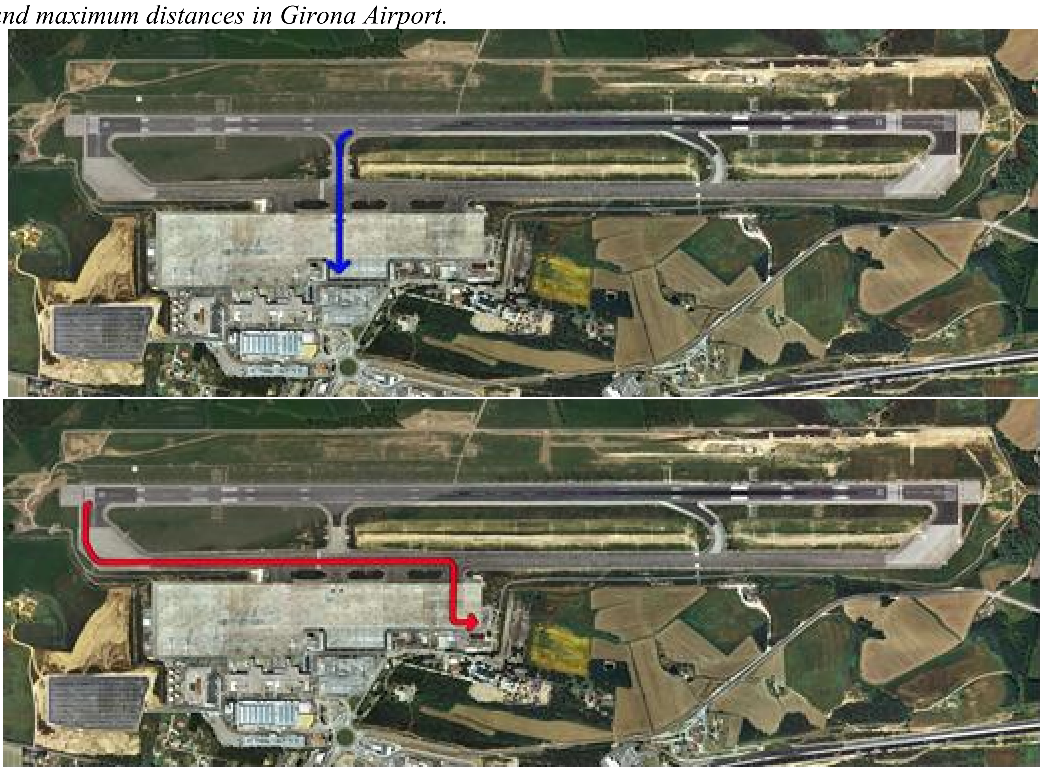


Fig. 4
Minimum and maximum distances in Liverpool Airport.

Results are presented below:

Fig. 4
Calculated and ICAO LTO cycle times.

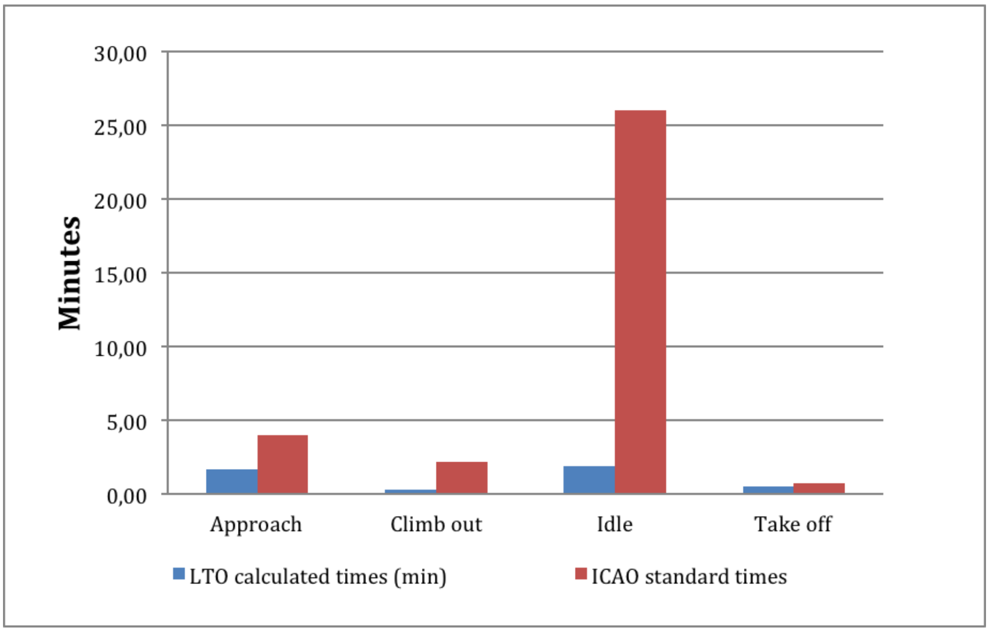


Fig. 5
ICAO, IPCC and calculated fuel consumptions.

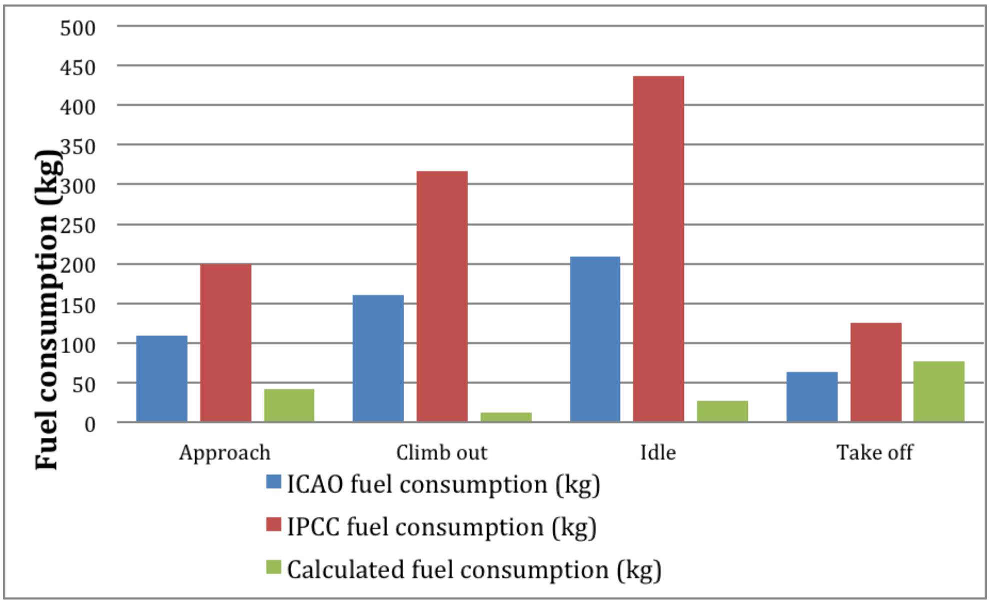


Fig. 6
Calculated and ICAO HC emissions.

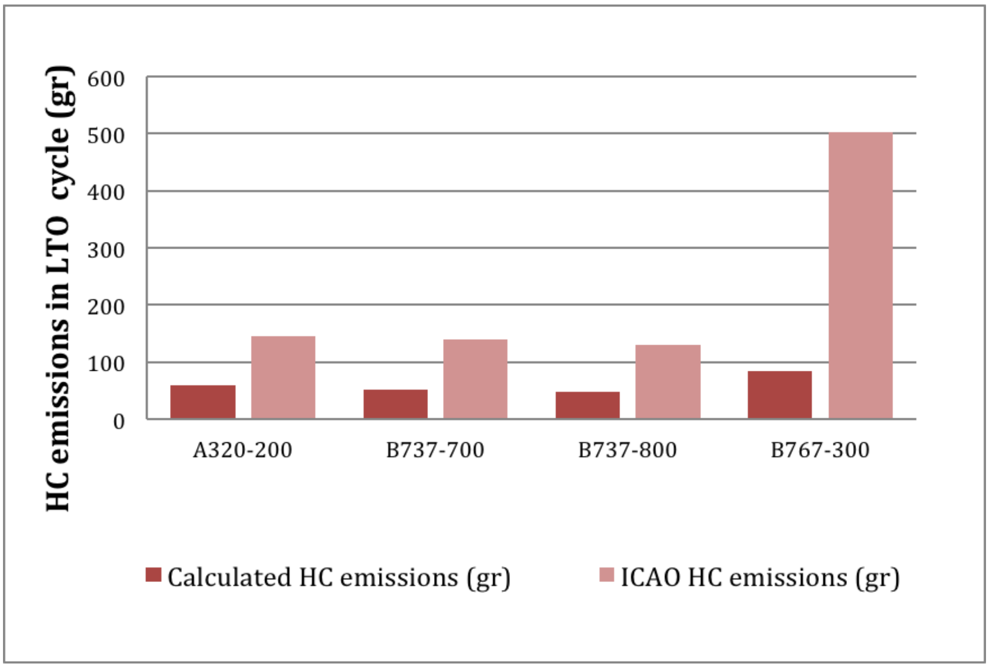


Fig. 7
Calculated and ICAO CO emissions.

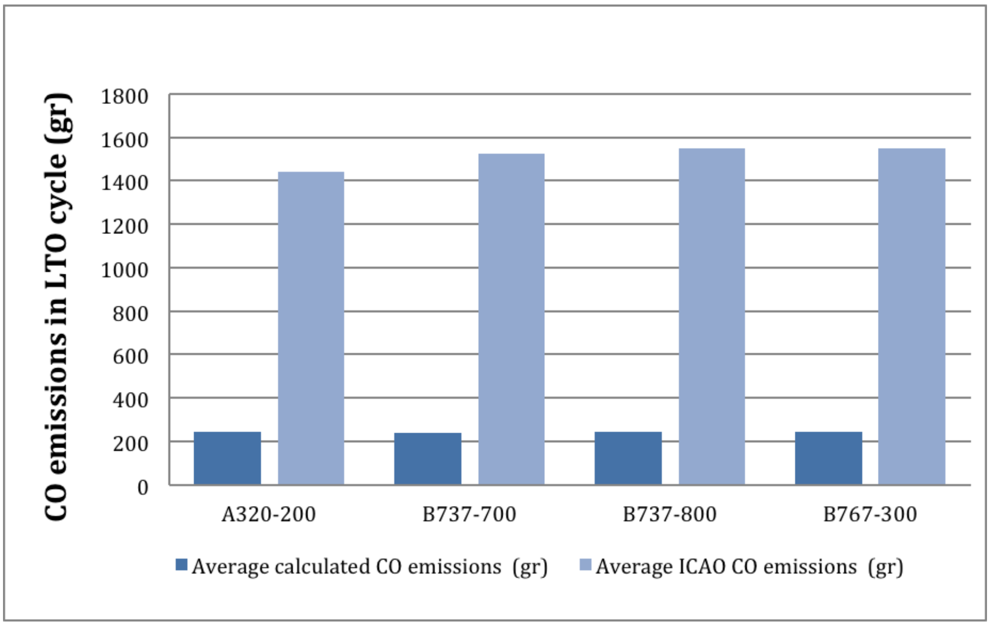


Fig. 8
Calculated and ICAO NO_X emissions.

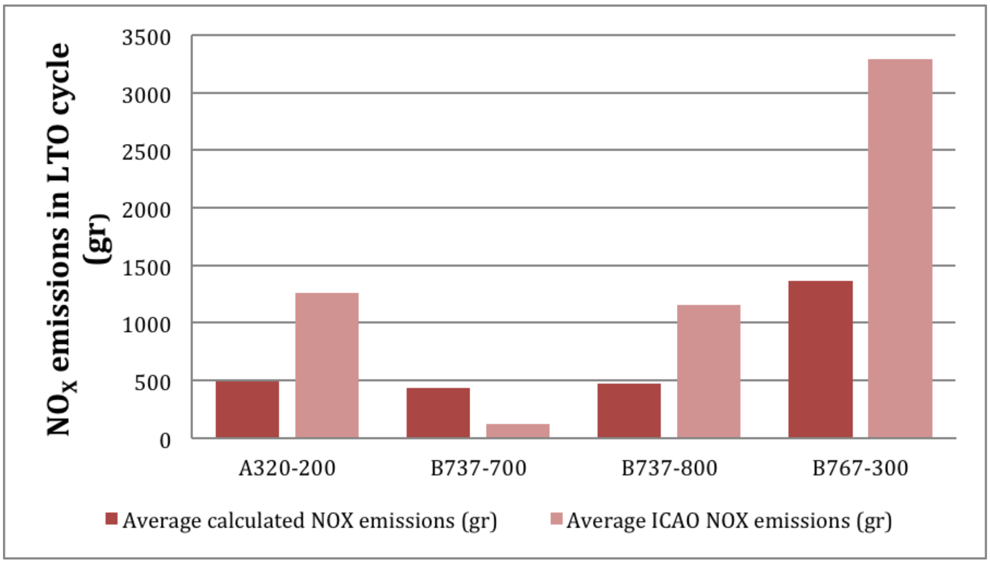
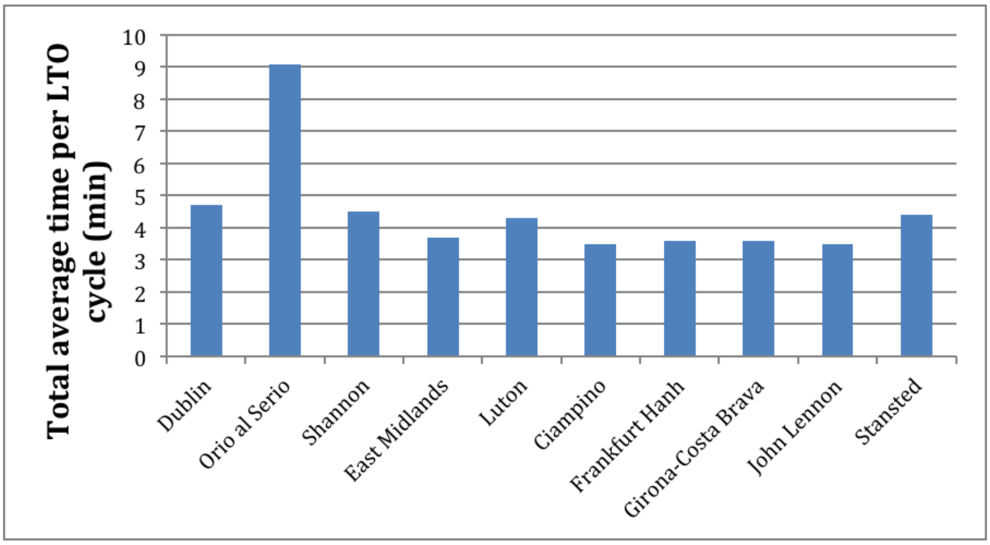


Fig. 9
Total average time per LTO cycle in each selected airport.



3. Conclusion

As a main conclusion, there are considerable differences in times, and therefore in emissions, between the calculated and ICAO LTO cycle standard times. Despite not considering queues, that evidently exist, the differences are shown. As a future development, the queues can be included in order to calculate the times more accurately, as well as more airports and aircrafts.

A development of a method in function of all the concerning parameters (times, power settings, airports, aircraft, etc.) is the ultimate goal for this work, in order to use it as a more accurate method to assess the fuel consumption and emissions in the LTO cycle.

References

Heywood, John B. 1983. *Internal combustion engine fundamentals.* McGraw-Hill, USA. 930 p.

2011. *Vision 2050 Report*. IATA. Available from internet: <http://www.iata.org/pressroom/facts_figures/Documents/vision-2050.pdf>.

2013. *ICAO 2013 Environmental Report*. ICAO. Available from internet: : <http://cfapp.icao.int/Environmental-Report-2013/>.

2013. *EMEP-inventory-guidebook-Tech12-2013-final*. EMEP. Available from internet: <http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook>.

2013. *ICAO Engine Emissions Databank*. EASA. Available from internet: <http://easa.europa.eu/document-library/icao-aircraft-engine-emissions-databank>.