Quantification of the Impact on the Environment of Romanian National Airlines

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Air quality is submitted to national and international standards and regulations, thus air traffic growth's implications on the environment can be analyzed only in compliance with such norms. While achieving the requirements of environmental protection reflected by legal frameworks, airlines have to establish their own responsibility policy based on emission reduction options, which can be approached by market strategies and technological developments. In this context, the paper aims at analyzing this long-term challenge for the Romanian aeronautical industry and assesses airlines' strategies and targets. The research also aims to quantify the impact on the environment of domestic flights performed by two national airlines (i.e. Tarom and Blue Air) on a peak period in terms of air traffic, with accent on the emissions of CO and CO_2 (which represents a linear function of fuel burn).

Keywords: air quality, emissions, environmental protection, Romanian national airlines

The air quality over the European continent has meliorated notably in the latest decades and nowadays, the European air quality values mainly show good to moderate index levels based on pollutant concentrations, over most of the countries [1, 2]. On a large scale, this goal was achieved due to the implementation of mitigation measures and the commitment to sustainability.

Whilst aviation contributes with a marginal rate to global atmospheric concentrations, it has adopted a set of high-aimed targets knowing that it can potentially produce forthcoming impacts. International aviation action plans, the implementation of specific regulations, technological and design improvements, and the transition to sustainable development represent important drivers to decreasing the environmental impact per flights. In recent years, without compromising on safety and having cost efficiency targets in mind, a better flight management and limiting engine emissions through technology were considered the best approach to reducing pollutants from air transport [3, 12].

In this context, determining the quality of the air in the vicinity of Romanian airports and the concentration of pollutants from the air space corresponding to the flight paths described by domestic flights during an imposed period, will be analyzed in comparison to national/international regulations; thus indicating the levels of local air quality.

Gaseous emissions tests must be performed on engines which have reached a constant operating temperature [7]. The report will include certification data for HC, NO_x, SO_2, but mainly for CO and CO_2, although in aviation carbon dioxide is not deemed as a regulated engine emission. Since CO_2 emissions are particularly a global concern given its importance to climate change [4], local CO_2 inventory development is useful for check purposes and can be used for global calculation where required [9].

Certificating authorities may recommend and provide guidance for the analytical techniques used to evaluate the concentrations of different gaseous emissions, but they may also accept alternative methods which provide accurate results. The indexes for various gaseous emissions will be calculated as follows:

$$EI_p = \frac{mass \quad of \quad p \quad produced(in \quad g)}{mass \quad of \quad fuel \quad used(in \quad kg)} \tag{1}$$

Experimental part

Air quality assessment reflected by airport-related and in-flight emissions represents the basis for calculating the impact on the environment of two Romanian national airlines, operating domestic flights. In the EU, local air quality regulations are expressed by the Air Quality Framework Directive, and the pollutant indicators are calculated (in $\mu g/m^3$) on an averaging period of 1/8/24 h or annually [9].

Table 1
LOCAL AIR QUALITY REGULATIONS FOR CO IN EU [9]

Country/ Organization	Pollutant (averaging period)	CO 8 hours $\mu g/m^3$
EU	Air Quality Framework Directive	10

For the measurements of CO and CO_2 concentrations, non-dispersive infrared analyzers are used, and each test must comprise a verification that the air/fuel ratio is in accordance with the engine air/fuel ratio appraisal within ± 15 % for the taxi mode, and within ± 10 % for all other modes: including takeoff, climb, descent and approach [6].

$$EI(CO) = \left(\frac{[CO]}{[CO_2]+[CO]+[HC]} \right) \left(\frac{10^3 M_{CO}}{M_C + (n/m)M_H} \right) (1 + T(P_O/m)) \tag{2}$$

The equation considers the mean concentrations of CO vol/vol, wet-[CO], of CO_2 vol/vol, wet-[CO_2] and of exhaust hydrocarbons vol/vol, (expressed as carbon)-[HC], the molecular mass of (equal to 28.011 g)-M_C, the atomic mass of carbon (equal to 12.011 g)-, the atomic mass of hydrogen (equal to 1.008 g)-M_H, the concentration of CO_2 in dry air, by volume (equal to 0.0003 normally)-T, the number of H atoms (in characteristic fuel molecule)-n and the number of C atoms (in characteristic fuel molecule)-m [6].

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Similarly, the emission indexes for, CO_2, HC, NO_x and SO_2 are calculated, applying, when appropriate, corrections to deem the deviations from the reference atmospheric conditions. The corrections take into account the fuel/air ratio in the combustor, the inlet pressure and temperature, and other constants specific to the pollutant or the type of engine analyzed [6].

The report presents an evaluation of air quality degradation in nearby communities during a week time. The period chosen for the study represents the week (18-24 December 2017) before Christmas, one of the busiest periods of the year in terms of the evolution of aircraft movements and the number of passengers.

Fig.1 Studied area/domestic flights performed by Tarom (red line) and Blue Air (blue line)

The study regards 7 of the 16 existing Romanian airports, the ones on which the two national air carriers perform internal flights: Otopeni (OTP/LROP), Cluj (CLJ/LRCL), Iasi (IAS/LRIA), Oradea (OMR/LROD), Satu Mare (SUJ/LRSM), Suceava (SCV/LRSV), Timişoara (TSR/LRTL), as well as the air space above/connecting these airports. The research does not include sources of pollution other than aircraft emissions and airport activities; therefore it does not take into account emissions from surface access to airports. Also, the scoring metrics presented do not consider the noise envelope around the Romanian airports to which reference is made.

For developing a scoring metric regarding the impact of domestic flights on the environment, the authors could also calculate the CO_2 emissions using data input from the two airlines analyzed. This regards the fleet of Tarom (RO/ROT) and Blue Air (OB/JOR), and it takes into account 7 different types of aircrafts: Airbus 318, Boeing 737-300/500/700/800, ATR 42-500 and ATR 72-500. The computations consider different parameters related to aircraft design and technology, such as: aircraft size, weight and fuel burn performance [11, 12]. This will be a focus point for bringing forward airlines' solutions and strategies as lever for meliorating air quality.

Results and discussions

For local and regional air quality assessment, the engine emissions data and the fuel flow rates were envisaged in the LTO cycles for takeoff, climb, descent, approach and taxi modes in accordance with Tarom and Blue Air's type of equipment used in the analyzed week.

The authors' approach on emission indexes calculations on the week analyzed eliminated the contaminants from the substances used in ADF and AAF fluids from de-icing/anti-icing procedures, since conditions ranging from snow, heavy or consistent snow, ice or overcooled rains were not present in the period considered; thus airport procedures did not involve any extreme weather operations.

The total number of domestic flights performed by the two Romanian national airlines (Tarom and Blue Air) during a busy week (i.e. 18-24th of December 2017) is 286. The flight scenario is valid for the mentioned period, as the number of flights differs from other periods of the year (i.e. is higher due to the holiday period). Other reasons may include Blue Air's decision to cancel operations on various routes such as Timisoara-Cluj-Iasi. However, the two airlines' destinations in the period analyzed has the following aspect (fig.2).

Since the greatest part of the pollutants are discharged under 3000 ft, the impact on the environment of analyzed flights and airport contaminants (including APU operations for the 7 types of aircrafts) are reflected in the air quality, modified by the effects of LTO cycles [10]. The duration of APU operation involves the production of different amount of pollutants, depending on the type of equipment involved in the process; including 25/40 g of PM (particular matter) [8]. Since all the aircrafts provided by the two Romanian

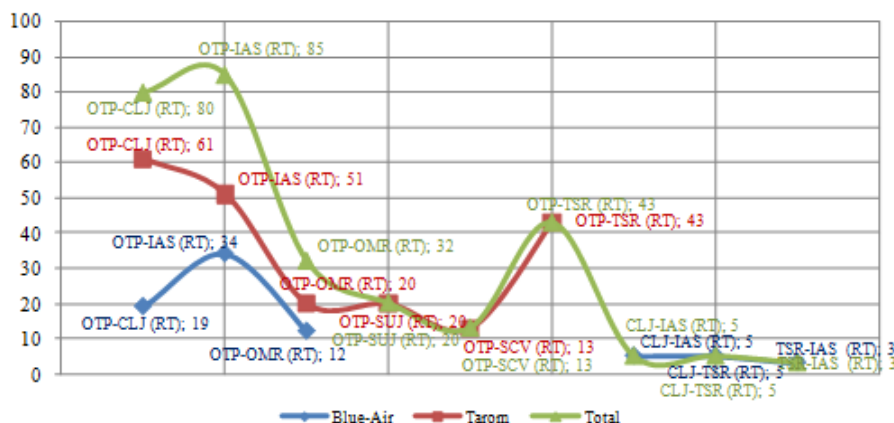| Aircraft	LTO emission factors/aircraft kg/LTO/aircraft					Fuel consumption (kg/LTO/aircraft)
	CO_2	HC	NO_x	CO	SO_2	
Airbus 318	2310	0.59	8.73	6.35	0.73	730
Boeing 737-300/500	2480	0.84	719	13.03	0.78	780
Boeing 737-700	2460	0.86	9.12	8.00	0.78	780
ATR 42/72	620	0.29	1.82	2.33	0.20	200

Fig. 2. Tarom and Blue Air flights/destination/period analyzed

	Leg	Tarom flights	Flights/Type of aircraft	Blue Air flights	Flights/Type of aircraft
1	OTP-CLJ	30	ATR 42-500 (19), ATR 72-500 (6), Boeing 737-700 (5)	9	Boeing 737-800 (9)
2	CLJ-OTP	31	ATR 42-500 (19), ATR 72-500 (7), Boeing 737-700 (5)	10	Boeing 737-800 (10)
3	OTP-IAS	25	ATR 42-500 (5), ATR 72-500 (19), Boeing 737-300 (1)	17	Boeing 737-500 (17)
4	IAS-OTP	26	ATR 42-500 (5), ATR 72-500 (13), Boeing 737-700 (7), Airbus 318 (1)	17	Boeing 737-500 (17)
5	OTP-OMR	10	ATR 42-500 (10)	6	Boeing 737-800 (6)
6	OMR-OTP	10	ATR 42-500 (10)	6	Boeing 737-800 (6)
7	OTP-SUJ	10	ATR 42-500 (10)	-	-
8	SUJ-OTP	10	ATR 42-500 (10)	-	-
9	OTP-SCV	6	ATR 42-500 (6)	-	-
10	SCV-OTP	7	ATR 42-500 (7)	-	-
11	OTP-TSR	21	ATR 42-500 (10), ATR 72-500 (11)	-	-
12	TSR-OTP	22	ATR 42-500 (11), ATR 72-500 (11)	-	-
13	CLJ-IAS	-	-	2	Boeing 737-500/800 (2)
14	IAS-CLJ	-	-	3	Boeing 737-500/800 (3)
15	CLJ-TSR	-	-	3	Boeing 737-500 (3)
16	TSR-CLJ	-	-	2	Boeing 737-500 (2)
17	TSR-IAS	-	-	2	Boeing 737-500 (2)
18	IAS-TSR	-	-	1	Boeing 737-500 (1)

Table 3
TAROM AND BLUE AIR FLIGHTS PER WEEK (18-24 DECEMBER 2017)

air carriers are short-haul, the emissions for one operation, are as follows:

Table 4
VALUES FOR APU EMISSIONS PER AIRCRAFT OPERATION [9]

Aircraft group	Fuel burn	CO emissions	HC emissions	NO_x emissions
Short-haul	80 kg	310 g	30 g	700 g

For the 286 flights corresponding to the scenario outlined by the two airlines, the APU operations involve 22880 kg of fuel burn, 88660 g of CO emissions, 8580 g of HC and 200200 g of NO_x.

Data provided by the national airlines involved in the study indicate that Tarom's average load factor (LF) for domestic flights in 2017 was 66% [13, 15], thus the authors could calculate the total aircraft fuel burn/journey and the emission index in kilograms for the CO_2 gaseous pollutant. For the same period, the computations will be performed considering Blue Air's flight schedule, with its load factor LF=69.77% [14, 16].

Considered leg	Distance (km)	Equipment (Type of aircraft)	No. of flights per aircraft	Pax carrying capacity	No. of revenue paying pax	Total pax per aircraft type	Total pax per legs
OTP-CLJ/ CLJ/OTP	309	ATR 42-500	38	48	32	1216	5269
		ATR 72-500	13	68	45	585	
		Boeing 737-700	10	146	96	960	
		Boeing 737-800	19	189	132	2508	
OTP-IAS/ IAS-OTP	311	ATR 42-500	10	48	32	320	5723
		ATR 72-500	32	68	45	1440	
		Boeing 737-300	1	134	88	88	
		Boeing 737-700	7	146	96	672	
		Airbus 318	1	113	75	75	
		Boeing 737-500	34	132	92	3128	
OTP-OMR/ OMR-OTP	423	ATR 42-500	20	48	32	640	2224
		Boeing 737-800	12	189	132	1584	
OTP-SUJ/ SUJ-OTP	426	ATR 42-500	20	48	32	640	640
OTP-SCV/ SCV/OTP	346	ATR 42-500	13	48	32	416	416
OTP-TSR/ TSR/OTP	398	ATR 42-500	21	48	32	672	1662
		ATR 72-500	22	68	45	990	

Table 5
CHARACTERISTICS OF FLIGHTS PER WEEK (18-24 DECEMBER 2017)

CLJ-IAS/ IAS-CLJ	301	Boeing 737-500	3	132	92	276	540	
		Boeing 737-800	2	189	132	264		
CLJ-TSR/ TSR-CLJ	211	Boeing 737-500	5	132	92	460	460	
TSR-IAS/ IAS-TSR	504	Boeing 737-500	3	132	92	276	276	

$$Aircraft\ fuel\ burn/journey = \sum Aircraft\ fuel\ burn/leg \tag{3}$$

$$Total\ passengers'\ CO_2/journey = \\ = \sum Passenger\ CO_2/pax/leg \cdot Number\ of\ pax \tag{4}$$

Taking into consideration the distance between the proposed destinations, the type of aircraft used, and measures of traffic (available seat km-ASK and revenue passenger per km-RPK), the final indicators for fuel burn were provided.

$$Aircrafts'\ fuel\ burn = A/cFb/OTP-CLJ\ legs + \\ +A/cFb/OTP-IAS\ legs + A/cFb/OTP-OMR\ legs + \\ +A/cFb/OTP-SUJ\ legs + A/cFb/OTP-SCV\ legs + \\ +A/cFb/OTP-TSR\ legs + A/cFb/CLJ-IAS\ legs + \\ +A/cFb/CLJ-TSR\ legs + A/cFb/TSR-IAS\ legs = \\ = (80 \cdot 1916.8 + 85 \cdot 1311.8 + 32 \cdot 1406.0 + 20 \cdot 795.1 + \\ +13 \cdot 699.5 + 43 \cdot 2157.2 + 5 \cdot 2233.4 + 5 \cdot 1735.1 + 3 \cdot 2944.9)\ kg \tag{5}$$

$$Total\ aircrafts'\ fuel\ burn = 456271.3\ kg \tag{6}$$

The computations for the 8 legs analyzed take into account the equipment used by the airlines (i.e. if it used a winglet system, or applies a continuous descent approach procedure). In the case of Tarom, the second procedure is meant to reduce fuel consumption and CO_2 emissions and involves the Airbus A318 aircrafts, since its objectives include obtaining an efficient fuel consumption of 1.5-2% and achieving carbon neutrality by 2020 [13].

Regarding the average CO_2 emissions/passenger, the single engine taxi procedure is used for both ATR 42/72-500 and for the Airbus 318-111 [13] (used in the analyzed case only for the IAS-OTP leg) and has proved to be a good tool for reducing emissions by a 0.4 percent.

$$Total\ CO_2/pax/legs = CO_2/pax/(OTP-CLJ)legs + \\ +CO_2/pax/(OTP-IAS)legs + CO_2/pax/(OTP-OMR)legs + \\ +CO_2/pax/(OTP-SUJ)legs + CO_2/pax/(OTP-SCV)legs + \\ +CO_2/pax/(OTP-TSR)legs + CO_2/pax/(CLJ-IAS)legs + \\ +CO_2/pax/(CLJ-TSR)legs + CO_2/pax/(TSR-IAS)legs = \\ = 80 \cdot 47.8 \cdot 5269 + 85 \cdot 42.7 \cdot 5723 + 32 \cdot 44.6 \cdot 2224 + \\ +20 \cdot 40.4 \cdot 640 + 13 \cdot 35.5 \cdot 416 + 43 \cdot 53.0 \cdot 1662 + \\ +5 \cdot 62.2 \cdot 540 + 5 \cdot 49.8 \cdot 460 + 3 \cdot 84.5 \cdot 276 \tag{7}$$

$$Total\ passengers'\ CO_2 = 48943625.3\ kg \tag{8}$$

The assessment of carbon dioxide emissions reflects the concentration of CO_2/leg in the exhaust samples, multiplied by the total number of passengers on each leg (i.e. 5269 on OTP-CLJ and CLJ/OTP, 5723 on OTP-IAS and IAS-OTP, 2224 on OTP-OMR/ OMR-OTP, 640 on OTP-SUJ/ SUJ-OTP, 416 OTP-SCV RT, 1662 on OTP-TSR RT, 540 on CLJ-IAS and IAS-CLJ, 460 on CLJ-TSR and TSR-CLJ, 276 on TSR-IAS and IAS-TSR; total 17210 pax) transported in the analyzed week (18-24 December 2017). The calculations took into account the total number of passengers transported, not the airlines' flight passenger carrying capacity.

In the light of the above mentioned directives, the implementation of a responsibility policy for all actors in aviation is meant to incentivize continuous improvement of environment protection measures for achieving compliance with international regulations. Blue Air's fleet consists of 28 Boeing 737 aircraft series (i.e. two 737-300, six 737-400, six737-500, one 737-700, thirteen 737-800) and states that the fleet selection mirrors the yearning and demand to reduce fuel consumption and to lower emissions [14]. Tarom's environmental responsibility program includes 3 major initiatives: Continuous Descent Approach procedure, Single Engine Taxi procedure and the use of Winglet System.

A forecast performed by the Council of Aerospace Industries Associations shows that new technologies will amend fuel burn by 1.6%-2.5% per year and will improve fuel efficiency from 5 liters (in 2005) to 3 liters/pax/100 km by 2025 [5].

National airlines will also have to implement solutions relative to the capabilities of their aircrafts for obtaining an even greater reduction of fuel/oil and emissions, in order to match one of the International Civil Aviation Organization's technology improvement related scenarios regarding the 2050 target for climate change solution.

Already, a 3% reduction on emissions and fuel consumption is achieved through the winglets installed on Tarom's Boeing 737-700 aircrafts, and for the Airbus 318, the continuous descend approach involves a reduction of 350 kg CO_2 on every flight [13].

Considered leg	OTP-CLJ	OTP-IAS	OTP-OMR	OTP-SUJ	OTP-SCV	OTP-TSR	CLJ-IAS	CLJ-TSR	TSR-IAS
Aircraft Fuel Burn/leg (kg)	1916.8	1311.8	1406.0	795.1	699.5	2157.2	2244.4	1735.1	2944.9

Considered leg	OTP-CLJ	OTP-IAS	OTP-OMR	OTP-SUJ	OTP-SCV	OTP-TSR	CLJ-IAS	CLJ-TSR	TSR-IAS
Passenger CO_2/pax/ leg (kg)	47.8	42.7	44.6	40.4	35.5	53.0	62.2	49.8	84.5

Scenario	Name	Technology improvement	Period
1	Low aircraft technology + moderate operational improvement	0.76%/year	2010-2050
2	Moderate aircraft technology + operational improvement	0.96%/year	2010-2050
3	Advanced aircraft technology + operational improvement	1.16%/year	2010-2050
4	Optimistic aircraft technology + advanced operational improvement	1.50%/year	2010-2050

Conclusions

The report presents the evaluation of Romanian air carriers Tarom and Blue Air's contribution to air traffic-related pollution, showing acceptable levels of local air quality.

The paper included the airlines' measures applied in order to achieve values of the concentrations of gaseous emissions within the limits imposed by standards and regulations, expressed for example by the Air Quality Framework Directive. The research has focused on the emissions of carbon dioxide, the largest driver of climate change, which was analyzed as a linear function of fuel burn. Taking into account different parameters related to aircraft characteristics: size, weight and fuel burn performance, but also regarding traffic indicators mirrored by the number of revenue paying passengers, the computations were performed for total CO_2 emissions.

In this concern, the authors consider that the two air carriers should focus on bringing forward solutions especially regarding carbon trading-as a key lever of responsibility policy improvement.

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