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ECONOMIC ESTIMATES OF THE CLIMATE COSTS OF THE AVIATION SECTOR DUE TO AIR MANAGEMENT: INSIGHTS FOR 2018 AND 2019

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Air navigation service providers are public or private legal entities that provide air navigation services. They are natural monopolies and ensure that aircraft on the ground and in the air under all weather conditions keep safely apart by prescribing vertical and horizontal distances to each other. Due to the nature of this activity, there can only be one player in a national market and therefore the operation needs to be regulated. In the European Union and its associated members, regulation is carried out via a performance scheme which measures and sets targets for the different key performance areas of safety, capacity, environment and cost effectiveness[1].

The targets for the 2015-2019 period (the so-called "second reference" period or "RP2") have been laid down in the European Commission Implementing Decision of 11 March 2014 (2014/132/EU)[2]. For the environmental area, the target aims to reduce the actual trajectory of a flight to minimise fuel consumption and thus greenhouse gas (GHG) emissions. Targets were set for RP2 assuming that there would be continuous improvements for the Key performance Environment indicator based on Actual trajectory (KEA) (or actual trajectory to Great Circle Distance), which is the shortest distance between two points on the surface of a sphere, measured along the surface of such sphere. This is

[1] *See Regulation EC No 1808/2009*
[2] *EUR-Lex - 32014D0132 - EN - EUR-Lex (europa.eu)*

HIGHLIGHTS

- Changes in air-traffic management capacity may lead to an increase in distances flown and fuel burn.
- The climate costs of carbon dioxide (CO_2) emissions due to capacity constraints in 2018 and 2019 ranged from 54 to 301 million EUR.
- Total climate costs for 2018 and 2019 may be as high as 1 bn EUR.

Keywords: economic cost, aviation sector, capacity management.

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reflected by a steady decrease of the KEA target from 2.96% in 2015 to 26% in 2019. In the assessment of horizontal flight efficiency (HFE)[3] targets, all planned network changes were taken into account, including the average use of military restricted areas. It should be noted that this regulation does not take into account actual wind and temperature conditions nor the presence of significant weather along the route, which may have a comparable impact on the flight time and fuel burn. In Figure 1 we can see annual values for the Single European Sky (SES) area, so-called SES-RP2 area. That is the one regulated under the Performance Scheme of SES in RP2. Note that KEP stands for Key Performance Indicator Horizontal Flight Efficiency with respect to the Flight Plan as defined in Implementing Regulation 390/2013, Annex I.

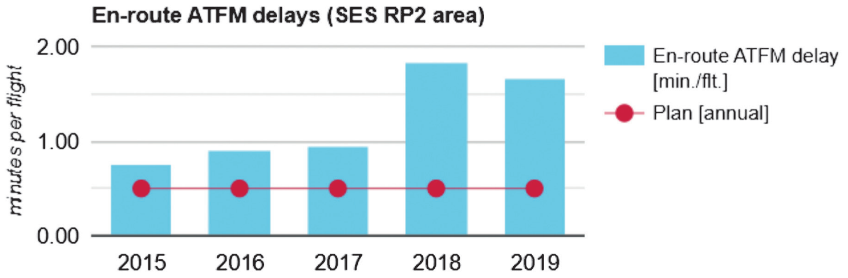

Figure 2. En-route ATFM delays in SES RP2 area. Source: ECTL, PRU Data-Dashboard

It is interesting to note that a higher horizontal flight efficiency measurement usually means a more direct flight trajectory, but this does not necessarily translate into a climate optimal trajectory. The Regulator uses the actual distance flown, as this correlates with fuel burn and therefore CO_2 emissions. However, vertical flight efficiency also needs to be considered in any measure of climate optimal trajectories and other circumstances - such as wind or the possible occurrence of contrails - also need to be taken into account. In addition, the latest scientific research indicates that CO_2 emissions are not the sector's only climate change impact. CO_2 represents approximately 34% of the effective radiative forcing (ERF) of the whole sector; around 66% of ERF comes from non-CO_2 impacts, mainly contrail cirrus and emissions of nitrogen oxides (NOX) (Lee et al, 2021).

At the same time, it is important to note that there is an interdependency between the different Key Performance Areas[4] as we have pointed out in earlier work (Abadie et al., 2020). One example is the link between airspace and Air Traffic Management (ATM) Capacity and Environment: when the offered capacity falls short of the demand for flights, ground delays, holdings and traffic shifts to adjacent areas occur. This entails detours and a deterioration of the HFE-indicator. Delays between 2015 and 2017 were in the same approximate order of magnitude but increased sharply in 2018 and remained close to this peak level in 2019 as shown in Figure 2.

For actual HFE, it should be noted that the target of 2.78% of KEA was met in 2017 but afterwards deteriorated to 2.95% - a difference of 0.17 points - which was a clear reflection of the shortfall of capacity and the increase in delays.

There are many interesting factors which can be analysed from these calculations, including how changes in HFE can be translated into costs. The chart below shows the logic:

In the draft Performance Review Report (PRR) (2020) there is an in-depth analysis of the situation in 2019/2020 and how the sharp decrease of traffic due to the COVID pandemic had an impact on both capacity (in terms of delays) and on the environment (in terms of HFE). As part of this analysis, PRR (2020) concluded that an improvement of 0.3 points in HFE leads to savings of 16.02 million NM (or 29.7 million km) in distance (see page 32), or 0.1 points leads to 5.4 million NM (or 9.9 million km).

It is possible to conclude that if the same amount of capacity as in 2017 had been available in 2018 and 2019, the improvement in HFE would have met the set targets. This is noted in Table 1.

If we now apply the differences in Table 1 and use the equivalence above from

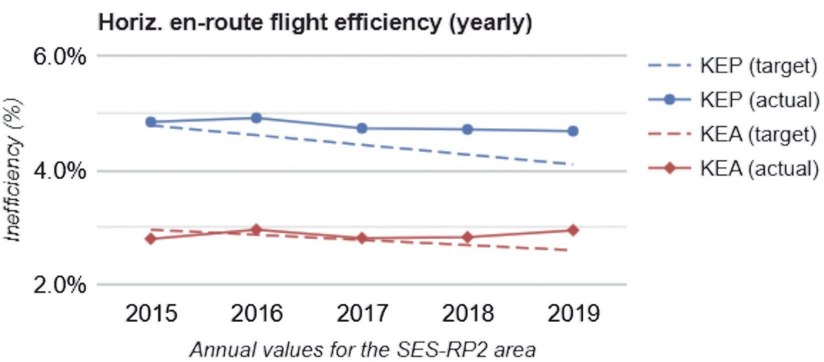

Figure 1. Annual values for the Single European Sky (SES-RP2) area. Source: ECTL, PRU Data-Dashboard

[3] *Which is defined as the comparison between the length of a trajectory and the shortest distance between its endpoints*
[4] *See definition in Regulation EC No 1808/2009*

	2017	2018	2019
KEA (target)	2.78	2.69	2.60
KEA (actual)	2.78	2.83	2.95
Difference	0.00	0.24	0.35

Table 1. KEA comparisons between target and actual

the PRR (2020), we can estimate the additional distance flown per year as:

2017: 0 NM additional distance flown
2018: 2.4 x 5.4 million NM = 12.96 million NM
2019: 3.5 x 5.4 million NM = 18.9 million NM

That is, in the period 2018 to 2019 something close to 31.86 million NM was flown beyond optimal distances as a result of capacity constraints.

According to EUROCONTROL (ECTL), Standard Inputs for cost benefit analyses (CBAs) in 2019 there was an average fuel burn for departing and arriving Instrument Flight Rules flights in the European Civil Aviation Conference (ECAC) region of 10.011 kg on an average flight length of 946 NM (PRR 2020, page 55). This means that per NM flown, some 10.58 kg of fuel was burnt. One kg of fuel burnt leads to an emission of 3.15 kg of CO_2; 1.237 kg of H_2O; and 0.00084 kg of SO_2 (PRR 2020, page 24).This means that for the 31.86 million NM additional distance flown in the period 2018 to 2019, 337,156,934 kg of fuel was burnt, corresponding to 1.06 million tonnes of CO_2. If we now use the ECTL Standard Inputs Climate Change Avoidance Costs measure shown in the table below, it is possible to quantify the carbon cost of that extra distance flown. The avoidance costs may vary depending on whether costs are measured over short-to- medium terms (up to 2030) or the long term (from 2040 to 2060). Costs may also vary depending on the calculated EUR-per-tonne of CO_2 equivalent, which ranges due to regulatory and political uncertainty between 63 EUR and 524 EUR (Table 2).

If we take the short to medium run up to 2030, the estimated costs would amount to 112 million EUR (1,062,044 tonnes of CO_2 times 105 EUR). In the long run, from 2040 to 2060 - and again taking the medium value of ECTL Standard Inputs of 283 EUR per tonne of CO_2 equivalent - the costs would amount to 301 Million EUR (1,062,044 tonnes of CO_2 times 283 EUR).

To sum up, the environmental costs of CO_2 emissions due to capacity constraints in 2018 and 2019 range from 112 to 301 million EUR as summarized below:

If we now note, as stated above from Lee et al (2021), that CO_2 emissions account for only 34% of the total climate impact of aviation, one could argue that the total costs may be up to three times higher than the figures calculated for CO_2 only. That is, the environmental costs of aviation for 2018 and 2019 can be estimated to be ranging from 336 to 903 million EUR.

Also, note that the values offered represent the Standard Inputs Climate Change Avoidance Costs which may significantly differ from the European Emissions Trading Scheme (EU ETS) carbon prices. Being aviation one of the sectors included in the EU ETS since 2012, the price or carbon will be determined by the market. Under this situation and considering the price of CO_2 in the future market in the period 2021-2027 (see Figure 3), it is possible to estimate a carbon price ranging from 50.81€ in 2030 to 144.6€ by the end of the century[5], which will be significantly lower than the Standard Inputs Climate Change Avoidance Costs economic estimates for the long run. In such a case, the cost by 2030 will be close to 54 million EUR and 153.5 million EUR for the long run. And consequently, the total cost varies from 162 to 460.5 million EUR.

So, all in all, the climate or environmental cost values will be ranging between 162 and 903 Million EUR depending on the carbon price used for the estimation.

Besides HFE, a vertical flight efficiency measure is also a very important aspect of operations, as aircrafts burn more fuel when flying at lower altitude as a result of capacity constraints and when they follow non-optimal flight profiles (see PRR 2020, Page 37-38). In addition, ECTL Network Manager has introduced the so-called "level caps", meaning that, for flow control purposes, an aircraft can be told to fly at a lower level than usual, leading to excess fuel burn. Furthermore, the number of occasions when environmentally friendly procedures such as Continuous Descent Operations (CDO) and Continuous Climb Operations (CCO) has fallen by some 5 to 10 per cent, as they cannot be flown during periods of high traffic density. This has also caused additional fuel burn. (See Figure 4). However, this cannot be quantified with the current available data.

Considerations on emerging challenges for ATM should be taken into account due to imminent effects of climate change and variability. Several studies performed by aviation meteorological institutions and associations (KNMI, WMO, EUMETNET, Met Alliance) have indicated an increased risk of severe weather linked to climate change and variability affecting the efficiency and economy of air traffic and its management. Increased frequency and intensity of convective weather situations

Forecast	Low	Medium	High
Short and medium run (up to 2030)	63	105	199
Long run (from 2040 to 2060)	164	283	524
(adjusted from € 2016 to € 2019 prices)			

Table 2. Climate change avoidance costs in euros per tonne of CO2 equivalent
Source: ECTL Standard Inputs for economic analysis, edition 9, December 2020, page 27

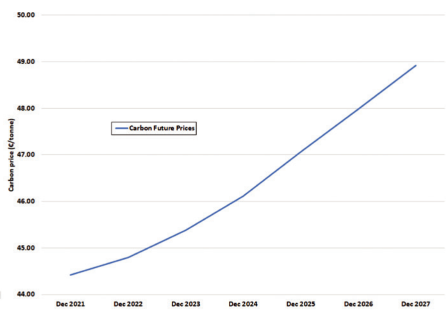

Figure 3. Future prices of carbon. Source: Market data CE EUA FUTURES PRICES for Mon, Apr 19th, 2021

[5] *Regression results are available upon request*

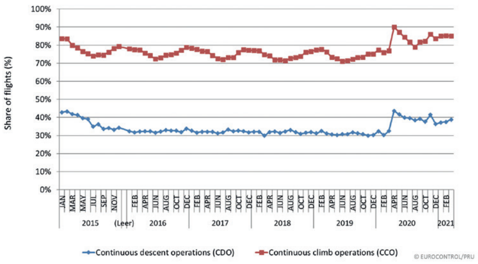

Figure 4. Changes in continuous descent operations (CDO) and continuous climb operations (CCO) from January 2015 to March 2020.
Source: www.ansperformance.eu

(thunderstorms, electric storms, intense precipitation and excessive wind speeds) affect not only the smooth operation of air traffic management and in particular, flow management, but also the predictability of demand-capacity imbalances. Such conditions require a highly flexible and well-trained staff of ANSP, and a close cooperation with meteorological service providers to minimize adverse effects of significant (adverse) weather on actual length of routes flown. Current research on the possibility of reducing, for example, the formation of long-lasting contrail-cirrus by avoiding areas and levels of ice-supersaturated volumes of air indicate the potential for significant environmental (climate change related) benefits, but require, again, a very close cooperation between the ANSP, operators and meteorological service providers. This cooperation can only be realized if sufficient capacity for training, education and collaborative decision-making processes is available and funded.

Conclusion and further research

There are many issues that have to be taken into consideration when defining targets in the performance scheme for air navigation services. This document has shown that the total economic cost perspective is a very important one and needs to be adequately considered. A shortfall of capacity leads to delay costs - which we have already investigated in Abadie et al. (2020) - and considerable environmental costs, which we have outlined in this paper. As capacity is planned in the medium to long-term, traffic forecasts are a crucial element. Therefore, further research is warranted into the interdependency of traffic forecasts, capacity and environmental costs.

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