Standard Inputs for EUROCONTROL Cost-Benefit Analyses

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12/25/22

Table of contents

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Economics.Business-Cases@eurocontrol.int

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Foreword

Although we cannot foresee when, or even if, the world will return to what it was prior to the COVID-19 pandemic, we have decided to publish this new edition of the standard inputs as a valuable source of inputs for economic and cost-benefit analyses in aviation. The recommended values are often based on 2019 statistics and data which do not yet take account of the impact of the pandemic.

For this edition, the focus is on environmental values, a new value for airports, turn-around time, and the introduction of two values related to drones. Drones represent a highly complex and fast-moving market, which makes forecasting more difficult than legacy aviation sectors. Suggestions for improvement and collaboration are welcome. Please send them to aviation.intelligence@eurocontrol.int.

We would like to make a special mention of the launch of the EUROCONTROL Aviation Intelligence Portal, which provides valuable and up-to-date information for economic analyses (https://ansperformance.eu/). The Portal will soon include the standard inputs (2021) and more information of use for cost-benefit analyses.

Introduction

This document provides a set of standard inputs for data commonly used in economic and financial ATM-related analyses and appraisals. The standard inputs will save time in the development, for example, of cost-benefit analyses (CBAs) and economic impact assessments and will also help achieve greater consistency and comparability between different CBAs.

We are using whatever.

In this, the 10.0.1th edition:

- the title has been changed to "EUROCONTROL standard inputs for economic analyses", a more accurate description of its use;
- the values have been regrouped by stakeholder and key topic of interest;
- all prices have been updated to 2019 euro values unless otherwise specified. The costs can be easily adjusted using the table of indices contained in the section Conversions, Inflation, Cost of Fuel, Exchange Rate;
- some values have been reviewed and replaced, namely turn-around time, all causes of delay, and statistics;
- comparable historical data have been added;
- two new values have been introduced, namely drone fleet and U-space related investments;
- the value "cost of an ATFM slot swap" was removed because the UDPP concept has evolved and makes reference to "measures" (which involves multiple swaps). The value of a measure has a big range and is still being worked on;
- a link to the EUROCONTROL Aviation Intelligence Portal providing latest information was added when and where appropriate;
- whenever single values are contentious, a range of low, base and high values is given, allowing users of the data to conduct sensitivity analyses.

The standard inputs have been compiled from EUROCONTROL data and intelligence, from values provided by airspace users, ANSPs, airports, IATA, EASA and other organisations, and from other relevant documents which are publicly available.

They are average values and may not be appropriate in all circumstances. The document also gives details of the sources of information, and discusses the applicability and use of the values.

This document will remain a living document, and so comments and suggestions are very welcome. Readers are invited to send these to aviation.intelligence@eurocontrol.int.

Details per data item

For each standard input, the following information is provided, where relevant.

Section	Description
Definition	A statement which describes the concept.
EUROCONTROL recommended value or source	One or a set of recommended values or sources put forward by EUROCONTROL for the specific indicator.
Source and date	The source documents and their publication dates.
Description	Any relevant information or details regarding the standard input. Information can be found here on how the value is computed, the specific use of the indicator, etc. Information regarding the limitations on using the values may also be included.
Other possible values	Other values found in different sources, which are included for the purpose of information or discussion.
Related standard inputs	A link to other related standard inputs included in the document in order to increase its consistency.
Further reading	References to other interesting sources.

Section	Description
Comments	Any questions or further comments regarding the source or derivation of the value, for example the degree of confidence in the values and sources cited.

General parameters

Below are presented some key values used in the Standard Inputs and that can serve as a reference for other uses.

For any questions relating to this document, please contact EUROCONTROL using the e-mail aviation.intelligence@eurocontrol.int[1], naming the Standard Inputs in the subject line.

Inflation

The inflation levels have been calculated based on the Harmonised Index of Consumer Prices (HICP), as the yearly difference in the HICP. The HICP data was extracted from Eurostat[2] HICP - annual data (average index and rate of change) database (prc_hicp_aind).

The annual change in the index is shown below. The values of the index are available from Eurostat[3] (table Table 2.)

```
Attaching package: 'dplyr'

The following objects are masked from 'package:stats':

    filter, lag

The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union

Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
```

[1] mailto:aviation.intelligence@eurocontrol.int?subject=Standard%20inputs
[2] http://ec.europa.eu/eurostat
[3] http://ec.europa.eu/eurostat

```
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
```

Table 2: Annual average inflation values

Year	Index	Rate of change
2021	NA	NA
2020	NA	NA
2019	105.42	1.47%
2018	103.89	1.89%
2017	101.96	1.71%
2016	100.25	0.25%
2015	100.00	0.10%
2014	99.90	0.55%
2013	99.35	1.50%
2012	97.88	2.64%
2011	95.36	3.10%
2010	92.49	2.09%
2009	90.60	0.98%
2008	89.72	3.54%
2007	86.65	2.34%
2006	84.67	2.20%
2005	82.85	2.17%
2004	81.09	2.01%
2003	79.49	1.96%
2002	77.96	2.08%
2001	76.37	2.19%
2000	74.73	1.90%

Source: Eurostat[a]

[a] http://ec.europa.eu/eurostat

Exchange Rate Conversion

The currency exchange rates provided below are based on the European Central Bank (ECB) rates as are published daily. The rates exposed in the table below correspond to the average rate for the year 2021 as published by ECB.

```
Rows: 2 Columns: 3
-- Column specification ----------------------------------------------------------
```

```
Delimiter: ","
chr (1): currency
dbl (2): to_eur, from_eur

i Use `spec()` to retrieve the full column specification for this data.
i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

Table 3: Average euro foreign exchange rate (2021)

Currency	Currency-€	€-Currency
USD	0.89	1.12
GBP	1.22	0.82

Source: European Central Bank[a]

[a] https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/index.en.html

Cost of fuel

The cost of fuel used in this document is based on the 2021 average jet fuel price handled by IATA[4], unless otherwise specified. All conversions are done using the values specified on this page.

Table 4: Average jet fuel price

Currency	Price per barrel	Price per gallon	Price per kg
USD	141.7	3.80	1.1
EUR	138.9	3.31	1.1

Source: IATA[a]

[a] https://www.iata.org/en/publications/economics/fuel-monitor/

Conversion values

Table 5: Units conversion values.

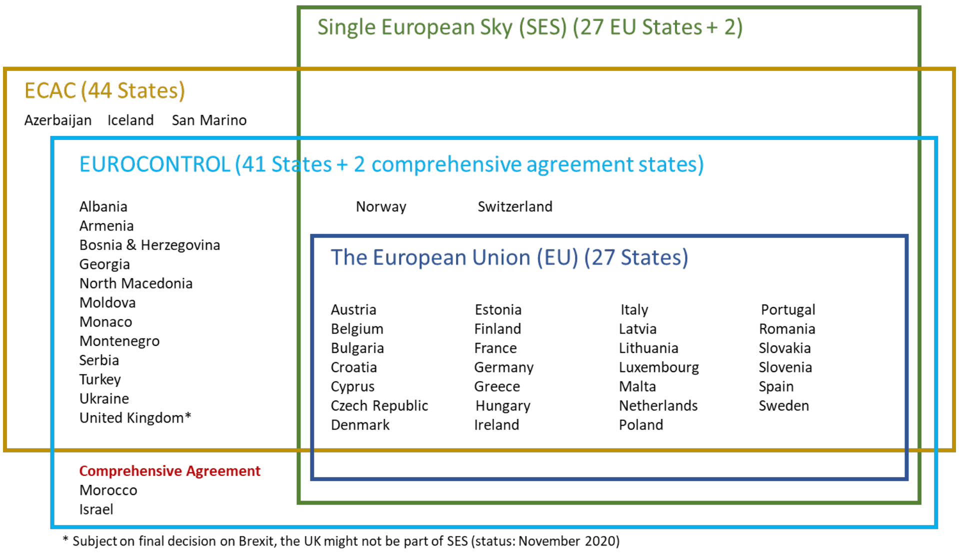
From	To
1 nautical mile (NM)	1.852 km
1 kilometre (km)	0.53996 NM

[4] https://www.iata.org/en/publications/economics/fuel-monitor/

1 tonne (metric = 1 000 kg) of jet fuel	325.33 US gallons
	1 235 litres
	7.8 barrels
1 barrel (bbl) of jet fuel	42 US gallons
	158.99 litres
	0.1291 ton = 129.10 kg
1 US gallon of jet fuel (US gal)	3.7854 litres
	3.073 kg
	6.7764 lb
Density of kerosene	0.812 kg/litre
1 litre of fuel (l)	0.26417 US gallons
1 kilogramme of fuel (kg)	2.2046 lb
1 pound of fuel (lb)	0.45359 kg

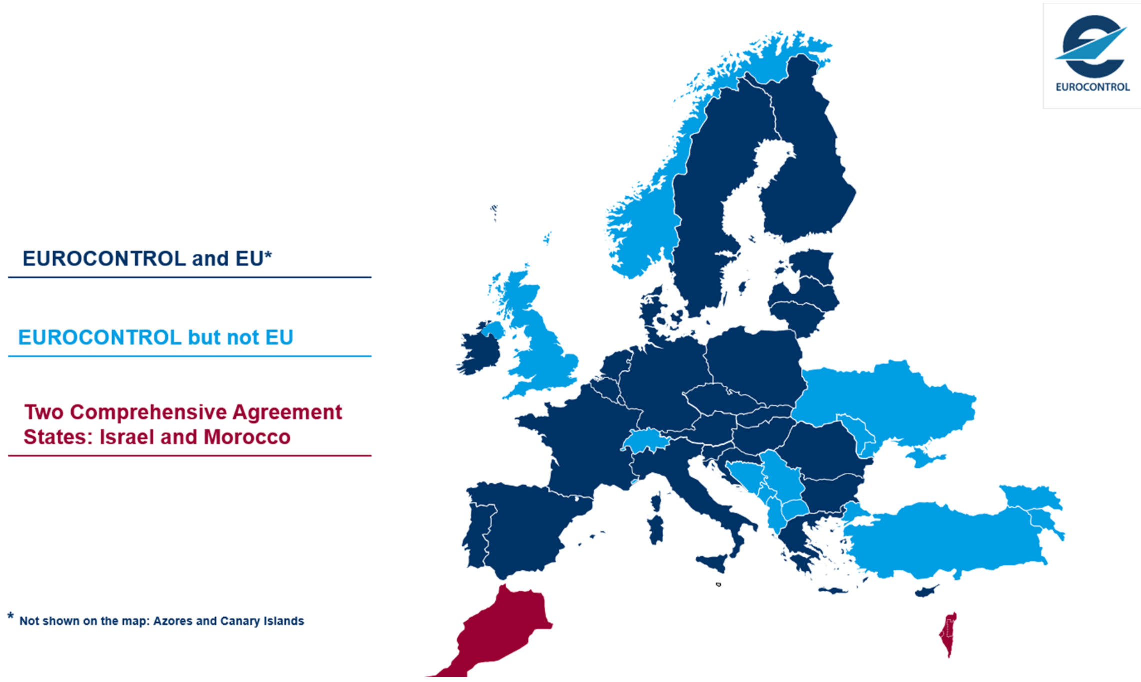
Geographical Areas

Member States and geographical areas covered



* Subject on final decision on Brexit, the UK might not be part of SES (status: November 2020)

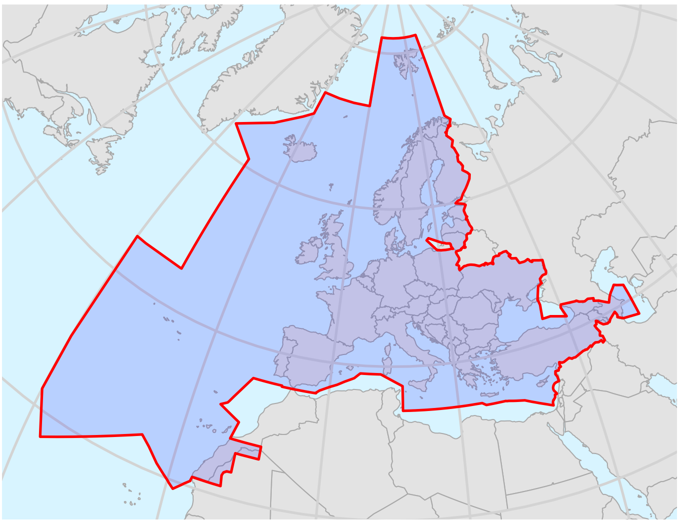
EUROCONTROL Member States (status: November 2020)



Airspace of the ECAC Member States

```
Attaching package: 'dplyr'

The following objects are masked from 'package:stats':

    filter, lag

The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

Country FIR for ECAC
at altitude FL000



Comment

ECAC is an intergovernmental organisation which was established by ICAO and the Council of Europe. ECAC now has 44 Member States, including all 27 EU Member States, 31 of the 32 European Aviation Safety Agency Member States, and all 41 EUROCONTROL Member States. Further information on traffic region definitions is available in the EUROCONTROL STATFOR 7-year IFR Flight Movements and Service Units Forecast, Annex 1. https://ansperformance.eu/traffic/statfor/

Part I

Traffic and capacity

Chapter 1

Air traffic statistics and forecasts

1.1 Definition

Actual and forecast numbers of flights and service units.

1.2 EUROCONTROL recommended source

Source EUROCONTROL Statistics and Forecasts Service (STATFOR) https://www.eurocontrol.int/forecasting

1.3 Description

The objective of the Statistics and Forecast (STATFOR) service is to provide statistics and forecasts on air traffic in Europe and to monitor and analyse the evolution of the air transport Industry.

It produces the following:

- Seven-year forecasts The 7-year forecasts give a comprehensive picture of anticipated air traffic development in Europe for the next seven years. They combine flight statistics with economic growth and models of other industry drivers, including costs, airport capacity, passenger numbers, load factors and aircraft size. Using high- and low-growth scenarios, they present a likely range for growth, to help planners manage risks. We publish them biannually, in spring and autumn, covering flights, and en route and terminal service units every year.
- Twenty-year forecasts The 20-year forecasts look at a range of distinct possible scenarios for how the air traffic industry might look in 20

years' time. This allows a range of 'what if?' questions to be explored, for factors inside the industry (e.g. the growth of small business jets, or of point-to-point traffic) or outside the industry (e.g. the price of oil or environmental constraints). Twenty-year forecasts are usually published every two to three years.

- Ad-hoc publications, such as the Challenges to Growth reports, trends in air traffic studies and other analyses can be found in the EUROCONTROL library: https://www.eurocontrol.int/library

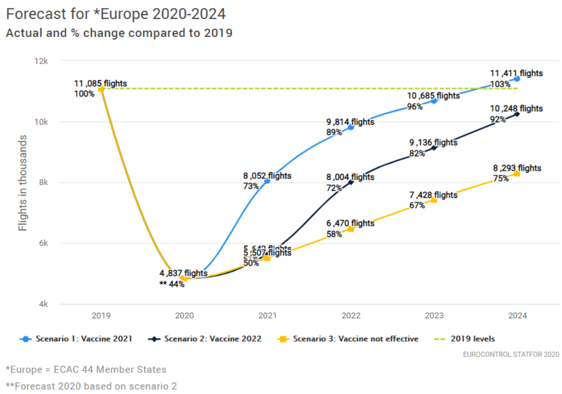
Traffic statistics and forecasts can be obtained directly from the **STATFOR Interactive Dashboard (SID)**: https://www.eurocontrol.int/dashboard/statfor-interactive-dashboard.

1.4 Related standard inputs

Medium-term capacity planning, air traffic delay, flow management delay and cost of delay.

1.5 Comments

The following chart (status: November 2020) shows the traffic forecast taking account of the impact of COVID.



Source: EUROCONTROL STATFOR 2020, https://www.eurocontrol.int/covid19

Chapter 2

Medium-term capacity planning

2.1 Definition

ATM capacity forecasts and planning targets over a specific period.

Capacity planning is the systematic determination of resource requirements for the projected output, over a specific period.

2.2 EUROCONTROL recommended sources

```
Warning: Since gt v0.3.0, `columns = TRUE` has been deprecated.
* Please use `columns = everything()` instead.
```

```
Warning: HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
```

what	description
Source 1	EUROCONTROL NMD, Network Operations Plan (NOP) 2019-2024 [https://www.euroconT
Source 2	EUROCONTROL NMD, NOP (6-week) Rolling Seasonal Plan, a consolidated network view
Source 3	European ATM Master Plan Level 3, Implementation Plan and European ATM Master Plan
Source 4	Local Single Sky Implementation (LSSIP) documents prepared for each country including ca

2.3 Description

Source 1 The Network Operations Plan (NOP) provides a short- to medium-term outlook of how the ATM network will operate. It gives details of capacity and flight efficiency enhancement measures planned at network level and by each area control centre (ACC), as well as a description of the airport performance assessment and improvement measures which are planned at those airports which generate a high level of delay.

Source 2 With the turmoil related to the pandemic, the next edition of the NOP is temporally replaced by source 2, the NOP Rolling Seasonal Plan, a special version of the NOP which focuses on the planning of the next six weeks and in managing the execution and implementation of the 5-year NOP. This Plan is currently playing a major role in helping European aviation to recover by providing aviation's key actors with the global view they need in order to plan effectively. The NM is coordinating with all partners to ensure that capacity is available at ACCs, in the airspace they manage and on the ground at airports, in order to meet the expected traffic demand from the airlines on every day of the next six weeks. The plan is updated every Friday and reviewed every Monday by operational stakeholders in the Ad hoc Enlarged NDOP Recovery Cell, a body which brings Europe's Network ANSPs, airports, airlines and military directors of operations together to enhance performance and tackle problems on a network basis, as inputs for the next edition. Note that the normal NOP planning processes will be reinstated as from autumn 2021. More information about network performance (and access to dashboards and the archive) can be found at https://www.eurocontrol.int/network-performance.

Source 3 The European ATM Master Plan Level 3 (MPL3) Implementation Plan provides the framework for the commonly agreed actions to be taken by ECAC stakeholders, in the context of the implementation of the SESAR Programme. These actions are consolidated in implementation objectives, addressing elements in SESAR which have reached the necessary operational and technical maturity and for which stakeholders have expressed an interest in their operational introduction. They provide all civil and military implementing parties (ANSPs, airport operators, airspace users and regulators) with a basis for short- to medium- term implementation planning. The 2020 edition of the implementation plan focuses on the results of the SESAR 1 Programme. It highlights the contribution of each SESAR solution and implementation objective to capacity, operational efficiency, cost-efficiency, safety, the environment and security. The plan integrates implementation objectives covering 20 SESAR solutions in order to ensure adequate coverage of the Pilot Common Project (PCP) requirements in relation to the SESAR Deployment Manager's (SDM) deployment programme families. It also fully addresses transition phase 1 of the Airspace Architecture Strategy up to 2025 through implementation objectives addressing 15 SESAR solutions. The Master Level 3 Implementation Plan is produced annually.

Source 4 The Local Single Sky Implementation (LSSIP) documents give a comprehensive overview of all ATM information for each State, hence they also show the ATM capacity forecasts and planning targets from the NOP. The documents reflect progress made and detail the plans for each ECAC State for the next five to seven years. LSSIP documents, one for each State, are derived from the European Single Sky Implementation (ESSIP) (also known as Master Plan Level 3) objectives, and stakeholder lines of action cascade down into the States. The information from the LSSIP documents is put together in the MPL3 Implementation Report to show progress at pan-European level. This report is also produced annually.

2.4 Related standard inputs

Air traffic statistics and forecast and flow management delay.

2.5 Comment

The European ATM Master Plan[1] is the main planning tool for setting ATM priorities, ensuring that the SESAR target concept becomes a reality. It is an evolving roadmap and the result of collaboration between all ATM stakeholders.

The Master Plan provides a high-level view of what needs to be done in order to deliver a high- performing ATM system, while also explaining why and by when. It sets the framework for the development activities carried out by the SESAR Joint Undertaking (SJU) and deployed by stakeholders in partnership with the SESAR Deployment Manager (SDM).

[1] https://www.eurocontrol.int/portal/european-atm-master-plan-portal

Chapter 3

Number of IFR flights

3.1 Definition

The number of IFR flights in Europe.

3.2 EUROCONTROL recommended sources

Value 1 Monthly and yearly number of flights by flow category, ECAC, year 2019

```
Rows: 13 Columns: 6
-- Column specification --------------------------------------------------------
Delimiter: ","
chr (1): Month
dbl (5): Arrivals, Departures, Internal, Overflights, Total

i Use `spec()` to retrieve the full column specification for this data.
i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

Month	Arrivals	Departures	Internal	Overflights	Total
January	85052	84909	601427	16115	787503
February	75500	75447	573216	13600	737763
March	87907	87966	653641	16928	846442
April	91421	91354	706721	17043	906539
May	94944	94649	780080	16189	985862
June	105522	105571	810253	16782	1038128
July	113863	114128	846783	17788	1092562
August	115290	115399	831933	17932	1080554
September	104350	104260	809520	16192	1034322

October	99236	99824	764457	16532	980049
November	85442	85748	615031	15740	801961
December	87339	87539	602431	16308	793617
Total	1145866	1146794	8595493	197149	11085302

Source 1 EUROCONTROL (2020) – STATFOR statistics Traffic statistics and forecasts can be obtained from the STATFOR Interactive Dashboard (SID). http://www.eurocontrol.int/statfor

Value 2 Flights by market segment[1] of operator, ECAC, year 2019

```
Rows: 8 Columns: 4
-- Column specification ------------------------------------------------------
Delimiter: ","
chr (3): Operator, Proportion, Evolution 2019 vs. 2018
dbl (1): Number of flights

i Use `spec()` to retrieve the full column specification for this data.
i Specify the column types or set `show_col_types = FALSE` to quiet this me
```

Operator	Number of flights	Proportion	Evolution 2019 vs. 2018
Traditional scheduled	5858759	52.9%	1.4%
Low-cost	3352186	30.2%	0.7%
Business aviation	704308	6.4%	-3.0%
Charter	441924	4.0%	2.7%
All-cargo	323395	2.9%	-2.7%
Other types	294766	2.7%	0.7%
Military	109964	1.0%	-4.7%
Grand total	11085302	100%	0.8%

Source 2 EUROCONTROL (2020) – STATFOR statistics Traffic statistics and forecasts can be obtained from the STATFOR Interactive Dashboard (SID). http://www.eurocontrol.int/statfor

Value 3 Top 20 number of flights by civil aircraft operating in airspace in Europe controlled by the EUROCONTROL Network Manager, year 2019.

```
Warning: One or more parsing issues, call `problems()` on your data frame f
e.g.:
  dat <- vroom(...)
  problems(dat)

Rows: 22 Columns: 4
```

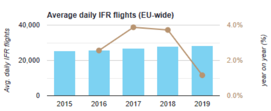
[1] Rules for EUROCONTROL classification of low-cost, all-cargo and business aviation types of flights: https://www.eurocontrol.int/publication/market-segment-rules]

```
-- Column specification --------------------------------------------------------
Delimiter: ","
chr (3): FPL aircraft type, Proportion, Cumulative
dbl (1): Flights

i Use `spec()` to retrieve the full column specification for this data.
i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

FPL aircraft type	Flights	Proportion	Cumulative
B738	2165864	19.54%	19.54%
A320	1896439	17.11%	36.65%
A319	870521	7.85%	44.50%
A321	664047	5.99%	50.49%
DH8D	311352	2.81%	53.30%
E190	278773	2.51%	55.81%
A20N	259032	2.34%	58.15%
B77W	189882	1.71%	59.86%
CRJ9	181291	1.64%	61.50%
A332	166619	1.50%	63.00%
AT76	162415	1.47%	64.47%
B737	161821	1.46%	65.93%
AT75	158337	1.43%	67.35%
A333	158229	1.43%	68.78%
E195	154665	1.40%	70.18%
B789	116394	1.05%	71.23%
B763	103803	0.94%	72.16%
B772	101232	0.91%	73.08%
B752	99583	0.90%	73.97%
CRJX	92270	0.83%	74.81%
Other types	2792733	25%	100%
Total	11107046	100%	,

Source 3 EUROCONTROL (2019) — Network Manager flight plans and PRISME fleet data (ECAC region)

Value 4 Daily average of IFR flights, 2015 to 2019, EU-wide area.



year	2015	2016	2017	2018	2019
Average daily IFR flights	25321	25972	26980	27987	28313

Source 4 Performance Review Board (PRB) – ANS performance monitoring (EU-wide) https://www.eurocontrol.int/prudata/dashboard/vis/2019/

3.3 Description

Value 1 shows the typical fluctuation in traffic during the year, peaking in July and August. The lowest level usually occurs in February.

Value 2 indicates an overall increase in flights of 0.8% in 2019 compared with 2018. Traditional scheduled traffic increased by 1.4% and charter traffic by 2.7%, whilst business aviation decreased by 3% and cargo by 2.7%. Military traffic covering only those flights operating as general air traffic (GAT) and excluding operational air traffic (OAT) decreased by 4.7%.

Value 3 Of those aircraft which flew IFR in 2019, four hundred and thirty-six (436) different civil aircraft types operated in Europe in 2019. Some 75% of the flights were carried out by the 20 aircraft types displayed.

3.4 Related standard inputs

IFR flight information per operator segment, fleet age, fleet size and fleet CNS capability.

3.5 Further reading

EUROCONTROL Performance Review Commission The Performance Review Commission publishes traffic analyses in the annual Performance Review reports (https://www.eurocontrol.int/prc/publications).

3.6 Comment

These traffic figures are from 2019 and do not yet reflect the impact of COVID. Estimated traffic figures for 2020 and beyond can be found in the EUROCONTROL five year forecast https://www.eurocontrol.int/publication/eurocontrol-five-year-forecast-2020-2024.

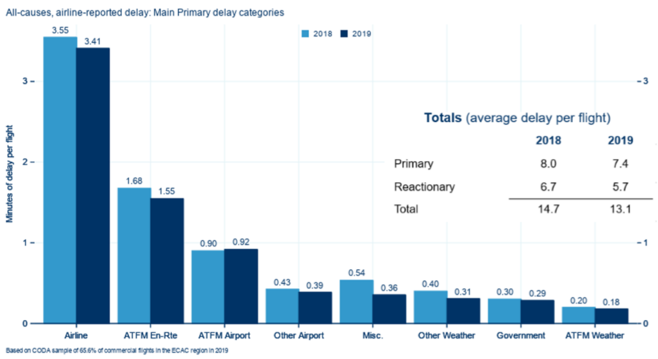
Chapter 4

Air traffic delay

4.1 Definition

Statistical reports on all causes of delay.

4.2 EUROCONTROL recommended sources



Value

Source EUROCONTROL CODA (2019) All-Causes Delay to Air Transport in Europe https://www.eurocontrol.int/sites/default/files/2020-04/eurocontrol-coda-digest-annual-report-2019.pdf

4.3 Description

The report identified in the source value gives an overview of the delay situation in the European Civil Aviation Conference area. It has been prepared by the Central Office for Delay Analysis (CODA), a EUROCONTROL service. It is based on delay data provided directly by airlines. This data on all causes of delay is derived by airlines, comparing actual timings with their published schedules.

Statistics on all causes of delay can be obtained directly from the CODA Interactive Dashboard (CID) (a request for access is required). This dashboard aims to provide the user with an enhanced understanding of the causes of delay to flights, both that relating to air traffic flow management (ATFM) and non-ATFM-related delay. ATFM delay constitutes only a fraction of primary delays from all causes, and around half of all delay is reactionary rather than primary. Analyses within the dashboard are based on flight-by-flight data provided by airspace users as well as the Network Manager.

More information about CODA can be found at https://www.eurocontrol.int/network-performance (go to CID).

4.4 Related standard inputs

Air traffic statistics and forecast, flow management delay and cost of delay.

Chapter 5

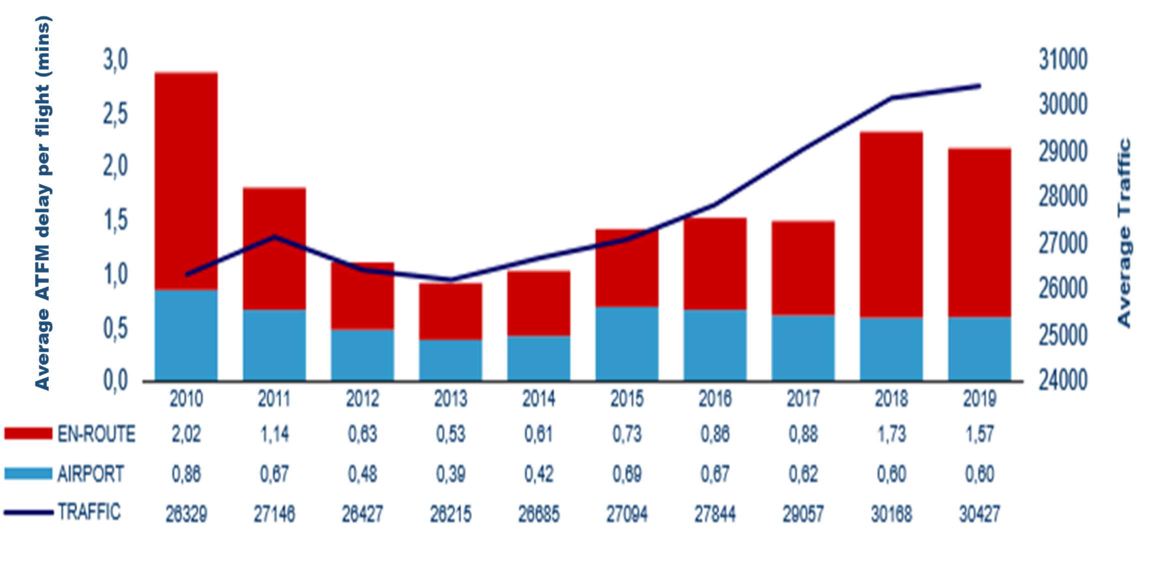
Flow management delay

5.1 Definition

Statistical reports on European ATM network performance in terms of the number of flights and levels of air traffic flow management (ATFM) delay[1].

5.2 EUROCONTROL recommended sources

Value Daily traffic and ATFM delay per flight (en route and airport) 2009-2019



[1]flights delayed by an ATFM regulation.

Source EUROCONTROL NMD, Network Operations Report 2019 https://www.eurocontrol.int/sites/default/files/2020-04/nm-annual-network-operations-report-2019-main-report.pdf Reports from previous years are available in the EUROCONTROL library: https://www.eurocontrol.int/library.

5.3 Description

The EUROCONTROL Network Manager produces regular reports on the overall performance of the network. These help the Network Manager to monitor and understand how the network is performing and to take action when a problem occurs.

The value above is extracted from a report providing an overview of the European ATM network's performance in the areas of traffic evolution, capacity offered by the air navigation service providers and airports, delays and flight efficiency. The report analyses the annual results in light of the main events which took place in the course of the year. Airspace users' opinions on network performance are also included. This report is updated annually.

Information can be accessed and downloaded from the EUROCONTROL Network Operations Monitoring and Reporting web page, https://www.eurocontrol.int/network-performance, together with access criteria for non-public reports or applications, and source/third party use. The page also gives access to historical data.

5.4 Related standard inputs

Air traffic statistics and forecast, air traffic delay and cost of delay.

5.5 Comments

Flow management delay differs from air traffic delay in that the latter relates to both ATFM-related delay and non-ATFM-related delay. Flow management delay, i.e. ATFM delay, constitutes only a fraction of primary delay from all causes, and around half of all delay is reactionary rather than primary.

Delay statistics for ECAC are also presented on a regular basis in the Performance Review reports (PRRs), published annually by the Performance Review Commission. These publications can be found in the EUROCONTROL library: https://www.eurocontrol.int/library.

Part II

Environment

Chapter 6

Rate of fuel burn

6.1 Definition

Average number of kilogrammes per hour of fuel burnt by an aircraft in different flight phases and with different load factors

6.2 EUROCONTROL recommended sources

Value
```
Warning: One or more parsing issues, call `problems()` on your data frame for deta
e.g.:
  dat <- vroom(...)
  problems(dat)

Rows: 1 Columns: 4
-- Column specification --------------------------------------------------------
Delimiter: ","
chr (2): Flight phase, Arrival management
dbl (2): Taxi, En route

i Use `spec()` to retrieve the full column specification for this data.
i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

Fuel burn rates (kg/minutes) in flight phases where delay can occur for most representative aircraft types flying (with restriction in use)[1]

Flight phase	Taxi	En route	Arrival management
Weight (% of max. useful load)[2]	65	80	50, 65

[1]It is strictly prohibited to use the fuel burn values to compare fuel efficiency and emission data between aircraft types from the same or different manufactures. Data are provided here to allow the drafting of aggregate business cases.
[2]The useful load is the sum of the payload and the fuel. The maximum useful load is approximately the MTOW minus the empty aircraft weight. The '% of max useful load' referred to in the recommended value indicates how the aircraft is loaded, in terms of payload and fuel (combined). This must also not be confused with the load factor, which indicates how the aircraft is loaded in terms of payload only (i.e. not taking the fuel into account).

Source EUROCONTROL BADA (Base of Aircraft Data) https://www.eurocontrol.int/model/b

6.3 Description

The above data originate from the Base of Aircraft Data (BADA), which is an aircraft performance model (APM) developed and maintained by EUROCONTROL, with the active cooperation of aircraft manufacturers and operating airlines. The data extracted make use of three different families of the BADA model (BADA 3, BADA 4 and BADA Helicopters).

The data are to be treated as approximations, which give an indication of the average fuel burn per flight phase. These data do not, however, take weather and atmospheric influences into account, nor the impact of specific flight conditions (speed, altitude, etc.), and they are therefore to be used with a correction factor when applied in a specific context.

Organisations which are interested in more aircraft types can request access to the full BADA model (see link above).

6.4 Related standard inputs

Amount of emissions released by fuel burn, cost of emissions and IFR flight information per market segment.

6.5 Other possible sources

Source 1 ICAO (2018) – ICAO Carbon Emissions Calculator Methodology, Version 11, June 2018 https://www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf

Description 1 ICAO has developed a methodology to calculate the carbon dioxide emissions from air travel for use in offset programmes. The

ICAO Carbon Emissions Calculator allows passengers to estimate the emissions attributed to their air travel. One of the inputs is the fuel burn for 312 equivalent aircraft types, Appendix C: ICAO Fuel Consumption Table, page 17.

Source 2 EUROCONTROL Advanced Emission Model (AEM) https://www.eurocontrol.int/model/adva emission-model

Description 2 The advanced emission model (AEM) is a standalone application, developed and maintained by the EUROCONTROL Experimental Centre, which estimates aircraft emissions and fuel burn. The AEM can estimate:

- the mass of fuel burned by the main engines of a specified type of aircraft with a specified type of engine flying a specified 4D trajectory;
- the corresponding masses of certain gaseous and particulate emissions which are produced by the burning of that fuel. Access to the tool requires an AEM user license.

Source 3 ICAO Engine Emissions Databank https://easa.europa.eu/document-library/icao-aircraft-engine-emissions-databank

Description 3 Rates of fuel burn for different phases of flight for individual engine types may be found in the manufacturers' datasheets in the ICAO Engine Emissions Databank.

Chapter 7

Amount of emissions released by fuel burn

7.1 Definition

Amount (mass) of emissions released by the combustion of aviation fuel.

7.2 EUROCONTROL recommended sources

Value
```
Warning: Since gt v0.3.0, `columns = TRUE` has been deprecated.
* Please use `columns = everything()` instead.

Warning: HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
```

Emissions	Amount emitted(per kg of fuel burned)
CO2	3.15 kg
H2O	1.237 kg
SO2	0.00084 kg

Source EUROCONTROL (2018) – "European Aviation Fuel Burn and Emissions Inventory System for the European Environment Agency" https://www.eurocontrol.int/publication/european-aviation-fuel-burn-and-emissions-inventory-system-feis-european-environment

7.3 Other possible sources

Source 1 European Environment Agency (2017) "EMEP/EEA air pollutant emission inventory guidebook – 2019" https://www.eea.europa.eu/publications/emep-eea-guidebook-2019 Values specific to aviation are available in Part B:

sectoral guidance chapters/1. Energy/1.A. Combustion/1.A.3.a Aviation https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation/view

Description 1 The Emission Inventory Guidebook gives values for emission factors (for CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2 and PM2.5) and fuel consumption in different phases of flight – including taxiing – for different aircraft types, using three different levels of accuracy and complexity. In the table, the emission factors for the "Very Simple" (called Tier 1) methodology are given on a representative aircraft basis, using jet kerosene as fuel.

Source 2 ICAO Aircraft Engine Emissions Databank (for turbojet and turbofan Aircraft with a static thrust greater than 26.7 kilonewtons), August 2020 https://www.easa.europa.eu/domains/environment/icao-aircraft-engine-emissions-databank

Description 2 This Databank contains information on exhaust emissions only for those aircraft engines which have entered production. The information was provided by engine manufacturers and collected by the International Civil Aviation Organization (ICAO). The European Aviation Safety Agency (EASA) hosts this Databank on behalf of ICAO.

Source 3 FOI, Swedish Defence Research Agency (for turboprop aircraft) https://www.foi.se/en/our-knowledge/aeronautics-and-air-combat-simulation/fois-confidential-database-for-turboprop-engine-emissions.html

Description 3 FOI is the keeper of a confidential database of emission indices (EI) of NO_x, HC and CO, with corresponding fuel flows for turboprop engines. Datasheets have been supplied by the turboprop engine manufacturers, originally for the purposes of calculating emissions-related landing charges. The data are presented in the same format as in the ICAO (International Civil Aviation Organization) Engine Emissions Database for jet engines, but have not been endorsed by ICAO in a certification process. It should be noted that the data contain many inaccuracies, resulting primarily from the unregulated test methodologies. The data is, however, considered to be the best available, and may be used for emissions inventories, emissions-related landing charges, etc. The data are available on request.

Source 4 Swiss Federal Office of Civil Aviation, FOCA – Aircraft Engine Emissions (for piston engine aircraft, helicopters) https://www.bazl.admin.ch/bazl/en/hon and-guidelines/environment/pollutant-emissions/aircraft-engine-emissions.html

Description 4 The Swiss FOCA has developed a measurement and calculation methodology for aircraft piston engine emissions in order to improve aviation emission inventories.

7.4 Related standard inputs

Rate of fuel burn, cost of emissions and IFR flight information per market segment.

7.5 Comments

The Committee on Aviation Environmental Protection (CAEP), a technical committee of the ICAO Council, recommends the use a conversion factor of 3.16 g of CO_2 per g of Jet A. The 3.16 value can be found in ICAO Doc 9889, 1st edition, 2011, and other documents.

However, in Europe, as early as 2009, Commission Decision 2009/339/EC indicated an emission factor of 3.15 for the mass conversion from Jet A to CO2. Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 (on the monitoring and reporting of greenhouse gas emissions), which integrates the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) in the Emission Trading Scheme (ETS), applicable since 1 January 2019, for the period after January 2021, now recommends, for the time being, that factor 3.15 for Jet A fuel is still to be used in Europe for the ETS and also for CORSIA.

In view of the above, emission factor 3.15 should continue to be used in SESAR 2020, for the sake of internal consistency within the programme, and at least unless the EU ETS decides to move to 3.16. Nevertheless, factor 3.16 should be used when the evaluation concerns comparisons with studies carried out within the ICAO framework or using the factor recommended by ICAO, in order to ensure external consistency. [Extracted from SESAR 2020 – Environment Impact Assessment Guidance Guidance Del: 4.0.080]

Chapter 8

Cost of emissions

8.1 Definition

Estimate of the cost of CO2 and other aircraft emissions released by the combustion of aviation fuel.

8.2 EUROCONTROL recommended sources and values

Value 1
```
Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
```

Price of CO2

Climate change avoidance costs in € per tonne of CO2 equivalent

Forecast	Low[1,2]	Medium[1]	High[1]
Short and medium run (up to 2030)	63	105	199
Long run (from 2040 to 2060)	164	283	524

[1]adjusted from € 2016 to € 2019 prices

[2]These values were derived by calculating the average of the low, central and high estimates for the relevant time periods of the values from the literature, but excluding the lowest and highest values in order to eliminate outliers.

Value 2
```
Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
```

```
Warning: Since gt v0.3.0, `columns = TRUE` has been deprecated.
* Please use `columns = everything()` instead.
```

Well-to-tank air pollution costs: damage cost estimates in €/kg emission
(emissions in the year 2016, EU-27+UK values)

Costs in € per kg	NOx[1]	NMVOC[1]	SO2[1]	High[1]
EU-27+UK	11.5	1.3	11.5	20.4

[1]adjusted from € 2016 to € 2019 prices

Value 3
```
Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.

Warning: HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
```

Total and average air pollution costs for aviation for 33 selected EU airports[1]

Distance group	Range	M€/year[2]	€-cent/km[2]	€-cent/ pax(complete flight)[2]
Short-haul	$<$ 1 500 km	284	0.32	171
Medium-haul	$<$ 1 500-5 000 km	400	0.14	243
Long-haul	$>$ 5 000 km	379	0.06	467

[1]The largest airports in each EU country (including the UK)
[2]adjusted from € 2016 to € 2019 prices

Value 4
```
Attaching package: 'dplyr'

The following objects are masked from 'package:stats':

    filter, lag

The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

Marginal air pollution costs of aviation for selected cases[1,2]

Distance [km]	Emission class	Example of aircraft type	€ per LTO[3]	€-cent per pax km[3]
Short-haul				
500	Low	Bombardier CRJ900	106.00	0.29

500	High	Embraer 170	144.00	0.32	1
Medium- haul					
1500	Low	Airbus 320	174.00	0.07	1
1500	High	Boeing 737	195.00	0.12	1
3000	Low	Airbus 320	230.00	0.05	1
3000	High	Boeing 737	258.00	0.07	2
Long-haul					
5000	Low	Airbus 340	528.00	0.03	1
5000	High	Boeing 777	876.00	0.04	2
15000	Low	Airbus 340	748.00	0.02	2
15000	High	Boeing 777	1.24	0.02	2

[1]For the following emissions: NH_3, NMVOC, SO2, NOx, PM2.5 and PM10
[2]For the cost factors for air pollution costs, the emissions during the LTO cycle are mainly relevant, as the cruise emissions lead to almost no damage costs.
[3]adjusted from € 2016 to € 2019 prices

Sources 1 to 4 "Handbook on the external costs of transport", CE Delft, January 2019 (commissioned by European Union DG Move), tables 24, 49, 17 and 23 https://www.cedelft.eu/en/publications/2311/handbook-on-the-external-costs-of-transport-version-2019 Also available from the Publications Office of the EU.

8.3 Description

The CO2 price used to calculate the external costs of climate change in **Value 1** is based on the cost avoidance approach. Extract from the "Handbook on the external costs of transport": *It determines external cost valuation factors (i.e. shadow prices) by determining the cost to achieve a particular policy target (e.g. EU CO2 reduction targets). This is done by estimating an avoidance cost function, which provides a proxy for the supply of environmental quality. It determines how much it would cost to supply an additional level of environmental quality (e.g. reduction of one additional tonne of CO2). Based on this cost curve, the minimal cost required to meet the policy target is estimated. The assumption is that this policy target reflects collective preferences with respect to the externality concerned and hence, that the minimum cost to reach this target is a good proxy of the (collective) willingness-to-pay (WTP) to avoid the damage caused by the externality.*

The calculations for **Value 2 and 3** have been made on the basis of the cost factor of €100 per tonne of CO_2 equivalent, the central value for short- and medium-run estimates given in value 1. As was the case in the 2008 Handbook, it is further assumed that the aviation emissions relevant for air quality are restricted to the emissions in the landing and take-off (LTO) phases. The total emissions have been cross-checked with the total emission database from the European Monitoring and Evaluation Programme under the auspices of the European Environmental Agency (EMEP/EEA). The values are for passenger flights.

8.4 Further reading

8.4.1 EASA/EEA/EUROCONTROL

- European Environmental Report, 2019 https://www.eurocontrol.int/publication/european-aviation-environmental-report-2019 The document provides an updated assessment of the environmental performance of the aviation sector published in the first report of 2016. The continued growth of the sector has produced economic benefits and connectivity within Europe and is stimulating investment in novel technology. This draws on a wider pool of expertise and innovative approaches from other sectors, thereby creating potential new opportunities to address the environmental impacts of aviation. However, it is recognised that the contribution of aviation activities to climate change, noise and air quality impacts is increasing, thereby affecting the health and quality of life of European citizens.

  Para. 5.3 touches on environmental charges levied by some airports.

- European Commission https://ec.europa.eu/clima/policies/ets/auctioning_en https://www.eex.com/en/

  Extracted from the EC website: "*Twenty-eight countries (25 EU Member States and 3 EEA/EFTA countries) auction their allowances on the common auction platform. The common auction platform is nominated for up to five years by a joint procurement between the Commission and the participating countries, in accordance to the rules laid down by the joint procurement agreement. Currently, the European Energy Exchange (EEX) in Leipzig is the common auction platform. Some countries participating in the EU ETS have opted out of the common auctioning platform: Germany has nominated EEX as its opt-out platform. Poland is making use of the common auction platform to auction its share of allowances until the appointment of its opt-out platform. ICE Futures Europe (ICE) in London acts as the United Kingdom's platform. The Withdrawal Agreement between the*

EU and the United Kingdom ensures that UK operators remain subject to compliance obligations for the years 2019 and 2020."

- ECAC (2011) NOx emission classification scheme, ECAC recommendation ECAC27/4, 11 September 2011 https://www.ecac-ceac.org/documents/
- UK Department for Environment, Food and Rural Affairs (DEFRA) Air quality damage cost update 2019, prepared by Ricardo Energy & Environment (Ricardo-AEA Ltd) https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1902271109_Damage_cost_update_2018_FINA

```
Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
```

```
Warning: HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
```

Revised sector PM and NOx damage cost estimates and sensitivity boundaries
(2017 prices, impacts discounted to 2017, average exchange rate 2017)

		damage cost sensitivity range	
Emission emitted by aircraft[1]	Central damage cost£(€)/kg	Low£(€)/kg	High£(€)/kg
PM2.5	194 (222)	41 (46)	560 (639)
NOx	12 (13)	1.1 (1.2)	45 (51)

[1]PM2.5 is the preferred metric for the change in PM emissions.
Extract from tables 20-21 of the 'Air quality damage cost update 2019'

8.5 Related standard inputs

Amount of emissions released by fuel burn and rate of fuel burn.

8.6 Comments

With regard to NOx charges, a LTO NOx charge is currently applied at several European airports. The level of the charge per kg of NOx is set according to the cost of damage caused by NOx to local air quality (LAQ), at or near airports. The charge is levied in several countries, namely Sweden, the UK, Germany, Demark and Switzerland. Two examples are provided below.

8.6.1 London Heathrow

At London Heathrow, a NOx emission charge is payable on each movement (per LTO cycle) by a fixed-wing aircraft over 8 618 kg. The charge per kg of NOx is calculated on the aircraft's ascertained NOx emission[^An aircraft's ascertained NOx emission means the product of the engine NOx emission as set out in the ICAO Emission Database and based on the number of engines on the aircraft.]. https://www.heathrow.com/content/dam/heathrow/web/common/documents/company/doing-business-with-heathrow/flights-condition-of-use/structure-of-charges-decision/Airport_Charges_Decision-5-August-2015.pdf

The Emissions Airport Charges for 2020 **per kg of NOx is £16.84** (€20.5 at the 2019 exchange rate) "Decision – 2020 Airport Charges" https://www.heathrow.com/content/dam/heathrow/web/common/documents/company/doing-business-with-heathrow/flights-condition-of-use/conditions-of-use-documents/Heathrow_Airpor

8.6.2 Copenhagen Airports

Copenhagen Airports support, through financial incentives, the use of engine types which emit the lowest emissions. The model used for calculating emissions and charges is based on the models currently found in Sweden and Switzerland. The model works with absolute NOx emissions of a specific aircraft engine during a standardised landing and take-off cycle (LTO). NOx emissions per aircraft engine are based on the ICAO specifications and guidelines. The published emissions charge (November 2020) is **kr.16.50 per kg NOx** (€2.2 at the 2019 exchange rate). https://www.cph.dk/en/cph-business/aviation/charges-and-slot/calculation-of-emission-charges

Chapter 9

Cost of noise

9.1 Definition

Estimate of the cost of noise per person affected, taking into account both the cost of annoyance and health costs due to exposure to traffic noise.

9.2 EUROCONTROL recommended sources

Value 1
```
Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
```

Environmental price of aviation traffic noise for the EU-27+UK
for different noise levels, per person per dB (€2019/dB/person/year)

Noise levels Lden in dB(A)[1,2]	Annoyance[3]	Health[3]	Total[3]
50-54	36	5	41
55-59	72	6	78
60-64	72	9	81
65-69	136	13	148
70-74	136	17	152
75	136	22	158

[1]Lden is the common EU indicator which corresponds to the average noise level throughout the day, evening and night to which a citizen is exposed over the period of a year. One fundamental feature of Lden is that it assumes that evening and night-time noise is more of a nuisance than daytime noise. (Evening noise is given a penalty of 5 dB(A). Night-time noise is given a penalty of 10 dB(A).)
[2]The basic measurement index for noise is the decibel (dB). It is indexed logarithmically, reflecting the logarithmic manner in which the human ear responds to sound pressure. Within the human range of hearing, deep and very high tones at the same sound intensity are experienced as less noisy. To correct for this sensitivity, a frequency weighting is applied to measurements and calculations. The most common frequency weighting is the 'A weighting', dB(A). Source: "Handbook on the external costs of transport", CE Delft, January 2019
[3]adjusted from € 2016 to € 2019 prices

Value 2
```
Warning: Since gt v0.6.0 the `fmt_missing()` function is deprecated and
removed.
* Use the `sub_missing()` function instead.

Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.

Warning: HTML tags found, and they will be removed.
* Set `options(gt.html_tag_check = FALSE)` to disable this check.
```

Total and average noise cost for aviation for 33 selected EU airports

		Average cost			
	Total cost€ billions[1]	€/LTO[1,2]	€/pax[1]	€/tonne[1]	€-cent/km[1]
Short-haul					0.48
Medium-haul	0.88	270	2.16	9.51	0.12
Long-haul					0.01

[1]adjusted from € 2016 to € 2019 prices
[2]Costs per pax include the complete flight (not only the half-way principle).

Source 1 and 2 "Handbook on the external costs of transport", CE Delft, January 2019 (commissioned by European Union DG Move) https://www.cedelft.eu/en/publications/2311/handbook-on-the-external-costs-of-transport-version-2019 Also available from the Publications Office of the EU: https://op.europa.eu/fr/publication-detail/-/publication/9781f65f-8448-11ea-bf12-01aa75ed71a1

9.3 Description

The table above was extracted from a study carried out by CE Delft (an independent research and consultancy organisation) on the external costs of different types of transport in Europe (tables 33 and 36). It gives an overview of the noise-related costs associated with people exposed to different noise level bands due to aviation. Two major aspects are considered in the study when assessing noise impact and cost:

- Annoyance: This refers to the disturbance which individuals experience when they are exposed to noise (traffic noise in this case), e.g. discomfort, inconvenience.
- Health impacts caused by long-term exposure to noise. The most common symptoms are stress- related health problems. Evidence has not been strong for all noise-related health impacts, and consequently in the European Handbook on External Costs of Transport, only the following health impacts are considered: hypertension, ischaemic heart disease, stroke and dementia. Insomnia is not included in order to avoid double-counting with the costs of annoyance.

The environmental price of noise reflects the welfare loss which occurs with one extra decibel (dB) of noise (CE Delft, 2018). The environmental price of noise needs to be determined implicitly, as there is no market for noise prevention. Previous editions of the European Handbook on External Costs of Transport have recommended using environmental prices based on HEATCO (2006), both for annoyance and health endpoints. HEATCO assumes a constant valuation per dB of noise for annoyance costs, which has recently been disputed. The new version of the Handbook therefore uses increasing prices per dB based on the most recent insights provided by Bristow et al. (2015) for annoyance costs. As for health costs, the prices according to Defra (2014) match the WHO's recommendations in its latest systematic reviews, and are therefore used in the European Handbook on External Costs of Transport.

Comparable values for road and rail noise costs are also presented in the same study.

Here is an example to show how the environmental price of noise should be applied in calculations: the annual cost for a person exposed to 57dB(A) of aviation noise would be equal to €439 (5dB x €41 + 3dB x €78).

9.4 Other possible value

Value
```
Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
```

Aviation noise marginal cost (€/household/year)

Increase in daytime noise metric by one decibel (dB)	Aviation noise marginal cost (excludin
45–46	
50–51	
55–56	
60–61	
65–66	
70–71	
75–76	
80–81	

[1]adjusted from £ 2014 to € 2019 prices at the 2019 exchange rate

Source UK Department for Environment, Food and Rural Affairs Environmental Noise “Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet”, November 2014 (Annex I: Noise marginal values in 2014 prices Table A1.3 & Table A1.4 p.42-43) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/380852/noise-valuing-imapcts-PB14227.pdf

Description The value presents the results of an economic valuation tool developed by the UK Department for Environment, Food and Rural Affairs. It converts changes in noise exposure to estimated monetary values, in order to support the assessment of the effects of environmental noise. The report details the current understanding of the links between environmental noise and various effects, including sleep disturbance, annoyance, hypertension and related diseases. A range of sensitivities is available around these values from the

Noise Modelling Tool (see report and excel file for more details https://www.gov.uk/guidance/noise- pollution-economic-analysis).

9.5 Further reading

9.5.1 WHO (2018)

"Environmental Noise Guidelines for the European Region", World Health Organisation (2018)

The World Health Organisation Regional Office for Europe has developed environmental noise guidelines for the European region. The main purpose of these guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources, such as transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise.

The guidelines focus on the WHO European region and provide policy guidance to Member States which is compatible with the noise indicators used in the European Union's Directive 2002/49/EC. For average noise exposure, the Guideline Development Group (GDG) strongly recommends reducing noise levels produced by aircraft below 45 dB Lden and for night noise exposure, below 40 dB Lnight. https://www.euro.who.int/___data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf

9.5.2 WHO (2009)

"Night noise guidelines for Europe",

The World Health Organization (WHO) set the European target limit for outdoor night noise levels at an annual average of 40 decibels (dB) in these guidelines. This would protect the public, including the most vulnerable, such as children and the elderly. http://www.euro.who.int/___data/assets/pdf_file/0017/43316/E92845.pdf

The reading suggested below broadens the scope of the cost of noise values with documents related to the overall noise levels and related rules and regulations.

9.5.3 EASA/EEA/EUROCONTROL (2019)

"European Environmental Report"

This second European Aviation Environmental Report (EAER) provides an updated assessment of the environmental performance of the aviation sector published in the first report of 2016. The continued growth of the sector has produced economic benefits and connectivity within Europe, and is stimulating investment in novel technology. This draws on a wider pool of expertise and innovative approaches from other sectors, thereby creating potential new opportunities to address the environmental impacts of aviation. It is, however, recognised that the contribution of aviation activities to climate change, noise and air quality impacts is increasing, thereby affecting the health and quality of life of European citizens. https://www.eurocontrol.int/publication/european-aviation-environmental-report-2019

9.5.4 EASA/EEA/EUROCONTROL (2019)

"Noise country fact sheets"

These country fact sheets summarise information on noise pollution for selected EEA member countries. The fact sheets are based on the latest official noise data reported every five years by EEA member countries under the Environmental Noise Directive (END). https://www.eea.europa.eu/themes/human/noise/noise-fact-sheets

9.5.5 EC (2002)

Environmental Noise Directive (END) 2002/49/EC

Directive 2002/49/EC relating to the assessment and management of environmental noise (the Environmental Noise Directive – END) is the main EU instrument to identify noise pollution levels and to trigger the necessary action both at Member State and at EU level. The introduction of the END in 2002 sought to monitor the effectiveness of EU emission controls by requiring the assessment of environmental noise at Member State level. The Directive introduced two key indicators for annoyance and sleep disturbance, which, if exceeded, require action plans to be drawn up which are designed to reduce exposure and protect areas not yet polluted by noise. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0049

9.5.6 EC (2014), Regulation (EU) No 598/2014

Regulation (EU) No 598/2014 establishes rules and procedures with regard to the introduction of noise-related operating restrictions at EU airports. It follows the guidelines of the ICAO Balanced Approach to Aircraft Noise Management and the rules defined to be applied to airports with more than 50 000 movements per year of civil aircraft. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R0598

9.5.7 European Parliament's Committee on Petitions (2020)

"Impact of aircraft noise pollution on residents of large cities", ENVISA/ Study requested by the EU Parliament

This study, provided by the Policy Department for Citizens' Rights and Constitutional Affairs at the request of the Committee on Petitions, aims to provide a clear and simple overview, for the non-expert reader, of the impact of aircraft noise pollution on residents of large cities, and to make recommendations addressed to the most relevant actors. https://www.europarl.europa.eu/RegData/etudes/STUD/2020/650787/IPOL_STU(2020)650787_EN.pd

9.5.8 ACI and CANSO (2015)

"Managing the Impacts of Aviation Noise: A Guide for Airport Operators and Air Navigation Service Providers"

"Managing the Impacts of Aviation Noise" examines the problem of aviation noise and describes methods which airport operators and ANSPs can use to manage and reduce its impact. It reviews four current approaches to managing noise, namely reducing noise at the source, land use planning, noise-reducing operational procedures, and operating restrictions. https://aci.aero/news/2015/09/23/aci-and-canso-launch-new-initiative-on-reducing-aviation-noise/

9.6 Example of estimating a noise reduction benefit

The "cost of noise" values can be used to calculate potential benefits in research project CBAs (cost- benefit analyses) in order to measure the monetary gain of a noise improvement. An example is the SESAR 2020 project Enhanced Arrival Procedures (EAPs). In this case, noise benefits were calculated as the reduction in the noise contour around the airport area when a different EAP concept was applied. The change in the noise contour area results were calculated per decibel band. This value was then multiplied by the number of people affected around the airport within a radius of 10 km, and the value of the cost of noise per person. The cost of noise (see table 1) is also calculated per decibel band. For noise contour results, scenarios were tested and compared using EUROCONTROL IMPACT tool[^ https://www.eurocontrol.int/platform/integrated-aircraft-noise-and-emissions-modelling-platform].

As mentioned in the further reading section, the EU in 2002 published Directive 2002/49/EC relating to the assessment and management of environmental noise (the Environmental Noise Directive – END). The

END, which is the main EU instrument to identify noise pollution levels, requires Member States to prepare and publish noise maps and noise management action plans every five years for major airports (more than 50 000 movements a year, including small aircraft and helicopters). https://ec.europa.eu/environment/noise/directive_en.htm

The NOISE Observation & Information Service for Europe of the EEA provides an interactive map displaying the exposure to NOISE levels from roads, railways, airports and industry. The map for airports illustrates the exposure to noise from airports in Europe during the average day and average night period. The example below is Brussels Airport. https://noise.eea.europa.eu/

(ref:noise-at-bru) Exposure to noise from Brussels airport.

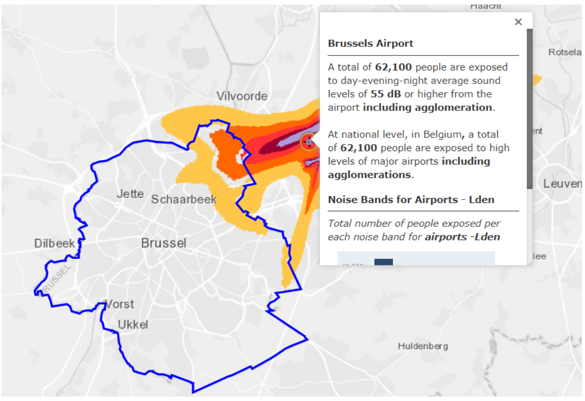


Figure 9.1: (ref:noise-at-bru)

Part III

Airspace Users

Chapter 10

Aircraft Operating Costs

10.1 Definition

Flight and ground costs linked to the operation of an aircraft, such as fuel and oil, flight deck crew, flight equipment depreciation and amortisation, aircraft rentals, landing fees, ground handling, aircraft parking, air bridges and maintenance.

10.2 EUROCONTROL recommended sources

		Flight operating costs (in $ 2019 prices)		
Aircraft type	per aircraft per year (M$)	per flight hour	per flight cycle	per available seat Km (U
B737 NG	14.11	4337	9231	
A320 Family	12.84	4829	8851	
B737 Classic	8.26	2683	5366	
B777	40.01	9507	60367	
A330	29.87	7827	35857	
B757	18.21	5357	18508	
B767	26.00	6675	40899	
B787	30.58	7184	50827	
EMB-190	10.87	4097	5770	
Dash 8	4.03	1921	1921	

Value

Source Values provided by IATA Airline Cost Management Group

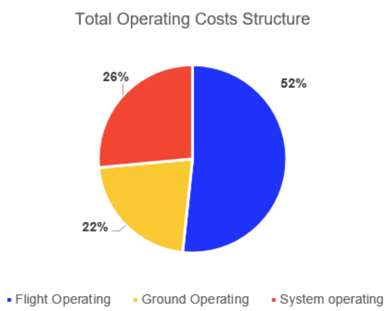
(ACMG[1])
https://www.iata.org/en/programs/workgroups/airline-cost-mgmt/

10.3 Description

The above values, provided by IATA, refer to the 2020 ACMG data collection (fiscal year 2019) and provide an overview of the operating costs for 10 types of aircraft (B737 NG, A320 family, B737 Classic, B777, A330, B757, B767, B787, EMB-190 and Dash 8).

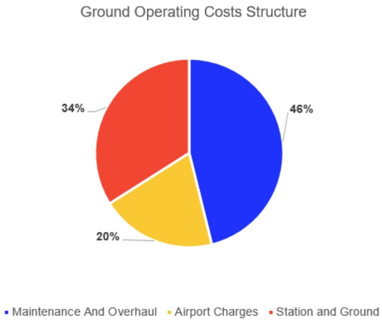
The IATA Airline Cost Management Group (ACMG) collects operating costs classified into three categories, which are defined as follows:

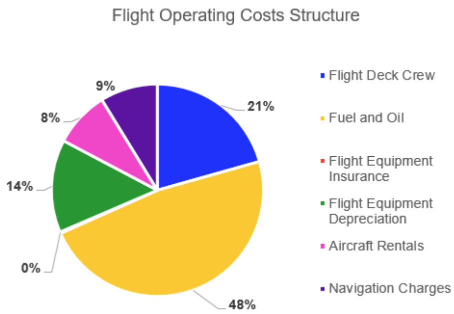
- Flight operating expenses are direct operating expenses. They are directly related to the aircraft and the flight activities of an airline, such as flight crews, fuel, flight equipment and navigation. The biggest component of flight operating expenses is fuel and oil at 48%.
- Ground operating expenses are also direct operating expenses. They are directly related to the ground activities of an airline, such as maintenance and overhaul, airport charges, station and ground. Maintenance and overhaul is the biggest cost component at 46%.
- System operating expenses are overheads and indirect operating expenses. They are not directly related to flight or ground operating expenses. They include costs for cabin attendants, passenger service, load insurance, reservations, ticketing, sales and promotion, IT and communications, and general and administrative costs, with the latter representing 34% of total system operating expenses.

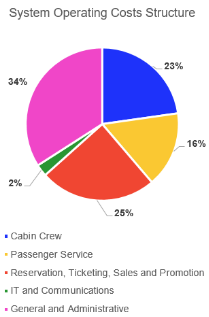


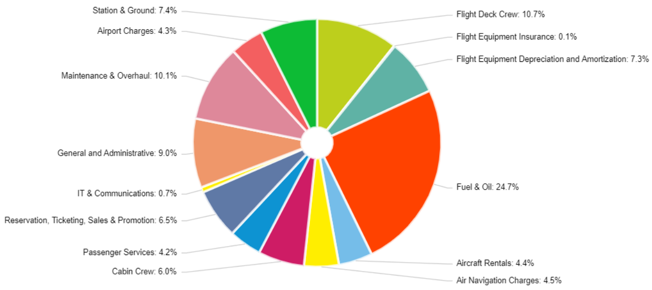
The airline cost structure for 2019:

[1] IATA industry group focusing on matters concerning airline costs and measures to optimise them


Ground Operating Costs Structure
34%
46%
20%
Maintenance And Overhaul
Airport Charges
Station and Ground


Flight Operating Costs Structure
9%
8%
21%
14%
0%
48%
Flight Deck Crew
Fuel and Oil
Flight Equipment Insurance
Flight Equipment Depreciation
Aircraft Rentals
Navigation Charges


System Operating Costs Structure
23%
34%
16%
2%
25%
Cabin Crew
Passenger Service
Reservation, Ticketing, Sales and Promotion
IT and Communications
General and Administrative



The values used for analysis are the result of aggregating the cost data provided by 51 airlines worldwide, covering over 35% of the industry in terms of revenue passenger kilometres (RPKs), with European airlines representing 16% of the share and 12% in terms of passengers carried.

Note from IATA

In a number of jurisdictions, airport charges and taxes which are levied on a per-passenger basis are not accounted for in airline profit and loss accounts. As a result, the share of airport charges is likely to be significantly understated, as airports may levy more on a per-passenger or per-aircraft basis in some jurisdictions. To give an order of magnitude, in some regions the ACI (Airports Council International) estimates that over 50% of airport charges are collected on a per-passenger basis, reaching as much as 80% in some regions worldwide.

Chapter 11

Average number of passengers per movement

11.1 Definition

Average[1] number of passengers per movement (take-off or landing) in Europe.

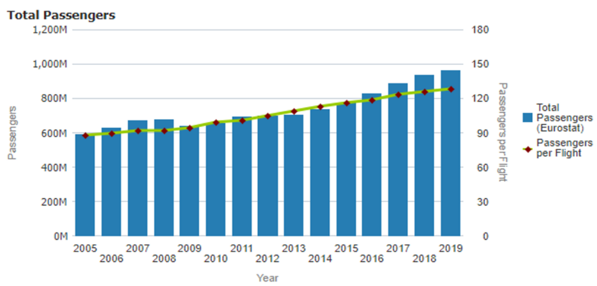
11.2 EUROCONTROL recommended sources

Average number of passengers per departing flight
EU-27+UK and EFTA[1]

2013	2014	2015	2016	2017	2018	2019
109	113	117	119	124	126	129

[1]European Free Trade Association: Iceland, Liechtenstein, Norway and Switzerland

Value



[1]In this context, the (arithmetic) mean value

Source Eurostat: air passenger transport by reporting country (extract: avia_paoc)
http://ec.europa.eu/eurostat/web/transport/data/database
EUROCONTROL STATFOR Interactive Dashboard (SID)19 (goto PAX+)
https://www.eurocontrol.int/dashboard/statfor-interactive-dashboard

Description The average number of passengers per movement[2] for a given year is obtained by dividing the number of 'departing passengers on board' by the number of 'departing flights for that year'.

11.3 Description

The Eurostat air transport domain contains national and international intra- and extra-EU data. This provides air transport data for passengers (in numbers of passengers) and for freight and mail (in thousands of tonnes) as well as air traffic data for airports, airlines and aircraft. Data are transmitted to Eurostat by the Member States of the European Union as well as the candidate countries Iceland, Norway and Switzerland. The air transport data have been calculated using data collected at airports.

11.4 Other possible value

Passengers per IFR movement
Values for the main 34 European airports (all operations)

2008	2010	2012	2013	2015	2017
96	102	108	111	118	125

Value

Source PRC and FAA, "2017 Comparison of ATM-related operational performance: US – Europe", March 2019 (page 25):
https://www.eurocontrol.int/publication/useurope-comparison-air-traffic-management-related-operational-performance-2017
Reports from previous years are available in the EUROCONTROL library:
https://www.eurocontrol.int/library.

Description The table below provides high-level indicators for the main 34 airports21 in Europe using data reported by the airports.
The number of passengers per IFR movement is calculated by dividing the 'average number of annual passengers per airport'

[2]A movement is either a take-off or a landing at an airport.

Average number of annual passengers per airport (million)

2008	2010	2012	2013	2015	2017
25	24	25	25	28	31

by the 'average number of annual IFR movements per airport'.

Average number of annual IFR movements per airport ('000)

2008	2010	2012	2013	2015	2017
260	237	233	228	223	248

11.5 Related standard inputs

11.6 Comment

Chapter 12

Cancellation Cost

12.1 Definition

The average cost of cancelling a commercial scheduled flight on the day of operation.

12.2 EUROCONTROL recommended sources

Value 1 Warning: Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.
Since gt v0.3.0, `columns = vars(...)` has been deprecated.
* Please use `columns = c(...)` instead.

Cost of c

	Narrow	
	Traditional network carrier	Traditional network car
Seats	50	
Value (€)[1]	6540	16
Of which passenger care and compensation (€)[1]	3280	8

[1]adjusted from 2014 prices

Value 2 System-wide average cancellation cost (adjusted from 2014 prices): € 18570

Source Data supplied by the airline members of the SESAR CBA team
Expert judgment derived from an analysis of 2012 total flights carried

out in Europe

12.3 Description

The values refer to cancellation on the day of operation and include the following:

- Service recovery costs, i.e. passenger care and compensation costs (passenger vouchers, drinks, telephone calls, hotels)
- Loss of revenue
- Interlining costs
- Loss of future value, i.e. passenger opportunity costs (individual passenger delay expressed in value)
- Crew and catering costs
- Passenger compensation for denied boarding and missed connections (estimated on the application of the Regulation (EC) No 261/2004)
- Luggage delivery costs
- Operational savings (fuel, airport and navigation fees, maintenance, handling outstations, lounge outstations)

Ground handling costs, e.g. ramp services, passenger services and field operation services, are not included.

12.4 Related standard inputs

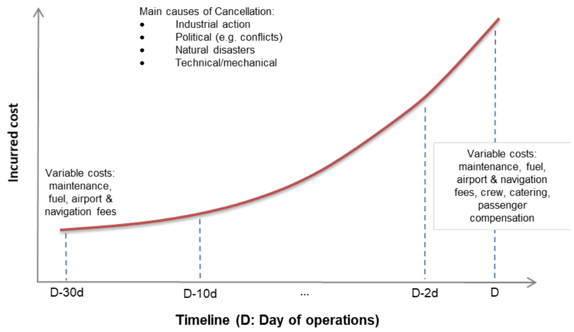
Operational cancellation rate.

12.5 Comments

When a flight is carried out, the airline incurs out-of-pocket expenses (i.e. variable costs) but receives revenues which are 60-100% greater than the out-of-pocket expenses. Cancelling a flight means that the airline forgoes a substantial operating profit. Also, in addition to the loss, costs are incurred for the care and compensation of passengers.

Cancellation costs vary as a function of the time of cancellation, as illustrated below.

Timely cancellation will enable the airline to take the necessary measures to mitigate the cost impact, for example by rebooking passengers on another flight and allocating crew and aircraft to a different destination. The cancellation costs will thus be minimal and more in the region of the incurred opportunity cost and passenger value of time. If the cancellation is nearer the flight time, i.e. on the day of operation (D), the cost of cancellation increases, to cover expenses such as fuel, maintenance and crew and catering.


Main causes of Cancellation:
• Industrial action
• Political (e.g. conflicts)
• Natural disasters
• Technical/mechanical
Incurred cost
Variable costs: maintenance, fuel, airport & navigation fees
Variable costs: maintenance, fuel, airport & navigation fees, crew, catering, passenger compensation
D-30d
D-10d
...
D-2d
D
Timeline (D: Day of operations)

Chapter 13

Operational Cancellation Rate

13.1 Definition

IFR flight cancellation rate in Europe.

13.2 EUROCONTROL recommended sources

Value

Operational cancellation rate

2013	2014	2015	2016	2017	2018	2019
1.5%	1.6%	1.5%	1.6%	1.5%	2.0%	1.7%

Source EUROCONTROL (2019) – Based on operational cancellation data supplied by 30 European coordinated airports reporting to CODA under EC Regulation No 390/2013.
https://www.eurocontrol.int/publication/all-causes-delay-and-cancellations-air-transport-europe-2019
Reports from previous years are available in the EUROCONTROL library:
https://www.eurocontrol.int/library.

13.3 Description

According to Annex IV of Commission Implementing Regulation (EU No 390/2013), an 'operational cancellation' means an arrival or departure of a scheduled flight to which the following conditions apply:

- the flight received an airport slot; and
- the flight was confirmed by the air carrier the day before operations and/or it featured in the daily list of flight schedules produced by the airport operator the day before of operations; but
- the actual landing or take-off did not occur.

For 2019, airlines providing operational cancellation data to CODA reported operational cancellations of 1.7% (this includes daily peaks of up to 9.4% due to ATC industrial action or large-scale weather events).

Section 9 of the referenced document contains a detailed analysis of the cancellations.

13.4 Related standard inputs

Cancellation cost.

Chapter 14

Cost of Delay

14.1 Definition

14.2 EUROCONTROL recommended sources

14.3 Description

14.4 Related standard inputs

14.5 Comment

Chapter 15

Cost of diversion

15.1 Definition

15.2 EUROCONTROL recommended sources

15.3 Description

15.4 Related standard inputs

15.5 Comment

Chapter 16

Turnaround time

16.1 Definition

16.2 EUROCONTROL recommended sources

16.3 Description

16.4 Related standard inputs

16.5 Comment

Chapter 17

IFR average flight distance and flight duration

17.1 Definition

17.2 EUROCONTROL recommended sources

17.3 Description

17.4 Related standard inputs

17.5 Comment

Chapter 18

IFR flight information per market segment

18.1 Definition

18.2 EUROCONTROL recommended sources

18.3 Description

18.4 Related standard inputs

18.5 Comment

Chapter 19

Distance flown by charging zone

19.1 Definition

19.2 EUROCONTROL recommended sources

19.3 Description

19.4 Related standard inputs

19.5 Comment

Chapter 20

Load factor – cargo

20.1 Definition

20.2 EUROCONTROL recommended sources

20.3 Description

20.4 Related standard inputs

20.5 Comment

Chapter 21

Load factor – passengers

21.1 Definition

21.2 EUROCONTROL recommended sources

21.3 Description

21.4 Related standard inputs

21.5 Comment

Chapter 22

Cost of aviation fuel

22.1 Definition

22.2 EUROCONTROL recommended sources

22.3 Description

22.4 Related standard inputs

22.5 Comment

Chapter 23

Value of an average passenger flight

23.1 Definition

23.2 EUROCONTROL recommended sources

23.3 Description

23.4 Related standard inputs

23.5 Comment

Chapter 24

Fleet age

24.1 Definition

24.2 EUROCONTROL recommended sources

24.3 Description

24.4 Related standard inputs

24.5 Comment

Chapter 25

Fleet size

25.1 Definition

25.2 EUROCONTROL recommended sources

25.3 Description

25.4 Related standard inputs

25.5 Comment

Chapter 26

Fleet CNS capability

26.1 Definition

26.2 EUROCONTROL recommended sources

26.3 Description

26.4 Related standard inputs

26.5 Comment

(PART) ATM

Chapter 27

En-route ANS Costs

27.1 Definition

27.2 EUROCONTROL recommended sources

27.3 Description

27.4 Related standard inputs

27.5 Comment

Chapter 28

Route charge share per market segment

28.1 Definition

28.2 EUROCONTROL recommended sources

28.3 Description

28.4 Related standard inputs

28.5 Comment

Chapter 29

ANSPs' Employment Costs

29.1 Definition

29.2 EUROCONTROL recommended sources

29.3 Description

29.4 Related standard inputs

29.5 Comment

Chapter 30

Asset life

30.1 Definition

30.2 EUROCONTROL recommended sources

30.3 Description

30.4 Related standard inputs

30.5 Comment

Chapter 31

ATM cost-effectiveness indicators

31.1 Definition

31.2 EUROCONTROL recommended sources

31.3 Description

31.4 Related standard inputs

31.5 Comment

Chapter 32

ATM operational units

32.1 Definition

32.2 EUROCONTROL recommended sources

32.3 Description

32.4 Related standard inputs

32.5 Comment

Chapter 33

CNS infrastructure

33.1 Definition

33.2 EUROCONTROL recommended sources

33.3 Description

33.4 Related standard inputs

33.5 Comment

Chapter 34

PBN and precision approach procedures

34.1 Definition

34.2 EUROCONTROL recommended sources

34.3 Description

34.4 Related standard inputs

34.5 Comment

(PART) Airspace users

Chapter 35

Airport classification

35.1 Definition

35.2 EUROCONTROL recommended sources

35.3 Description

35.4 Related standard inputs

35.5 Comment

Chapter 36

Taxiing times

36.1 Definition

36.2 EUROCONTROL recommended sources

36.3 Description

36.4 Related standard inputs

36.5 Comment

(PART) Drones

Chapter 37

Investment in U-space

37.1 Definition

37.2 EUROCONTROL recommended sources

37.3 Description

37.4 Related standard inputs

37.5 Comment

Chapter 38

Drone fleet

38.1 Definition

38.2 EUROCONTROL recommended sources

38.3 Description

38.4 Related standard inputs

38.5 Comment

(PART) Passengers

Chapter 39

Purpose of passenger travel

39.1 Definition

39.2 EUROCONTROL recommended sources

39.3 Description

39.4 Related standard inputs

39.5 Comment

Chapter 40

Passenger value of time

40.1 Definition

40.2 EUROCONTROL recommended sources

40.3 Description

40.4 Related standard inputs

40.5 Comment

(PART) Safety

Chapter 41

Accident/Incident Statistics

41.1 Definition

41.2 EUROCONTROL recommended sources

41.3 Description

41.4 Related standard inputs

41.5 Comment

Chapter 42

Value of a statistical life (VSL)

42.1 Definition

42.2 EUROCONTROL recommended sources

42.3 Description

42.4 Related standard inputs

42.5 Comment

Chapter 43

Value of a statistical injury

43.1 Definition

43.2 EUROCONTROL recommended sources

43.3 Description

43.4 Related standard inputs

43.5 Comment

(PART) Financial values

Chapter 44

Discount rate

44.1 Definition

44.2 EUROCONTROL recommended sources

44.3 Description

44.4 Related standard inputs

44.5 Comment

Chapter 45

Exchange rate

45.1 Definition

45.2 EUROCONTROL recommended sources

45.3 Description

45.4 Related standard inputs

45.5 Comment

Abbreviations

References

(APPENDIX) Annexes

Chapter 46

Data

```
Attaching package: 'dplyr'

The following objects are masked from 'package:stats':

    filter, lag

The following objects are masked from 'package:base':

    intersect, setdiff, setequal, union
```

The various data sets introduced are available as CSV files as follows:

(ref:csv-files-table) Data sets (at 2016 EUR price level).

filename	description	url
inflation.csv	Inflation	https://example.com
exchange_rate.csv	Exchange rate	https://example.com

(ref:csv-files-table)

All released versions of this website/document are available at GITHUB repo.