# 11. Annex C Catania Airport case study

## 11.1. Annex C.1 Airport Data

### *Airport characteristics*

Catania–Fontanarossa Airport (Italian: *Aeroporto Internazionale Vincenzo Bellini di Catania-Fontanarossa*) (IATA: CTA, ICAO: LICC), also known as Vincenzo Bellini Airport, is an international airport 2.3 NM (4.3 km; 2.6 mi) southwest[101] of Catania, the second largest city on the Italian island of Sicily.[102]

- Class 4E (ICAO)Surface 217 ha, (parking area 16.6 ha)
- Distance from Urban Centre 4 km

Table C.1 shows airport passenger and cargo[103] development. The table shows a continuous growth in passengers with an increase of +38% flights & +59% passengers in 2018.

| Year | n. Flights | Passengers | Goods (t) |
|---|---|---|---|
| 2012 | 53,178 | 6,246,888 | 7,512 |
| 2013 | 54,406 | 6,400,127 | 6,123 |
| 2014 | 59,926 | 7,304,012 | 6,206 |
| 2015 | 54,988 | 7,105,487 | 6,220 |
| 2016 | 61,080 | 7,914,117 | 6,379 |
| 2017 | 68,170 | 9,120,913 | 6,691 |
| 2018 | 73,494 | 9,933,318 | 6,418 |

***Table C.1 Catania-Fontanarosssa Airport passenger and cargo development***

The Airport has one runway (08-26) with east-west orientation and is located very close to the sea and approximately 5km south of the City of Catania.

For completeness, the urban areas closest to the Airport and its activities are:

- North, the residential areas of Catania;
- West, the village of Librino;
- South-South West, the villages of Fontanarossa and Torregalliera (Industrial areas);
- East, mainly touristic activities/beach.

[101] https://en.wikipedia.org/wiki/Catania%E2%80%93Fontanarossa_Airport
[102] http://www.aeroporto.catania.it/?lang=en
[103] https://assaeroporti.com/wp-content/plugins/multipage_xls_reader/pdf_file/2018.pdf)

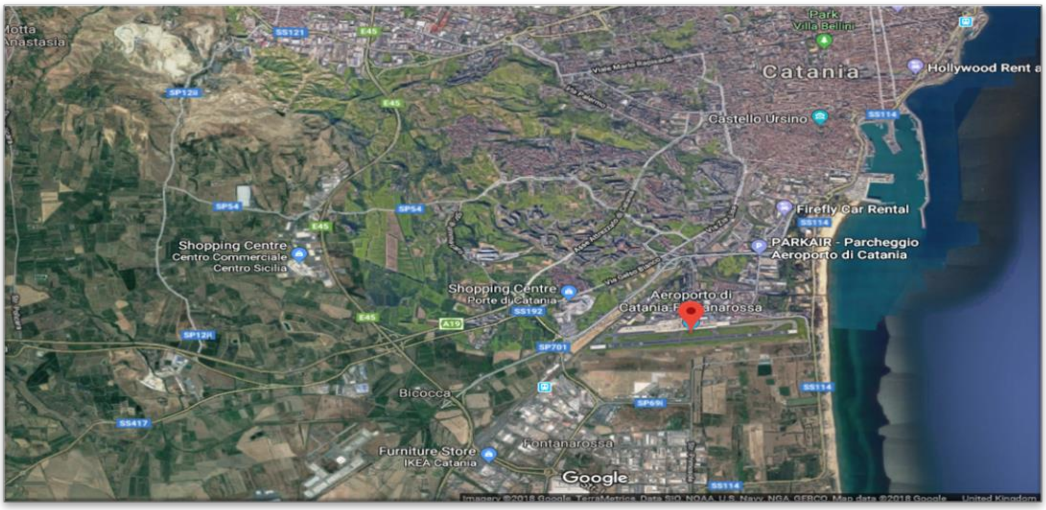


***Figure C.1 Catania Airport location (Source: Google maps-Dec 2018)***

***Figure C.2 The proximity of city centre to runway***
***(Source: Catania Airport Environmental unit, Dec 2018)***

## *The Environmental Policy*

Catania Airport is part of SAC – Societa' Aeroporto Catania, an organisation with an ambitious environmental policy and an environmental impact management system in place. SAC's aim goes beyond merely fulfilling the basic legislative requirements, to constantly look for new ways and means to prevent and mitigate any negative impact on the environment, caused by the airport operations.

**Noise policy** is the most stringent one, the Airport being located only 4 km from the city center.

## Noise monitoring network

SAC is currently monitoring noise levels (at several sites) and has, since 2018 a real-time info point for passengers. Catania Airport is planning to implement a new approach based on ADS-B (GPS data from aircraft) to produce more reliable and real-time paths (Radar is not currently available).

In the wider areas around Catania Airport other noise sources from transport systems are present, such as the rail line west to the Airport, in proximity of the end of track 08, the SP55 road, going in parallel to the rail line and the military heliport "Mario Calderara".

From a legislative point of view, the noise zoning system with noise maps was approved in 2005 by the Commission in charge, (ex Article 5 of D.M. 31/10/1997 in 2005) and the Catania Council acoustic classification plan was approved on the 04/03/2013.

At present, the noise monitoring network at Catania Airport is constituted by a monitoring system of three fixed and one mobile noise monitoring sites, being located within the Airport area, as shown in figure C.3. The whole Airport complies with the ARPA[104];[105] guidelines ("Linee guida per la progettazione e la gestione delle reti di monitoraggio acustico aeroportuale"). Table C.2 illustrates the characteristics of the noise monitoring network.


***Figure C.3 Noise monitoring network (fixed sites)***

[104] http://www.aeroporto.catania.it/?lang=en

[105] ARPA – Agenzia Regionale per la Protezione dell'Ambiente

| ID number | Site name | Location | Coordinates | Related Weather station |
|---|---|---|---|---|
| **P1 - 1301** | Testata 26 | Inside (B) | 37° 27' 58.94" N<br>15° 4' 56.59" E | SI<br>"Vaisala Weather Transmitter WXT533" |
| **P2 - 1302** | Testata 08 | Inside (A) | 37° 27' 47.28" N<br>15° 2' 59.00" E | SI<br>"Vaisala Weather Transmitter WXT533" |
| **P3 - 1303** | Pista lato sud | External | 37° 27' 43.77" N<br>15° 3' 54.25" E | NO |
| **P4 - 1304** | Mobile | N.D. | N.D. | NO |

***Table C.2 Noise monitoring network characteristics***

## Noise Maps

Noise maps have been generated in 2017 using specific software, Integrated Noise Model (INM).


***Figure C.4 Noise Maps, Lden, 2017***

| Range (dB) | Exposed Population | |
|---|---|---|
| | LDEN | LNIGHT |
| 55-59 | 1378 | 619 |
| 60-64 | 399 | 330 |
| 65-69 | 268 | 215 |
| 70-74 | 126 | 59 |
| >75 | 61 | 39 |

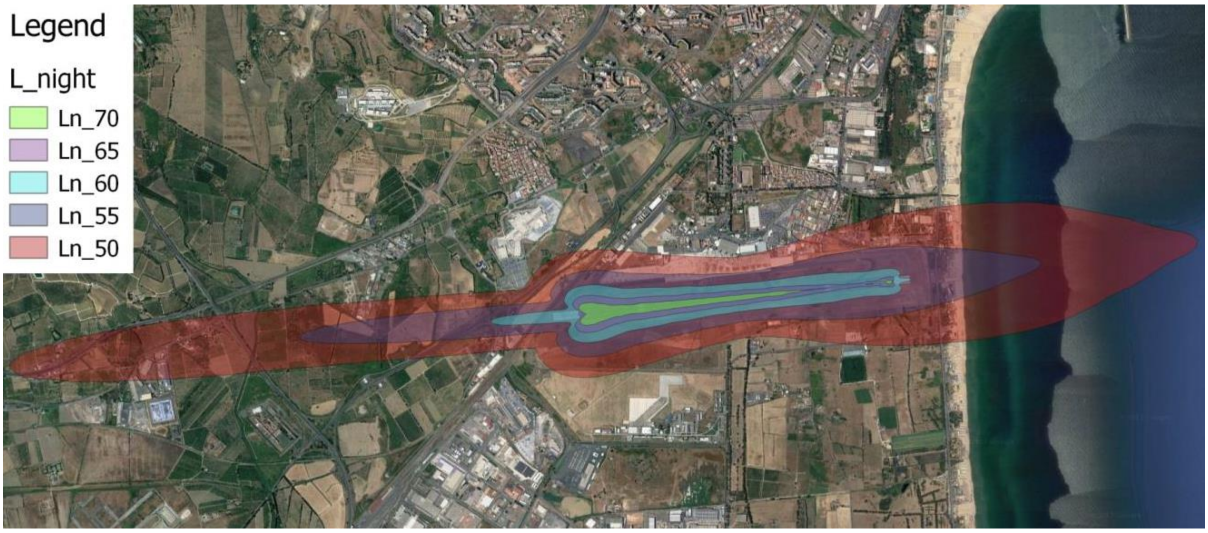


***Figure C.5 Noise Maps, L_night, 2017***

## *Air Quality Monitoring Network*

Catania Airport has also a good coverage of Air Quality monitoring. Monitoring stations are in line with the Italian Environmental Agency and can be static or mobile, but in both cases are based on cabins equipped with different pollution sensors.

The location of the stations has been designed and selected with great attention and all of them are within the airport premises. This makes possible the analysis of correlations between measured levels and sources of emissions in the surrounding areas. Most of the stations have been located in proximity of the *primary landing and taking off* routes, projected to maximise the relevance of the data collected to support the environmental impact analysis. Similarly, some stations have been located in front of the terminal, in the urban area, to assess the contribution to airport pollution levels due to road traffic (road).

Some example of the stations type is provided in figure C.6 below where both versions, static and mobile are represented. Also, the figure below provides the map of the location of the two monitoring stations.


***Figure C.6 Air Quality monitoring systems and a partial mapping***
***(Source: Catania Airport, March 2019)***

**The relevance of the Environmental Totem**: recently, an environmental totem, part of the SARA platform has been installed inside the airport terminal, displaying to passengers, on a large screen, the environmental information (noise and air quality), monitored in real-time.

This was the start of ANIMA & Airport cooperation: existing data and willingness to take part in research.

The screen particularly shows the following information:

- Position of flights in real-time, as the aircraft taxi on apron area, or fly in the vicinity of the airport;
- Real-time information on noise level monitored by the network during the take-off and landing procedures;
- Trend of noise level over the previous 5 minutes;

- Level of atmospheric pollution in the previous hour (see above pollutants);
- Trend of atmospheric pollution over the previous 24 hours;
- Weather conditions in real-time.

### Operational Procedures

Information on the airport (noise abatement) *operational procedures* is essential when conducting research on interdependencies. Below, some *departure procedures* are presented, as both ANOTEC and NLR have selected departure procedure to conduct their research, based on the fact that noise & emissions trade-offs are easier to be quantified during departure flights, comparing to the approach.

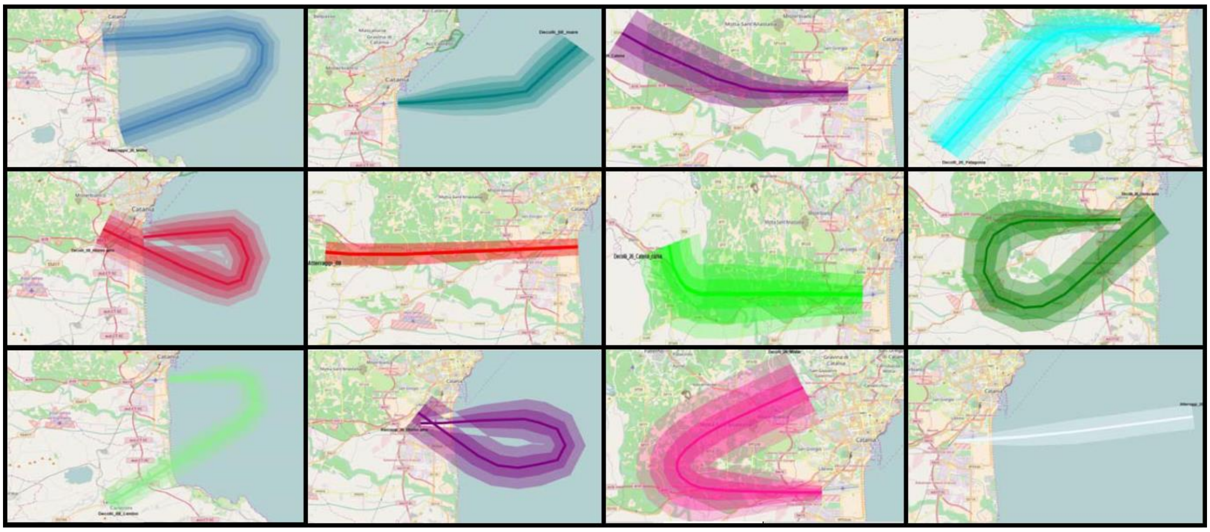

***Figure C.7 Standard Instrument Departure Route (SID) (Source: Catania Airport, Dec 2018)***

## 11.2. Annex C.2 ANOTEC case-study

**Note:** tools, results and discussions on ANOTEC case-study are presented together in Annex C.2, for a better understanding of work involved.

### *Tools*

In order to determine interdependencies between noise and emissions in an efficient and consistent manner, it is convenient to calculate both environmental aspects with models that can use the same input data and that provide results in a compatible format. To this end the SONDEO and SONDEO/EM models are used here, since both have been integrated in the tool chain, developed in ANIMA WP4 (Figure 5-Chapter 5; Figure C.8 below).

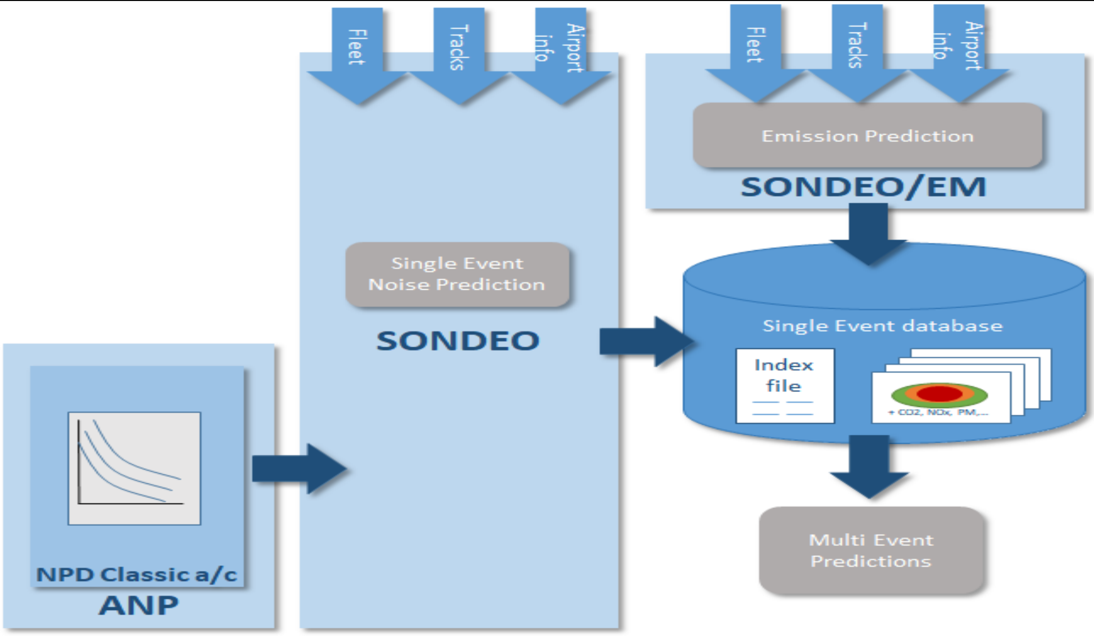


***Figure C.8 Airport noise and emissions models, integrated in the ANIMA WP4 tool chain***

**SONDEO** is an airport noise modelling tool that calculates the noise contours for single events in accordance with ECAC Doc 29 and the corresponding ANP database. These single events are stored in a database, and for a given scenario (typically a specific fleet/track combination), the relevant single event results are merged to simulate the total noise around the airport, representative for that specific scenario. For this, SONDEO basically needs the following input:

- Fleet (operations)
- Flight Tracks
- Airport information (runway data etc)

**SONDEO/EM** is a model that calculates the emissions generated by aircraft operating at an airport. Several methods are incorporated (ICAO LTO, Boeing Fuel Flow Method 2, FOA), with which the main emissions can be obtained (CO2, NOx, PM, …). As with the noise model, SONDEO/EM calculates the emissions for each single event and stores the results in the single event database, together with the noise data. For a specific scenario the total emissions are then calculated by combining the results of the corresponding single events. For this, SONDEO/EM uses the same input as that used by SONDEO.

### *Application of the tools to the Catania case*

Both the SONDEO and SONDEO/EM models were used to determine the noise and emissions for the Catania case study, based on data of actual flight operations (incl. trajectories).

To this end, a first dataset was provided by the airport, corresponding to the first week of August 2018. This data was based on the monitoring system installed at the airport, and contained:

- Flight trajectories (4D)
- Aircraft type
- Route
- Peer airport
- Time of day
- Daily noise metrics
- Daily average pollution values for some pollutants

*Results based on initial dataset*

Figure C.9 provides an overview of some flight trajectories contained in the initial dataset.

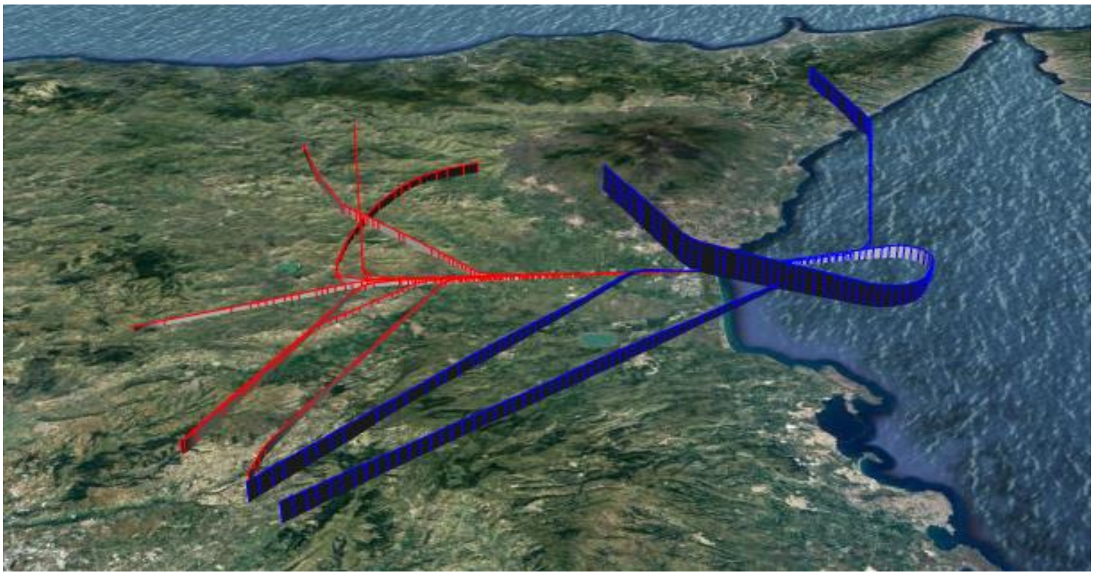

***Figure C.9 Catania Airport basic flight procedures (blue: departures, red: arrivals) (Source: Catania airport)***

However, when preparing the input for the noise and emissions toolchain, several issues with this dataset were encountered:

- The altitude as provided by the monitoring system appeared much lower than expected. When matching the ANP standard profiles to find the best fit, this would result in a much too low profile (corresponding to the highest aircraft weight), resulting in unrealistically big noise contours.
- The destination is not available in 80% of the operations. This information is required to estimate the aircraft range and hence weight, so it has to be obtained from other sources.
- Horizontal trajectory (track) data is given in a local coordinate system, not compatible with the standard WGS84 or UTM system, resulting in a misalignment with the runway
- There is no trajectory data near or on the runway, probably due to a shadow zone of the track antenna (ADS-B). This requires processing to split between e.g. landing and taxi

When discussing these issues with the airport, it appeared difficult to resolve them at short notice. In order to avoid a delay in the delivery of the study results, it was decided to start the interdependencies study, acknowledging that the results would not be representative, but considering that in this way at least the methodology could be tested.

Both SONDEO and SONDEO/EM were executed for the initial dataset provided by the airport. Table C.3 provides the main results of these calculations, as entries in the single event database.

| ID | Date | Time | Flight | Airline | ACFT | A/D | Org/Dest | Org/Dest2 | AC_ANP | PROFILE | STG | km2LAMAX65 | km2SEL70 | ENGUSED | BADAENG | KGNOX | KGCO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 02/08/2018 | 0:21:47 | MAC393 | MALTA CHARTER | A320 | A | N.A. | GMMN | A320-211 | STANDARD | 1 | 14.8 | 66.0 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.5 |
| 2 | 02/08/2018 | 0:28:00 | AMC648 | AIR MALTA | A320 | A | N.A. | LMML | A320-211 | STANDARD | 1 | 14.8 | 65.9 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.5 |
| 3 | 02/08/2018 | 0:39:48 | MSA792 | AIRMERCI | B733 | A | LIPO | LIPO | 737300 | STANDARD | 1 | 16.6 | 45.6 | CFM56-3-B1 | CFM56-3-B1 | 0.887 | 522.5 |
| 4 | 02/08/2018 | 1:20:50 | MAC394 | MALTA CHARTER | A320 | D | N.A. | GMMN | A320-211 | ICAO_B | 5 | 32.7 | 136.5 | CFM56-5-A1 | CFM56-5B | 12.604 | 1633.4 |
| 5 | 02/08/2018 | 2:55:54 | AMC649 | AIR MALTA | A320 | D | N.A. | LMML | A320-211 | ICAO_B | 5 | 32.4 | 135.5 | CFM56-5-A1 | CFM56-5B | 12.604 | 1633.4 |
| 6 | 02/08/2018 | 4:06:03 | AZA1722 | ALITALIA | A320 | D | N.A. | LIRF | A320-211 | ICAO_A | 5 | 33.3 | 145.8 | CFM56-5-A1 | CFM56-5B | 13.303 | 1773.1 |
| 7 | 02/08/2018 | 4:30:05 | EWG3NV | EUROWINGS | B738 | A | N.A. | EDDN | 737800 | STANDARD | 1 | 21.4 | 73.2 | CFM56-7B2 | CFM56-7B2 | 1.552 | 667.3 |
| 11 | 02/08/2018 | 4:32:12 | RYR4851 | RYANAIR | B738 | D | LIRF | LIRF | 737800 | ICAO_B | 4 | 52.1 | 484.4 | CFM56-7B2 | CFM56-7B2 | 10.966 | 1404.5 |
| 9 | 02/08/2018 | 4:32:52 | AZA5CM | ALITALIA | A319 | D | LIML | LIML | A319-131 | ICAO_A | 4 | 19.8 | 112.1 | V2522-A5 | V2522-A5 | 10.850 | 1457.8 |
| 8 | 02/08/2018 | 4:40:12 | N.A. | | A320 | A | N.A. | | A320-211 | STANDARD | 1 | -1 | -1 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.5 |
| 10 | 02/08/2018 | 4:50:02 | AMC184 | AIR MALTA | A320 | A | N.A. | EGMC | A320-211 | STANDARD | 1 | -1 | -1 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.5 |
| 13 | 02/08/2018 | 4:52:46 | EZY17DM | EASY | A319 | D | N.A. | LIMC | A319-131 | ICAO_B | 4 | -1 | -1 | V2522-A5 | V2522-A5 | 9.986 | 1292.4 |
| 14 | 02/08/2018 | 4:58:38 | AZA1367 | ALITALIA | A320 | D | LIPE | LIPE | A320-211 | ICAO_B | 5 | 32.1 | 134.6 | CFM56-5-A1 | CFM56-5B | 12.604 | 1633.4 |
| 15 | 02/08/2018 | 5:05:03 | AZA5LW | ALITALIA | A321 | D | LIRF | LIRF | A320-211 | ICAO_B | 5 | 32.3 | 134.5 | CFM56-5-A1 | CFM56-5B | 12.604 | 1633.4 |
| 18 | 02/08/2018 | 5:38:00 | AMC641 | AIR MALTA | A320 | D | LMML | LMML | A320-211 | ICAO_B | 5 | 32.2 | 136.2 | CFM56-5-A1 | CFM56-5B | 12.604 | 1633.4 |
| 19 | 02/08/2018 | 5:42:26 | AMC184 | AIR MALTA | A320 | D | N.A. | EGMC | A320-211 | ICAO_A | 5 | -1 | -1 | CFM56-5-A1 | CFM56-5B | 13.303 | 1773.1 |
| 21 | 02/08/2018 | 5:49:44 | AZA1700 | ALITALIA | A319 | D | LIPZ | LIPZ | A319-131 | ICAO_A | 5 | 27.1 | 114.5 | V2522-A5 | V2522-A5 | 12.478 | 1656.7 |
| 17 | 02/08/2018 | 5:50:21 | N.A. | | B738 | A | LIPE | LIPE | 737800 | STANDARD | 1 | 21.3 | 72.0 | CFM56-7B2 | CFM56-7B2 | 1.552 | 667.3 |
| 23 | 02/08/2018 | 5:59:20 | EWG4189 | EUROWINGS | B738 | D | N.A. | EDDN | 737800 | ICAO_A | 6 | -1 | -1 | CFM56-7B2 | CFM56-7B2 | 12.804 | 1670.9 |
| 20 | 02/08/2018 | 5:59:43 | EZS52YJ | | A319 | A | N.A. | LSGG | A319-131 | STANDARD | 1 | -1 | -1 | V2522-A5 | V2522-A5 | 1.018 | 548.0 |
| 25 | 02/08/2018 | 6:09:47 | CFG4YW | CONDOR | A320 | A | N.A. | GCLA | A320-211 | STANDARD | 1 | -1 | -1 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.5 |
| 28 | 02/08/2018 | 6:09:48 | RYR358E | RYANAIR | B738 | D | N.A. | LIRF | 737800 | ICAO_B | 6 | -1 | -1 | CFM56-7B2 | CFM56-7B2 | 12.333 | 1586.8 |
| 22 | 02/08/2018 | 6:12:06 | AZA1761 | ALITALIA | A320 | A | N.A. | LIRF | A320-211 | STANDARD | 1 | -1 | -1 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.5 |
| 26 | 02/08/2018 | 6:20:20 | RYR55NN | RYANAIR | B738 | A | N.A. | LIME | 737800 | STANDARD | 1 | -1 | -1 | CFM56-7B2 | CFM56-7B2 | 1.552 | 667.3 |
| 27 | 02/08/2018 | 6:27:00 | N.A. | | B738 | A | N.A. | | 737800 | STANDARD | 1 | -1 | -1 | CFM56-7B2 | CFM56-7B2 | 1.552 | 667.3 |
| 30 | 02/08/2018 | 6:42:59 | RYR318Q | RYANAIR | B738 | D | N.A. | LIPE | 737800 | ICAO_A | 6 | -1 | -1 | CFM56-7B2 | CFM56-7B2 | 12.804 | 1670.9 |
| 32 | 02/08/2018 | 6:57:53 | EDW398 | EDELWEISS | A320 | A | LSZH | LSZH | A320-211 | STANDARD | 1 | 14.0 | 65.9 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.5 |
| 33 | 02/08/2018 | 7:02:24 | RYR61UQ | RYANAIR | B738 | A | EPRZ | EPRZ | 737800 | STANDARD | 1 | 21.3 | 71.0 | CFM56-7B2 | CFM56-7B2 | 1.552 | 667.3 |
| 35 | 02/08/2018 | 7:10:46 | AZA1744 | ALITALIA | A320 | D | LIRF | LIRF | A320-211 | ICAO_B | 5 | 32.0 | 135.9 | CFM56-5-A1 | CFM56-5B | 12.604 | 1633.4 |

***Table C.3 Single event database based on initial dataset***

Figure C.10 presents the noise contours of some operations. It can be observed that, due to the too low altitude, the noise contours are indeed much longer than may be expected. Also some misalignments between trajectory and runway can be found.

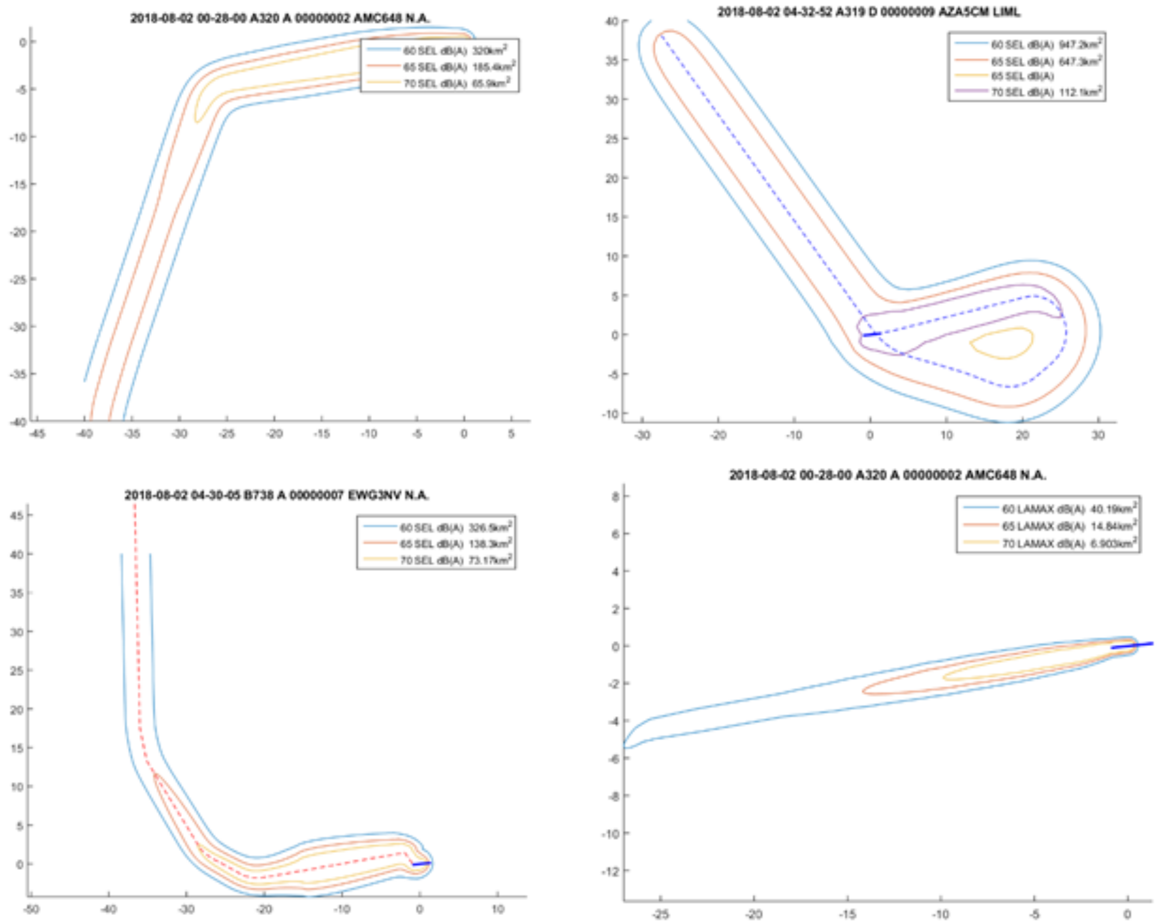


***Figure C.10 Noise contours based on trajectories from initial dataset***

Based on the single event emissions various assessments can be made:

- Total CO2 / NOx for each aircraft type, per destination, per airline, etc..
- What-if studies ➔ example: replacement of CFM56 by LEAP

To demonstrate the capabilities of the tool chain, the latter assessment has been worked out in more detail. For the operations with A320 and A321, the standard CFM56 engines were replaced by LEAP engines and the corresponding emissions were calculated for the same flight profiles.

Figure C.11 shows the results of this exercise. It can clearly be seen that both CO2 and NOx are significantly reduced thanks to the introduction of the LEAP engine. Here it should be noted that these calculations are based on the wrong trajectory data, and absolute values are therefore not correct.

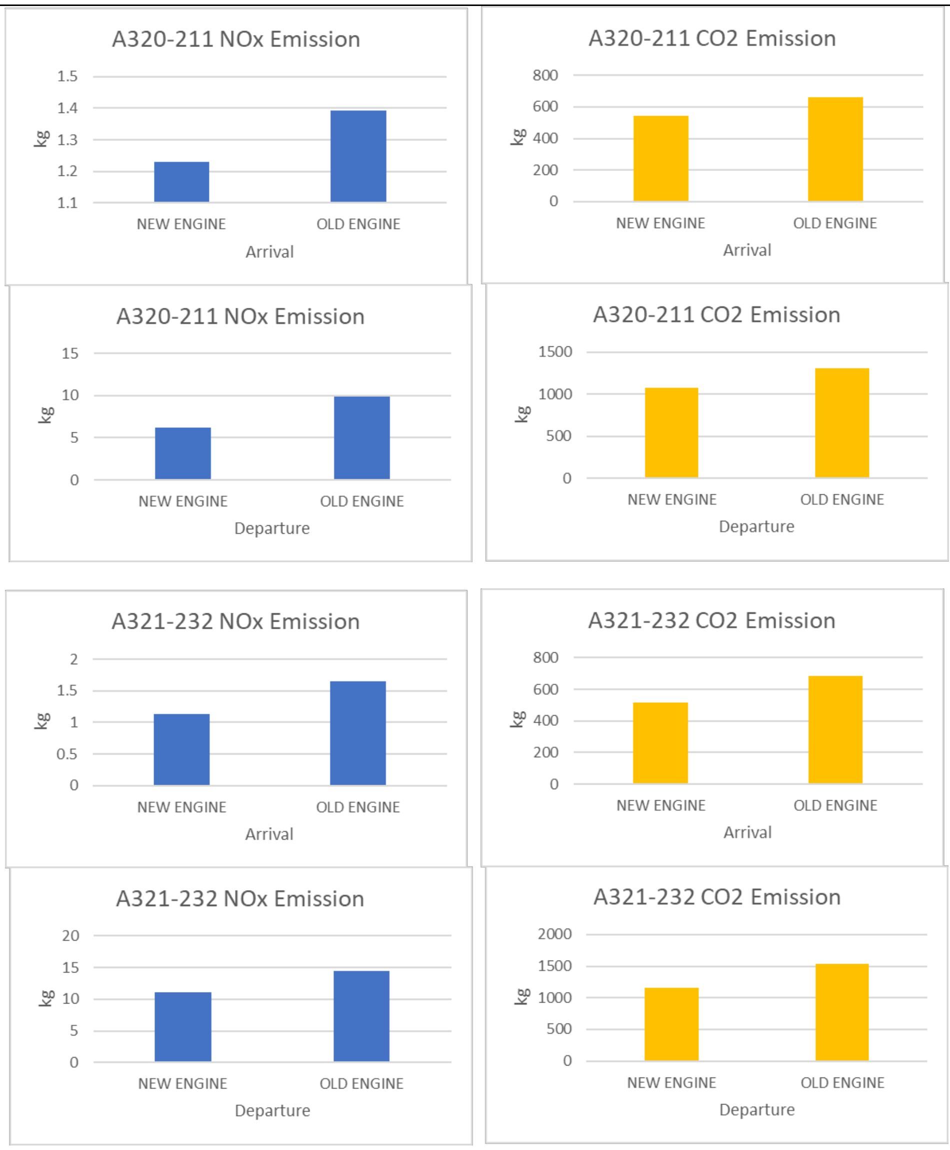


***Figure C.11 Effect on emissions of re-engining A320 and A321 with LEAP engines***

### *Updated dataset*

For a full and representative interdependencies study it is necessary to work with correct trajectory information, especially with correct altitude. Since improving the monitoring system at the airport would take more time than that available, it was decided to acquire some data with an interim solution. To this end an ADS-B receiver of ANOTEC was installed at Catania airport, with data stored in a local PC. A first check of the data confirmed that the altitude in the initial dataset was wrong. As can be seen in Figure C.12, the glide slope in approach according to the initial dataset was around 1.7º, whereas the ANOTEC receiver shows a 3º slope, which is as expected, considering the ILS installed at Catania.


***Figure C.12 Check on altitude information provided by Catania and ANOTEC systems***

A new single event database was then created, based on the updated dataset (see Table C.4).

| ID | Date | Time | Flight | Airline | ACFT | A/D | Org/Dest | AC_ANP | PROFILE | STG | km2LAMAX65 | km2SEL70 | ENGUSED | BADAENG | KGNOX | KGCO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 190221010 | 21/02/2019 | 15:50:30 | RYR36YU | RYANAIR | B738 | D | BGY | 737800 | ICAO_B | 6 | 46.711 | 97.305 | CFM56-7B26 | CFM56-7B27 | 12.333 | 1586.802 |
| 190221014 | 21/02/2019 | 16:07:55 | RYR70SJ | RYANAIR | B738 | A | MXP | 737800 | STANDARD | 1 | 21.595 | 59.255 | CFM56-7B26 | CFM56-7B27 | 1.552 | 667.321 |
| 190221018 | 21/02/2019 | 16:29:42 | RYR5UD | RYANAIR | B738 | D | TRN | 737800 | ICAO_A | 6 | 58.543 | 122.585 | CFM56-7B26 | CFM56-7B27 | 12.804 | 1670.904 |
| 190221020 | 21/02/2019 | 16:42:41 | AZA1723 | ALITALIA | A319 | A | LIN | A319-131 | STANDARD | 1 | 12.076 | 29.511 | V2522-A5 | V2522-A5 | 1.018 | 547.981 |
| 190221022 | 21/02/2019 | 17:04:43 | RYR52HX | RYANAIR | B738 | A | BLQ | 737800 | STANDARD | 1 | 21.115 | 54.247 | CFM56-7B26 | CFM56-7B27 | 1.552 | 667.321 |
| 190221015 | 21/02/2019 | 17:13:27 | RYR3T | RYANAIR | B738 | D | MXP | 737800 | ICAO_A | 6 | 59.175 | 123.614 | CFM56-7B26 | CFM56-7B27 | 12.804 | 1670.904 |
| 190221013 | 21/02/2019 | 17:17:58 | RYR8YD | RYANAIR | B738 | D | FCO | 737800 | ICAO_B | 5 | 57.726 | 135.125 | CFM56-7B26 | CFM56-7B27 | 11.912 | 1530.683 |
| 190221019 | 21/02/2019 | 17:47:07 | RYR664P | RYANAIR | B738 | A | TSF | 737800 | STANDARD | 1 | 21.419 | 49.515 | CFM56-7B26 | CFM56-7B27 | 1.552 | 667.321 |
| 190221023 | 21/02/2019 | 18:01:02 | RYR11UR | RYANAIR | B738 | A | MAD | 737800 | STANDARD | 1 | 21.537 | 50.576 | CFM56-7B26 | CFM56-7B27 | 1.552 | 667.321 |
| 190221021 | 21/02/2019 | 18:11:11 | AZA1704 | ALITALIA | A319 | D | LIN | A319-131 | ICAO_A | 4 | 22.407 | 85.697 | V2522-A5 | V2522-A5 | 10.850 | 1457.823 |
| 190221024 | 21/02/2019 | 19:07:05 | RYR4065 | RYANAIR | B738 | D | MAD | 737800 | ICAO_B | 2 | 46.822 | 121.927 | CFM56-7B26 | CFM56-7B27 | 9.524 | 1213.410 |
| 190222003 | 22/02/2019 | 09:10:07 | AZA5ZB | ALITALIA | A321 | A | LIRF | A320-211 | STANDARD | 1 | 12.362 | 25.255 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.498 |
| 190222024 | 22/02/2019 | 09:29:07 | EZY38AC | EASYJET | A320 | A | MXP | A320-211 | STANDARD | 1 | 7.041 | 12.271 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.498 |
| 190222029 | 22/02/2019 | 10:38:42 | THY2SU | TURKAIR | A321 | A | IST | A320-211 | STANDARD | 1 | 4.802 | 7.951 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.498 |
| 190222004 | 22/02/2019 | 10:42:46 | AZA1710 | ALITALIA | A321 | D | LIRF | A320-211 | ICAO_B | 5 | 31.937 | 85.362 | CFM56-5-A1 | CFM56-5B | 12.604 | 1633.429 |
| 190222026 | 22/02/2019 | 10:53:35 | BMS3MZ | BLUEAIR | B738 | A | TRN | 737800 | STANDARD | 1 | 9.642 | 17.453 | CFM56-7B26 | CFM56-7B27 | 1.552 | 667.321 |
| 190222025 | 22/02/2019 | 10:56:05 | EZY47DN | EASYJET | A320 | D | MXP | A320-211 | ICAO_A | 5 | 29.610 | 69.899 | CFM56-5-A1 | CFM56-5B | 13.303 | 1773.125 |
| 190222032 | 22/02/2019 | 11:04:22 | AZA1746 | ALITALIA | A320 | A | LIN | A320-211 | STANDARD | 1 | 14.877 | 34.086 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.498 |
| 190222001 | 22/02/2019 | 11:21:45 | AZA1731 | ALITALIA | A321 | A | LIRF | A320-211 | STANDARD | 1 | 8.401 | 15.231 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.498 |
| 190222030 | 22/02/2019 | 12:00:13 | THY5BK | TURKAIR | A321 | D | IST | A320-211 | ICAO_A | 5 | 33.105 | 94.120 | CFM56-5-A1 | CFM56-5B | 13.303 | 1773.125 |
| 190222027 | 22/02/2019 | 12:03:23 | BMS6GT | BLUEAIR | B738 | D | TRN | 737800 | ICAO_B | 6 | 59.679 | 123.045 | CFM56-7B26 | CFM56-7B27 | 12.333 | 1586.802 |
| 190222022 | 22/02/2019 | 12:05:16 | EZY92JA | EASYJET | A319 | A | VCE | A319-131 | STANDARD | 1 | 8.189 | 14.658 | V2522-A5 | V2522-A5 | 1.018 | 547.981 |
| 190222033 | 22/02/2019 | 12:25:17 | AZA1747 | ALITALIA | A320 | D | LIN | A320-211 | ICAO_A | 5 | 33.526 | 81.362 | CFM56-5-A1 | CFM56-5B | 13.303 | 1773.125 |
| 190222017 | 22/02/2019 | 12:33:21 | EZY16WD | EASYJET | A320 | A | MXP | A320-211 | STANDARD | 1 | 12.231 | 24.298 | CFM56-5-A1 | CFM56-5B | 1.393 | 659.498 |
| 190222034 | 22/02/2019 | 13:14:37 | RYR4DH | RYANAIR | B738 | A | BGY | 737800 | STANDARD | 1 | 7.924 | 13.946 | CFM56-7B26 | CFM56-7B27 | 1.552 | 667.321 |
| 190222023 | 22/02/2019 | 13:50:25 | EZY67KY | EASYJET | A319 | D | VCE | A319-131 | ICAO_A | 5 | 25.596 | 85.640 | V2522-A5 | V2522-A5 | 12.478 | 1656.707 |
| 190222016 | 22/02/2019 | 14:13:56 | EZY71WU | EASYJET | A319 | A | NAP | A319-131 | STANDARD | 1 | 11.260 | 22.791 | V2522-A5 | V2522-A5 | 1.018 | 547.981 |
| 190222031 | 22/02/2019 | 14:36:33 | RYR2537 | RYANAIR | B738 | A | MLA | 737800 | STANDARD | 1 | 21.061 | 67.935 | CFM56-7B26 | CFM56-7B27 | 1.552 | 667.321 |

***Table C.4 Single event database based on updated dataset***

Figure C.13 gives some noise contours, calculated for the updated dataset. Both contour shapes and areas appear more realistic. The updated dataset was provided to NLR for further analysis.

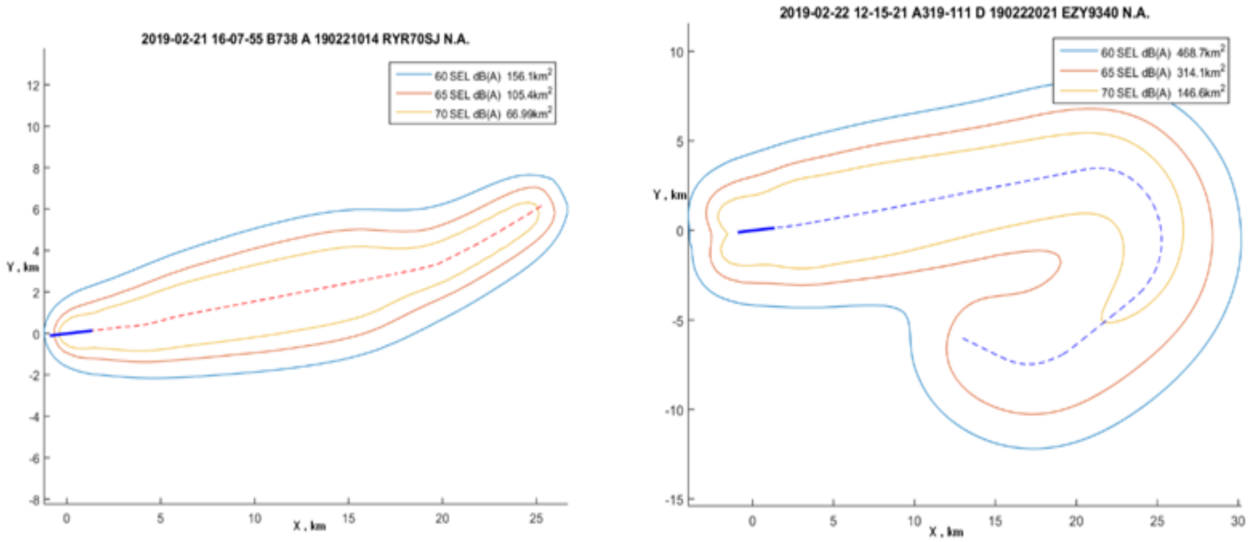


***Fig C.13 Noise contours, calculated for the updated dataset***

### *Conclusions*

The initial dataset provided by the airport appeared to contain incorrect altitude information. A permanent solution for this takes more time than is available for the delivery of the present document. A temporary solution made it possible to obtain some correct data, with which the full process could be validated.

Based on the results described in this section, it can be concluded that the methodology developed for the interdependencies study, based on a simultaneous application of compatible models, is valid and gives useful results.

## 11.3. Annex C.3 NLR Approach

Note: the NLR approach is presented together, as results and discussion, to facilitate the understanding of the information flow, the work input and the method undertaken.

As explained in Chapter 5, the NLR objective was different (from the one taken by ANOTEC), aiming to investigate the potential for a *trade-off between noise and emissions* of four departure procedures. The purpose of the **NLR analysis was to demonstrate trade-off potential.**

Regarding the impact of different flight procedures, it is important to know the difference between emissions and air quality. The NLR analysis looks at emissions and not the impact of the emissions (air quality). This is important to emphasize, as for example, emissions of NOx above 1000 feet will have little impact on ground level – so a change in operational measures may have little impact on local or regional Air Quality (though PM and UFP may be different – but the science is not mature yet). Noise versus CO2 emissions is a much more relevant interdependency to look at, in this case.

Though the data used is specific to Catania Airport, the analyses are intended to be also valuable (examples) for other airports.

*Data sources*

Two datasets were provided by Catania Airport/ANOTEC as explained earlier. The first received dataset did contain inconsistencies, as described in section 5.3.

However, since the datasets contained sufficient information for its purpose, the NLR study was performed with concluding remarks. The following data was used in the NLR study:

- Aircraft type
- Airport of departure
- Airport of destination
- Distance along flight path (including ground roll)
- Time
- Altitude

*Data analysis*

The study approach and data analysis is described in the following three sub-sections:

- **Profiles**: Calculate flight profiles (speed, altitude, thrust as function of distance) for four different ANP procedures, and compare these to the average profile in the Catania dataset
- **Methodology**: Describe the applied methodology for assessing noise and emissions

*Results*

Present and discuss the noise and emissions results. The impact of procedure choice on noise and emissions is investigated and presented as *trade-off*. The idea is to provide the airport with an example of a choice between possible procedures which – of course – is up to the airport to trade-off applying the airport weights to the different aspects considered.

*Profiles*

As a first step in the analysis the aircraft speed was approximated from the location and time parameters present in the Catania Airport dataset. Aircraft speed and altitude were plotted as function of distance and these "departure profiles" were then compared with departure profiles calculated using ECAC Doc29 and aircraft performance data from the international Aircraft Noise and Performance (ANP) Database. This was necessary, since the Catania data did not provide information on thrust setting and knowledge about the thrust setting is necessary to calculate noise and emission levels. Four types of Doc29 profiles were considered (1x NADP1 and 3x NADP2). The NADP profiles were calculated for different de-ratings. As an example, four profiles for a specific aircraft type are shown in figure C.14. The presented profiles include a 85% de-rating on standard LTO settings in the take-off phase, no de-rating in the climb out phase and are calculated for an ISA+20 deg temperature.

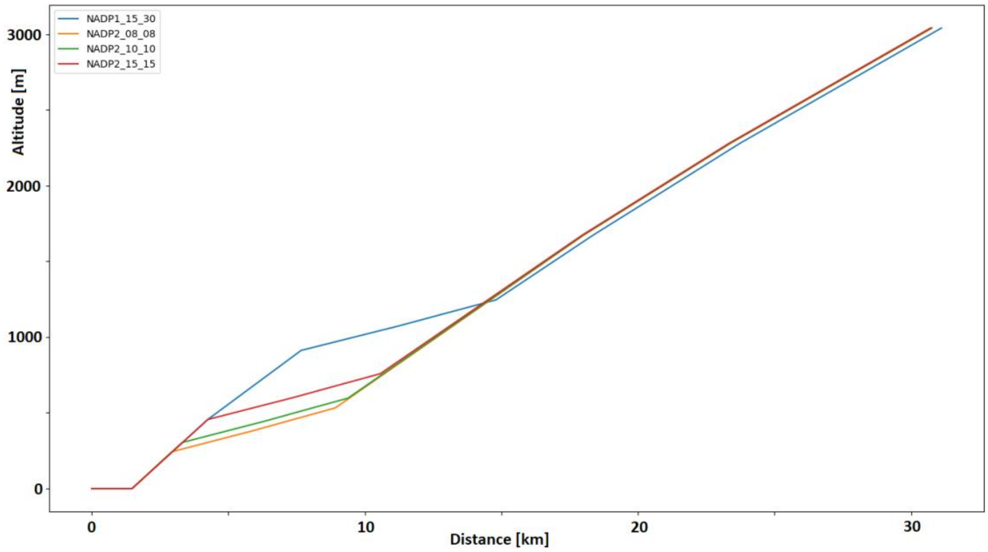


***Figure C.14 Examples of four NADP procedures (NLR, March 2019)***

The Legend of figure C.14 describes the four profiles generically as NADP1_xx_yy or NADP2_xx_yy where "xx" denotes the cutback altitude[106] of the flight profile (10 = 1000 ft, 15 = 1500 ft etc) and "yy" denotes the acceleration altitude[107] (10 = 1000 ft, 15 = 1500 ft etc).

The chosen NADP profiles have different cutback and acceleration altitudes, and therefore the *NADP profiles show different altitudes and speeds at the same time instance and distance from airports*. The latter is clearly shown in figure C.14 for altitude as a function of distance flown. The four variants were generated by taking one of the example departure procedures from the ANP database and applying modifications to thrust cutback altitudes and acceleration altitudes, in line with NADP1 and NADP2 definitions.

Aircraft departing from Catania airport have an average flight distance which corresponds to a pre assigned weight class. This weight class is class 2 and is used for the analysis of the profiles. This weight class corresponds to flights with a flight distance of 500-1000 nautical miles which is representative for the average of flights departing from this airport.

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[106] The cutback altitude is the altitude at which the aircraft engine thrust setting is reduced

[107] The acceleration altitude is the altitude at which the flaps and slats are retracted

Since accurate information on aircraft engine types for Catania airport was not available, and since the **purpose of the current analysis is to demonstrate trade-off potential,** not be as accurate as possible, the analysed aircraft were matched to typical engines used for the same aircraft types at Schiphol Airport.

The profiles were calculated for ISA+20 temperature (International Standard Atmosphere), since this temperature represents the temperature around Catania airport in, for instance, August. However, profiles were also calculated for ISA temperature. The effect of temperature on calculated profile is presented in Figure C.15.

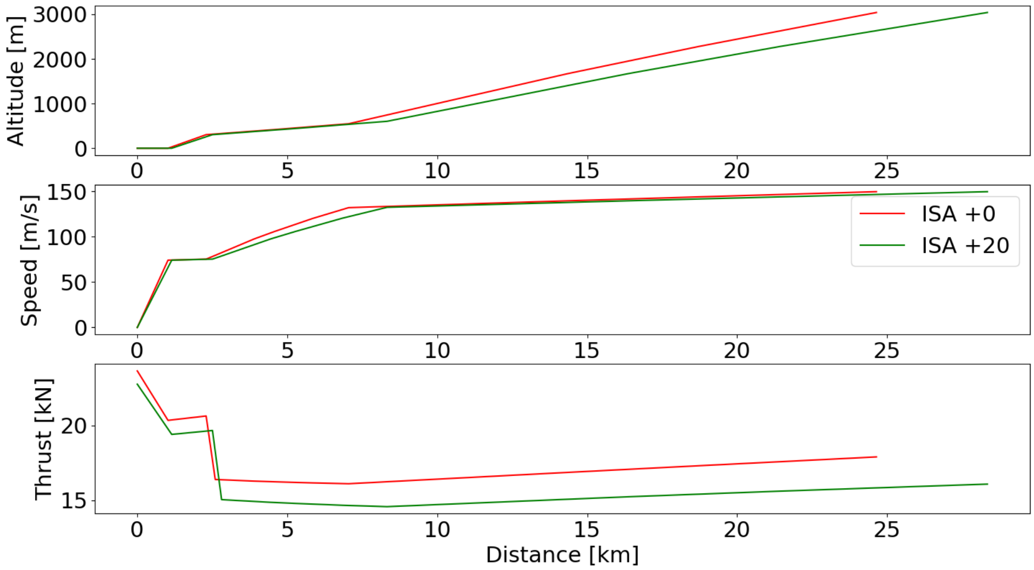


***Figure C.15 Effect of temperature on aircraft performance shown by comparing a NADP2_10(-10) profile for two different temperatures***

Figure C.15 shows that the higher the atmospheric temperature, the less thrust the engine produces with consequently both a *lower climb rate and a slower speed build-up.*

Comparison of the calculated profiles with the Catania profiles showed that the NADP2_10(_10) profile appeared to be most similar to Catania profiles. The de-ratings that fitted the Catania flights best was 85% for standard LTO take-off thrust setting and 100% for standard LTO climb-out thrust setting.

In the presentation of the results hereafter the NADP2_10(_10) procedure was therefore used as reference for the comparison with the three other procedures NADP1_15(_30), NADP2_08(_08) and NADP2_15(_15).

### *Methodology*

The current study aims to investigate the **trade-off between metrics for noise and emissions**. As a case study NLR chose a typical day of traffic at Catania airport for two temperatures (a colder day and a warmer day), while varying NADP starting procedures.

As a ranking analysis does not critically depend on absolute noise values, the traffic distribution at Catania is approximated for the most common take-off (runway 08 east straight out, 8 knot head-wind) without the contribution of landings or other take-offs. Also we consider only LAeq (thus neglecting Lden penalties for evening and night flights).

The traffic is represented by taking the three most commonly observed aircraft at Catania (mid-sized jets) that make up approximately 90% of all flights. The relative contribution of these aircraft has been modelled (16, 27 and 31.5) with a total of 75 take-offs.

Since temperatures at Catania in summer are rather hot, the effect of a temperature of 35 degrees Celsius is also investigated as compared to a temperature of 15 degrees Celsius. The relative humidity is assumed to be constant (60%).

*Noise modelling*

Noise modelling has been calculated using INM software, version 7d. The fixed point profiles and noise tables have been adjusted for temperature and relative humidity.

Noise emission metrics are based on LAeq contour at 55 dB level. In addition to size of contour, the shape represented by the aspect ratio is calculated, defined as maximum width divided by maximum length. Defined in such a way, a larger aspect ratio represents a larger impact on the population of Catania, because most houses are situated lateral to the runway. On examination of the traffic at Catania, it was found that the number of flights at Catania is about a factor 10 smaller than a typical larger airport. Thus, a 45 dB contour at Catania corresponds to 55 dB contour at an airport with tenfold traffic. Therefore, the metrics calculated for a 45 dB contour are also included.

*Emission modelling*

CO2 and NOx emissions were calculated along the flight paths for each of the considered profiles. The calculated emissions depend on number of operating engines on the aircraft (aircraft type), engine type, engine thrust setting, engine operating time and other parameters like installation effects, aircraft speed, aircraft altitude, atmospheric temperature and humidity. As mentioned before, the calculations were done for the three most common aircraft types at Catania airport matched to typical engines for these aircraft types at Schiphol airport. The thrust settings and engine operating times during departure (85% of full thrust) were obtained from the profiles and translated to fuel flow and NOx emissions using ICAO Aircraft Engines Emissions Databank[108]. CO2 emissions were derived from fuel by applying a 3.14 kg CO2/kg fuel conversion factor.

A correction has been added for installation effects correcting the bare engine fuel flow to the installed fuel flow at a given thrust setting. Emissions were also adjusted for the effect of temperature and altitude.

A trapezoidal method was used to integrate the fuel consumption over time to obtain the total fuel within the chosen time frame. (The time frame originates from the time required to obtain a predefined altitude).

The Doc29 profiles consist of data up to an altitude of 3000m. So, in principal the emissions can be calculated from ground level up to a maximum altitude of 3000m. However, CO2 emissions were calculated up to 1500m (5000ft) and NOx emissions up to 300m (1000ft).

The CO2 emissions were calculated up to 1500m because the four considered departure profiles are approximately the same from this point onwards. So for the *comparison of the profiles* the CO2 emissions above this altitude are less relevant, though these emissions at higher altitudes – of course - do also have an impact on climate change.

NOx is modelled up to an altitude of 300m (1000ft) because above this altitude NOx has only a small impact on local air quality. Since the four profiles considered differ only for altitudes above 800 ft the difference in presented NOx emissions for the four profiles will be limited.

### *Results*

#### Noise contours for Catania departure procedures

The effect of departure procedures on 45 and 55 LAeq contours is shown in Figure C.16 for the reference temperature (T=15, top) and a higher temperature (T=35, bottom). Clearly, the area size is reduced by about 40% at a higher temperature. When comparing top and middle graph, one can deduce that the area reduction due to changes in the flight profile (e.g. a decreased height, speed and thrust with higher temperature) is only modest. The reduction can be attributed to largest extent to a change in atmospheric propagation (e.g. a slight increased absorption) at higher temperatures (compare middle and bottom graph).

Furthermore, at each temperature, a change in shape is evident as a function of procedure. A narrowing and lengthening of contours for NADP2 compared to NADP1 can be observed for the 55 dB contour. This narrowing and lengthening seems in line with previously reported case study results for Schiphol (ANIMA)

[108] https://www.easa.europa.eu/easa-and-you/environment/icao-aircraft-engine-emissions-databank

which showed that compared to NADP1, the NADP2 procedure tends to decrease the noise levels near the airport (attributable to a lower exposure duration and thrust) and increase the noise levels further away (attributable to a less steep ascend). This trend is not observed for the lower 45 dB noise contour.

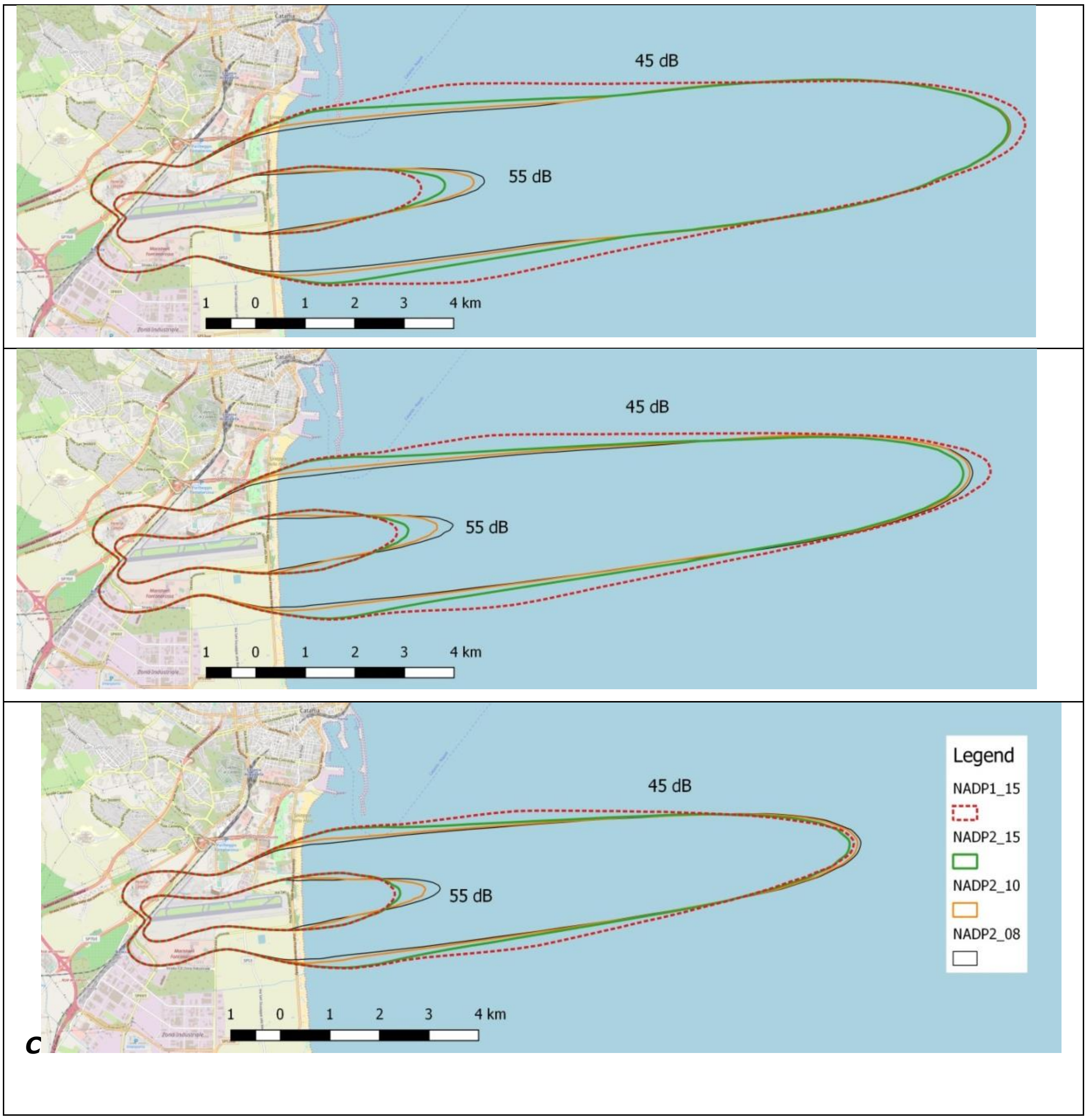


***Figure C.16 Effect of start procedure on 45 and 55 dB LAeq contours for T=15 degree (top) and 35 degree (bottom). Middle graph: contours for T=35 degree flight profiles and T=15 degree noise propagation.***

## ***Trade-offs/interdependencies***

Figure C.17 shows the effects of changing the departure procedures at both temperatures (T=15 and T=35 degree) after normalising the metrics for each temperature with Catania's most common procedure (NADP2_10). Metrics are normalized by dividing aspect ratio, area and emissions values for each considered profile by the corresponding value of the NADP2_10 profile (for the same temperature). Note that by scaling metrics per temperature, a representation is given that does not show the large effects of temperature on noise area (and the effect on NOx emissions), **but does reveal the trade-offs as a function of a parameter that can be manipulated**. Interestingly, trade-offs between noise metrics and emissions can be observed, as well as trade-offs within noise or within emission metrics.

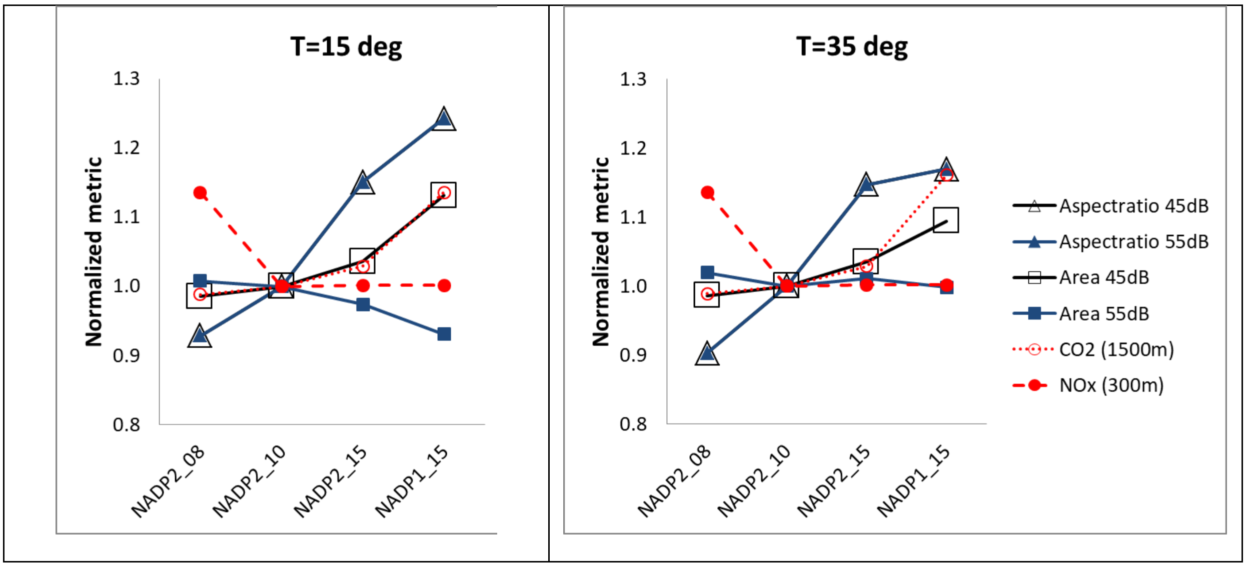


***Figure C.17 Trade-off between metrics for noise (aspect ratio and area at 45 and 55 dB LAeq contour levels) and emissions (CO2 and NOx) as a function of NADP procedure.***

First of all, the aspect ratio (width vs length) shows an upward trend with increasing NADP2 cutback height and is largest for the NADP1-15 procedure. This upward trend is independent of contour and temperature. In contrast, the trend for area size for T=15 degree is upward for the 45 dB contour, but downward for the 55 dB contours. ***Thus, a trade-off can be observed between aspect ratio and noise area for the 55 dB noise contours***. A trade-off between aspect ratio and 55 dB area metrics is still present at T=30 degree, albeit less pronounced.

Secondly, figure C.17 shows, on the one hand, a downgoing trend for the NOx emissions for both temperatures. This trend is a result of the lower cutback and acceleration altitude for the NADP2-08 profile as compared to the other three profiles, resulting in more flying time below 1000ft and therefore more NOx emissions at lower altitude than the other three profiles. As mentioned before the expected impact of this difference in NOx emissions on local air quality will be small. On the other hand, the CO2 emissions show an upgoing trend since more time is flown with (more) extended flaps up to 1500m altitude. The decreasing trend in NOx emissions and the increasing trend in CO2 emissions also show that a trade-off may be considered to take place between types of emissions.

The same trade-off trends can be observed in Table C.5 after ranking. Note, the noise aspect ratio is the same for 45 and 55 dB (see also fig. C.16). Both scaled and ranked-based analyses indicate that a more advanced weight and cost-function will be necessary to determine which procedure is best to reduce the emissions.

| **T** | **Procedure** | **Noise (aspect ratio)** | **Noise (Area 45 dB)** | **Noise (Area 55 dB)** | **CO2 (kg, 1500m)** | **NOx (kg, 300m)** |
|---|---|---|---|---|---|---|
| **15** | NADP2-08(-08) | - | - | + | - | +++ |
| | NADP2-10(-10) | 0 | 0 | 0 | 0 | 0 |
| | NADP2-15(-15) | + | + | - | + | ++- |
| | NADP1-15(-30) | ++ | ++ | -- | ++ | ++- |
| **35** | NADP2-08(-08) | - | - | ++ | - | +++ |
| | NADP2-10(-10) | 0 | 0 | 0 | 0 | 0 |
| | NADP2-15(-15) | + | + | + | + | ++- |
| | NADP1-15(-30) | ++ | ++ | - | ++ | ++- |

***Table C.5 Trade-off table illustrating results***

Trade-off table expressing results in for instance: "+, 0, -, ++, ..." (depending what is important/of value to Catania Airport).

Note that care must be taken to generalise these trade-off trends to larger airports. First of all, the noise metric LAeq scales logarithmically with the number of flights. To generalise these trade-off results to airports with more flights, the noise metrics would therefore need to be calculated for contour levels that are scaled appropriately (e.g. 10 dB per tenfold increase in number of flights). Also, the aircraft modelled here are mid-size aircrafts so that trade-off relations may be different if more heavy weight classes are included.

In summary, the above presented data indicates that trade-offs between and within (for) noise and emission metrics can be found when using normalized or ranked metrics. However, due to a small number of flights involved in this exercise, a clear conclusion can't be drawn.

It also shows that a more advanced cost-function is required to determine which procedure is best to reduce the emissions. Since it is up to the airport (and other stakeholders) to decide upon the procedure that would best fit the local evaluation of different environmental aspects, no final choice can be made here regarding the procedure to be chosen. A further discussion with Catania airport will take place during T2.5.

The trade-offs are applicable to higher temperatures as well (ISA+20 degree Celsius). For the noise area metric, the trade-offs depend critically on the chosen contour level.