ANIMA
Aviation Noise Impact Management through Novel Approaches

Case Study – Barcelona Airport

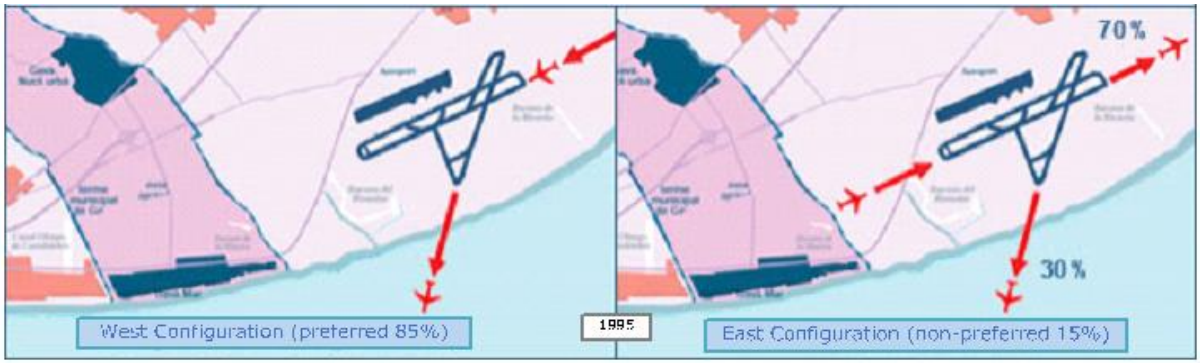
Background

In 2018 Barcelona airport saw the record figure of 50,172,457 passengers (6.1% more than the previous year) and 335,651 operations and 172,940 tonnes of cargo. The airport is open 24 hours a day and can handle 90 operations per hour (currently, 78 slots per hour). The airport can process 55 million passengers per year (Terminal T1 33 million PAX and Terminal T2 22 million PAX). A new Master Plan is needed for this airport, which raises new challenges for all stakeholders.

It is the seventh busiest airport in Europe and 17th in the world. Located in "El Prat de Llobregat", 15 km southwest of central Barcelona, the airport is the main driver of the Catalan economy.

The airport is operated by AENA, the world's leading airport operator (by number of passengers). AENA is a state-owned company that manages general interest airports (46) and two heliports in Spain. Through its subsidiary company AENA International it also participates in the management of 17 airports abroad.

In 1948, runway 07-25 was built – the one that is currently used as the primary runway – crossing over the runway that existed at the time.
In 1963, Barcelona-El Prat airport reached its first million passengers, while in 1965 two new extensions were carried out on runway 07-25. Between 1965 and 1970, runways 07-25 and 02-20 took on their current configuration and the apron expansion was completed. In 1977, passenger traffic grew over 5 million.
In 1994, departure point 25, for instrument (ILS) approaches, became fully operational. From that moment on, the airport implemented a basic operations configuration based on landings on runway 25 and take-offs on runway 20, which made it possible to increase the capacity of the airfield progressively from 38 operations per hour to 50.

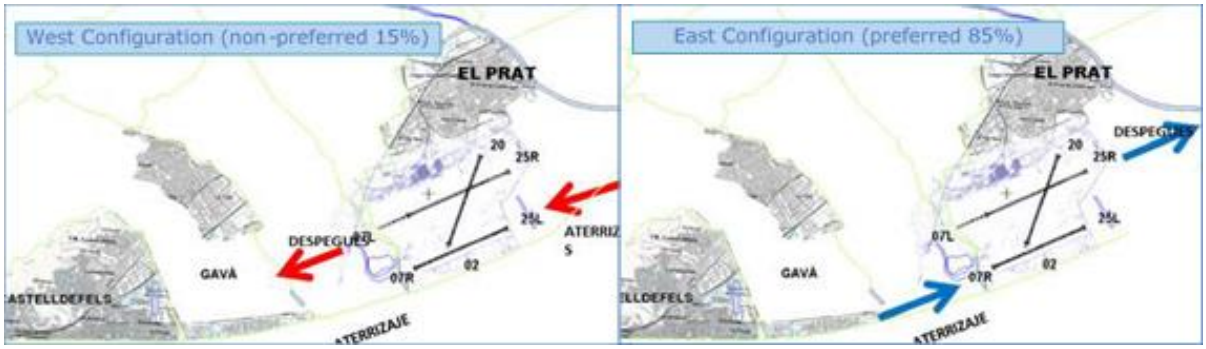


From 1995, Barcelona-El Prat Airport was consolidated as one of the top 15 airports in Europe and one of the top 50 in the world.

In 1999, the Ministry of Public Work approved the Master Plan for Barcelona-El Prat Airport, formally implemented as the Barcelona Plan. The third great transformation operation of the airfield was inaugurated in September 2004 and brought the third runway, parallel to the main runway, into service.

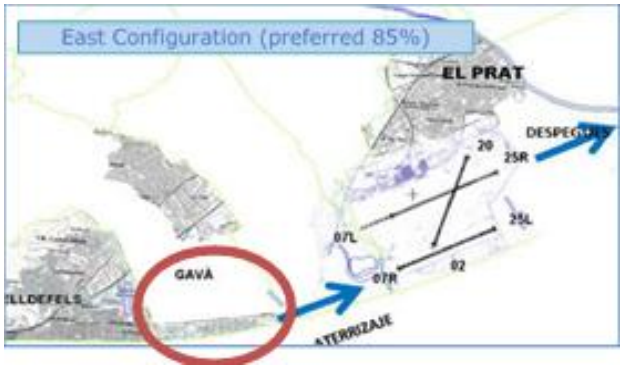
The new infrastructure is equipped with the maximum category runway lighting facilities (ILS Category II/III systems in each departure point). This enables its use in both directions and in foggy conditions. Runway 07L-25R has also been lengthened to 3,743 m and widened to 60 m.

The construction and introduction of the third runway in September 2004 and the extension to the primary runway were decisive steps to increase the airport's capacity to reach 90 operations per hour.



The whole project of the new Master Plan was approved and got an **Environmental Impact Statement** as the result of a complex and participatory process in 2002 (lengthy discussions with the territory to preserve certain sites of community importance). The third condition of this statement was to establish measures to protect the population affected by the noise impact, and a New Commission on Environmental Monitoring of the Airport Expansion Works (CSAAB) had to approve all these measures (local authorities which had airport noise issues were members). For two years all the noise studies prescribed by the Environmental Impact Statement were done and were

approved by the Commission, even with positive votes from the local authorities, except Castelldefels (affected by take offs on west configuration).



However, in October 2004, the new runway (the third one) started to operate. It immediately caused a lot of complaints, mainly because of the overflights on Gavà community in the east configuration.

In order to resolve this situation and after the request of the local councils and even the Spanish Congress, the Barcelona Technical Working Group of Noise (GTTR) was created at the beginning of 2005.

Barcelona Operating restrictions Case

The ICAO Balanced Approach (BA) was registered by European Law under directive 2002/30/EC on 26 March 2002 in the European Parliament, Royal Decree 1257/2003 of 3 October adapted this Directive to the Spanish legal code.

Following this Royal Decree, the Resolution of 31 May 2011 of the Spanish Air Safety Agency (AESA) was published, introducing operating restrictions in El Prat Barcelona Airport, following the Balanced Approach procedure. The content can be found in item 21 of AIP ESPAÑA AD2-LEBL.

What is Balanced Approach?

Aircraft noise is the most significant cause of adverse community reaction related to the operation and expansion of airports. The main overarching ICAO policy on aircraft noise is the Balanced Approach to Aircraft Noise Management (ICAO Doc 9829, Guidance on the Balanced Approach to Aircraft Noise Management).

The Balanced Approach consists of identifying the noise problem at a specific airport and analysing the measures available to reduce the noise, which can be classified into four principal elements:

1. **Reduction of noise at source.** Controlled by setting up the noise limits for aircraft in the "Standard and Recommended Practices" published in Annex 16 of the Convention on International Civil Aviation (the Chicago Convention);
2. **Land-use planning and management.** ICAO guidance on this subject is published in Annex 16, Volume I, Part IV and in the ICAO Doc 9184, Airport Planning Manual, Part 2 — Land Use and Environmental Control. The manual provides guidance on the use of various tools for the minimisation, control or prevention of the impact of aircraft noise in the vicinity of airports and describes the practices adopted by some countries;
3. **Noise abatement operational procedures**. ICAO assists on the development and standardisation of low noise operational procedures that are safe and cost-effective. The possibilities include noise preferential runways and routes and noise abatement procedures for take-off and landing. The selection of any of these measures depends on the physical layout of the airport and its surroundings. In all cases, the procedure must give priority to safety considerations)ICAO document 9888, Noise Abatement Procedures review of research);
4. **Operating restrictions**. Apart from phase-out, other possible operational restrictions include curfews, night-time restrictions, noise quotas and budgets, cap rules, non-addition rules and restrictions related to the nature of flight. ICAO Assembly in 2001 urged the states not to introduce any operating restrictions at any airport before fully assessing available measures to address the noise problem at the airport concerned in accordance with the Balanced Approach. Any restriction should be based on the noise performance of the aircraft and should be tailored to the noise problem of the airport concerned. The special circumstances of operators from developing countries should be taken into account. The goal is to address noise problems on an individual airport basis and to identify the noise-related measures that achieve maximum environmental benefit most cost-effectively using objective and measurable criteria.

How was "The Balanced Approach" deployed into European legislation?

Firstly, by the Directive 2002/30/EC of the European Parliament and of the Council of Europe on 26 March 2002 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at community airports.
The report from the Commission on 15 February 2008 entitled "Noise Operation Restrictions at EU Airports" pointed to the need to clarify the allocation of responsibilities in the text of Directive 2002/30/EC, as well as the precise rights and obligations of interested parties during the noise assessment process in order to guarantee that cost-effective measures are taken into account to achieve the noise abatement objectives for each airport.

After 12 years, an update was necessary on how to use operating restriction measures in order to enable authorities to deal with the current noisiest aircraft and to improve the noise environment around EU airports within the international framework of the Balanced Approach. Thus, a new Regulation (EU) Nº 598/2014 of the European Parliament and of the Council on 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within the Balanced Approach and repealing Directive 2002/30/EC.

Noise Management at Barcelona-El Prat Airport

Reduction of Noise at Source

Since 2007 the noisiest aircraft had to pay a charge for landing. The extra cost depends on the cumulative margin of the acoustic certification limits.
Airport charges are determined according to the maximum take-off weight (MTOW), and vary depending on the type, class of flight and the noise level of the aircraft.
The amounts resulting from the application of the regular rates shall be increased by the following percentages according to the noise level of each aircraft and to the schedule of the landing or take off.
The criteria applied to determine the noise category for each aircraft is as follows:

- Category 1: Aircraft with accumulative margin up to 5EPNdB;
- Category 2: Aircraft with accumulative margin between 5EPNdB and 10EPNdB;
- Category 3: Aircraft with accumulative margin between 10EPNdB and 15EPNdB;
- Category 4: Aircraft with accumulative margin over 15EPNdB.

Land use planning and management

Planning instruments
In 1999, a new concept was introduced into the Air Navigation Law to protect land planning around the main airports "Servidumbres aeronáuticas acústicas" – "Aeronautical acoustic easements". This was a new kind of aeronautical space limitation with a right way. In order to comply with this law, the DGAC (Spanish Directorate General for Civil Aviation) must issue a favourable report about each urban plan under a noise contour around the civil airports of 55 dB $LAeq_{day}$ 16 h / 45 dB $LAeq_{night}$ 8 h.
Generally, they do not allow new housing, schools and hospitals inside this contour.
All the land use plans around Barcelona airport inside these noise contours have been informed by DGAC in or der to avoid new residential, educational or healthcare areas.

Mitigating instruments
AENA carries out Acoustic Insulation Plans (PAA), which are aimed at minimising the disturbance caused around airports, the noise produced by aircraft during take-off, landing, taxiing, engine tests and many other operations.
To achieve this goal, AENA soundproofed homes and buildings that are used for sensitive purposes (residential, educational, healthcare and cultural centres which require special protection from noise pollution) and that are located within the noise footprint of the airports (isophones 60 dB $LAeq_{day}$ and $LAeq_{evening}$ and $LAeq_{night}$ 50 dB).
Depending on the noise levels to which these buildings are subjected, the soundproofing projects characteristically entail installing double-glazed windows, insulating façades and soundproofing roofs.
Through its Acoustic Insulation Plan Office, AENA provides anyone who may be interested with all the advice they need about the execution of Acoustic Insulation Plans.

Financial instruments
In 2010, compensatory measures were introduced into the Air Navigation Law in order to compensate the noise impact over some areas. It needed a new regulation to develop the law and clarify the measures.

Operational procedures

Noise abatement flight procedures

- **Continuous Descent Operations (CDO)**, referred to in the past as Continuous Descent Arrival or Approach (CDA). During night hours (between 23:00 h - 07:00 h), arrival procedures in continuous descent (CDA) are authorised for noise abatement reasons. This procedure avoids the stage flight segments that occur during a conventional landing and has a lower noise impact as well as reduction of fuel and emissions;
- **Noise Abatement Departure Procedures (NADP).** Published in the AIP and must be followed by all aircraft, except for safety reasons or air traffic control (ATC) instructions:
    - Take off (RWY 25L) – in order to avoid excessive noises at the runway centre line extension, the initial turn prescribed in the standard instrument departure (SID) shall begin no later than reaching 500 ft altitude;
    - Aircraft must follow the nominal trajectory of SID until they have reached 6000 ft, unless they are over the sea, above 3500 ft, in ascent and moving away from the coastline or at more than three nautical miles from the coast and parallel to it;
- **Modified approach angles, staggered, or displaced landing thresholds.** Some heads of runway have a displaced threshold to allow an increase of the altitude of the flights over the surrounding areas of the airport;
- **Low power/low drag approach profiles.** According to each aircraft manual for SIDs 25R;
- **Minimum use of reverse thrust after landing.** Reverse thrust use restrictions during night-time hours.

Spatial management

- **Noise preferred arrival and departure routes**. Airplane flight paths are constantly monitored by the airport's Environmental Division, which analyses any potential procedural or regulatory violations and reports potential non-compliances to Spain's Aviation Safety Agency, as appropriate;
- **Flight track dispersion or concentration.** RNAV (Area Navigation) for departure procedures to optimise the paths and to minimise the dispersion around the nominal track. It makes for an optimal path. So as to gradually decrease the number of non-compliances and improve operations, thereby, reducing noise levels in surrounding communities, individual meetings are held with specific airlines to discuss improvements to follow standard routes, analysing specific points of contention and coordinating follow-up actions to improve flight procedures;
- **Noise preferred runways.** Whenever the traffic demands and the weather and operational conditions permit, the preferential night time configuration may be extended beyond 07:00 h or to advance before 23:00 h. ATC follows the preferential configurations and the preferential runway use in order to reduce noise annoyance.

Ground management

- **Hush houses and engine run up management (location, aircraft orientation, time of day, maximum thrust level).** Engine tests higher than idle regime may be carried out at the engine test area established for such purposes;
- **Auxiliary power-unit (APU) management.** There are limitations on the use of auxiliary power units (APU) – it depends on the kind of aircraft and also on the stand (contact or remote). Each aircraft is allowed to make use of APU for a specific time;

- **Taxi and queue management, towing, taxi power control (taxi with fewer than all engines operating).** Depending on the air company procedures.

Operating restrictions

Specific bans
Gradual reduction of aircraft having Marginal Conformity levels, up to 28 September 2012, in compliance with resolution of Resolution of 31 May 2011 of the Spanish Air Safety Agency. Any marginally compliant aircraft has not operated in this airport since May 2015.

Community engagement

The Commission for Environmental Monitoring of the Airport Expansion Works (CSAAB) was created in February 2003, according to the environmental statement of the Barcelona airport expansion. It included members of the Ministry of the Environment, Civil Aviation Authority, AENA, ENAIRE, the Generalitat de Catalunya and the surrounding towns' councils. Its aim is to monitor and control the compliance of the preventive, corrective and off-setting measures developed during the construction and operation phase of Barcelona Airport's expansion, as well as to approve the studies and previous investigations indicated in condition 13 of the environmental statement such as:

- The studies of prediction and design of the network of monitoring stations of air quality;
- The study on measures to control the emissions of volatile organic compounds;
- Programme of emissions of pollutants from aircraft, ground support equipment (GSE) and APU;
- Noise studies;
- Acoustic insulation plan;
- Other corrective measures in relation to noise produced by aircraft operations;
- Design of the network of noise meters;
- Operational programme for monitoring and control of noise, in the terms established in the environmental impact statement (EIS).

So far, the regularity of the meetings is linked with the presentations of new studies or measures, which have to be approved.

Noise Technical Working Group (GTTR) was created in 2005 and is composed of technicians, appointed by the members of the CSAAB belonging to the Ministry of Environment, Civil Aviation Authority, AENA, the Government of Catalonia and representatives of the town councils. Its purpose is to study proposals and initiatives on possible actions aimed at improving noise exposure around the airport. Until now, 59 meetings have been held on a quarterly basis.

Both commissions are linked and all members are being informed promptly about noise data, configuration changes or exceptional situations that arise at the airport.
To provide all the necessary information to these groups, AENA and Barcelona Airport have a noise monitoring system which receives information of flight plans and radar paths, correlates them with the measurements taken by the noise monitoring terminals (NMTs), allowing the system to evaluate the data from the general airport system. The characteristics of each sound event and all the data related to the aircraft responsible for an event are recorded – aircraft identifier, position, altitude, airline, destination, etc.

The locations of the NMTs are selected in order to measure the environmental noise levels in the points that are the most exposed to aeronautical noise, close to air routes, and also to improve the measuring and control of the level of noise pollution caused by aeronautical operations in towns that could be affected.

Since 2010, all this information can be consulted by citizens through the interactive noise map (WebTrak system), which provides reliable and transparent information on aeronautical operations and the acoustic levels they generate. This information includes flight numbers, aircraft type, altitude and the flight path used by the aircraft. In addition, this tool allows the identification of which flight has caused the noise and to send a complaint to be answered by the corresponding department of the airport.

Complaints channels
Additionally, AENA has a virtual environmental office on its public website, where anybody can fill in a complaint, environmental request or a suggestion.

Collaborative environmental management (CEM) concept
Even if AENA has different operational coordination mechanisms, it is necessary to pool the experience with the different actors involved and to address the different environmental challenges through collaborative actions. In this regard, on the basis that no one can resolve the environmental challenge of the aviation sector alone, in June 2018, Barcelona Airport (along with the Madrid Airport) launched the first meeting with ENAIRE in the framework of the most significant airlines setting the collaborative environmental management (CEM) working arrangement based on the EUROCONTROL specifications. They have just began to work with the collaborative working group and the main aim is to find common solutions to minimise noise impacts and protect the environment.

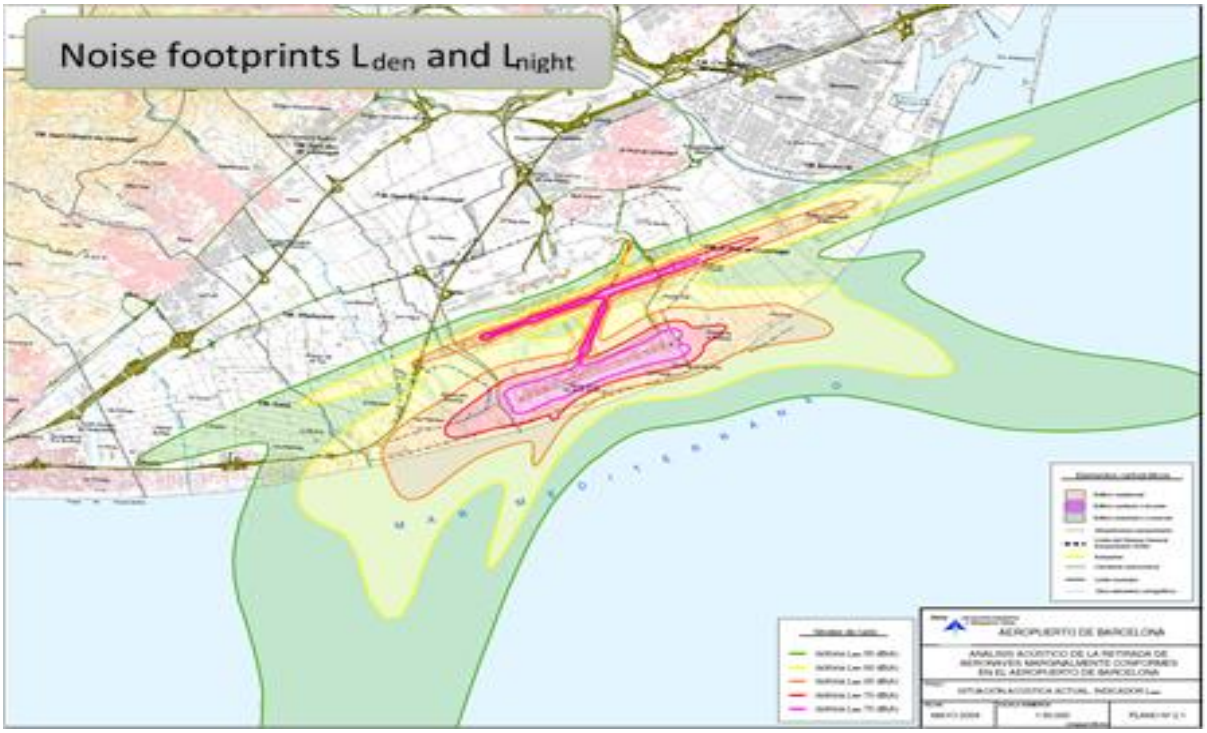
In this context, what was the process of introducing the operating restriction in 2011?

The case study is framed in the previous regulation, directive 2002/30/EC, the new Regulation 598/2014 came into force in June 2016. The Royal Decree 1257/2003 of 3 October adapted this Directive to the Spanish legal code. The process started with a detailed study and a comprehensive examination into the current inventory of measures, noise and objectives, secondly the expected evolution with several scenarios, in third place the assessment of new measures and finally the conclusions.

1. Current inventory and objectives:
    - Airport description;
    - Physical configuration;
    - Operational configuration;
    - Environment and implemented measures;
    - Acoustical description;
    - Acoustic modelling;
    - Indicators.

The first chapters of this case study summarised Barcelona Airport's description, physical configuration (two parallel runways and other one crossing, TWR and terminals), operational configuration (after switching the role of each runway), the Environment and implemented measures adopted always after the study by the GTTR. As it was explained in point 1.3.3, Barcelona Airport had been worked through the first three Balanced Approach pillars.

Considering the acoustical description, modelling and indicators, this study was looking for the benefits of operating restrictions, consequently, the study characterised the global noise in terms of number of people exposed and m^2 of exposed areas to each L_{den} and L_{night} levels, moreover, the study characterised the noise from the noisiest aircraft with its influence to general noise.



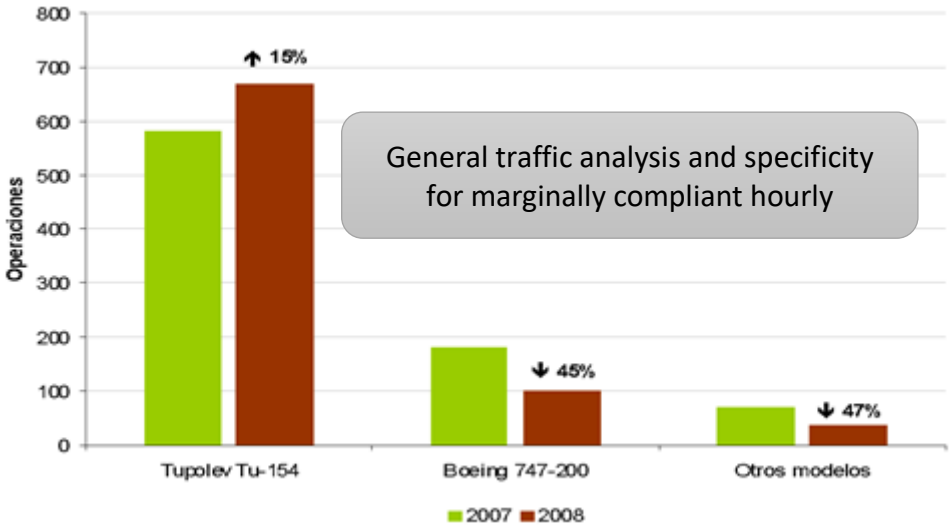
Current Situation	Indicator L_{den} (dBA)				
	55-60	60-65	65-70	70-75	>75
Area (ha)	4.914	1.781	698	246	164
People	2.727	442	19	11	-

Current Situation	Indicator L_{night} (dBA)				
	50-55	55-60	60-65	65-70	>70
Area (ha)	2.457	909	357	131	95
People	8	8	19	-	-

Areas affected and number of people affected by aircraft noise

For general noise, L_{den} and L_{night} indicators are used for a complete year of operation with the assessment of area and people exposed to each level of noise per each indicator.

Deep analysis of marginally compliant operations at Barcelona Airport, hour by hour, was performed to characterise properly the noise from the noisiest aircraft with its influence on general noise. In 2006-2008 there wasn't a global database with noise certification data, thus the study wasn't easy because of the lack of reliable noise aircraft data.



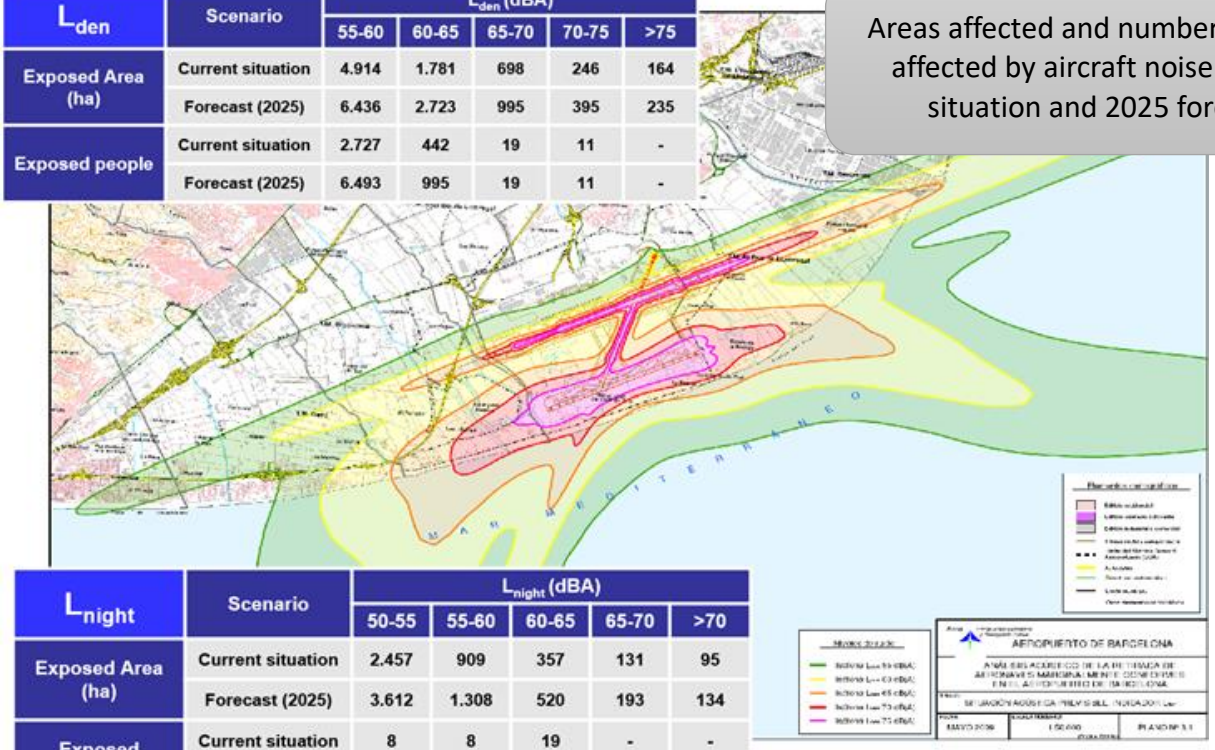
Recertification issues appeared, f.e. aircraft with different certificates for winter or summer and other aircraft with new engines and new certificates. Until 2007, it was not mandatory to present a certificate to the airport operator in Spain, thus the official noise data base did not exist.

Compañías aéreas	%ops./tot op 2007 MC	Compañías aéreas	%ops./tot op 2008 MC
Rossiya Airlines	23,7	Rossiya Airlines	33,8
Transaero Airlines	20,1	Ural Airlines	16,2
Vladivostok Air	10,8	Transaero Airlines	11,8
Aeroflot - Russian Airlines	6,0	Globus	9,2
Aviaprad Airlines	4,6	Tatarstan Air	8,5
Belavia Belarussian Airlines	4,6	S7 Airlines	5,2
S7 Airlines	4,3	Belavia Belarussian Airlines	4,6
Otras	25,9	Otras	10,7

After a deep study of the current situation, it was necessary to characterise the future: what would happen to the airport's development for the next 5-7 years, the noise action program, the fleets, the traffic evolution and etc.

2. Evolution scenarios
    - Airport development;
    - Programmed actions;
    - Expected benefits;
    - Traffic evolution;
    - Acoustic development;
    - Acoustic modelling;
    - Indicators.

L_{den}	Scenario	L_{den} (dBA)				
		55-60	60-65	65-70	70-75	>75
Exposed Area (ha)	Current situation	4.914	1.781	698	246	164
	Forecast (2025)	6.436	2.723	995	395	235
Exposed people	Current situation	2.727	442	19	11	-
	Forecast (2025)	6.493	995	19	11	-



L_{night}	Scenario	L_{night} (dBA)				
		50-55	55-60	60-65	65-70	>70
Exposed Area (ha)	Current situation	2.457	909	357	131	95
	Forecast (2025)	3.612	1.308	520	193	134
Exposed people	Current situation	8	8	19	-	-
	Forecast (2025)	165	8	21	-	-

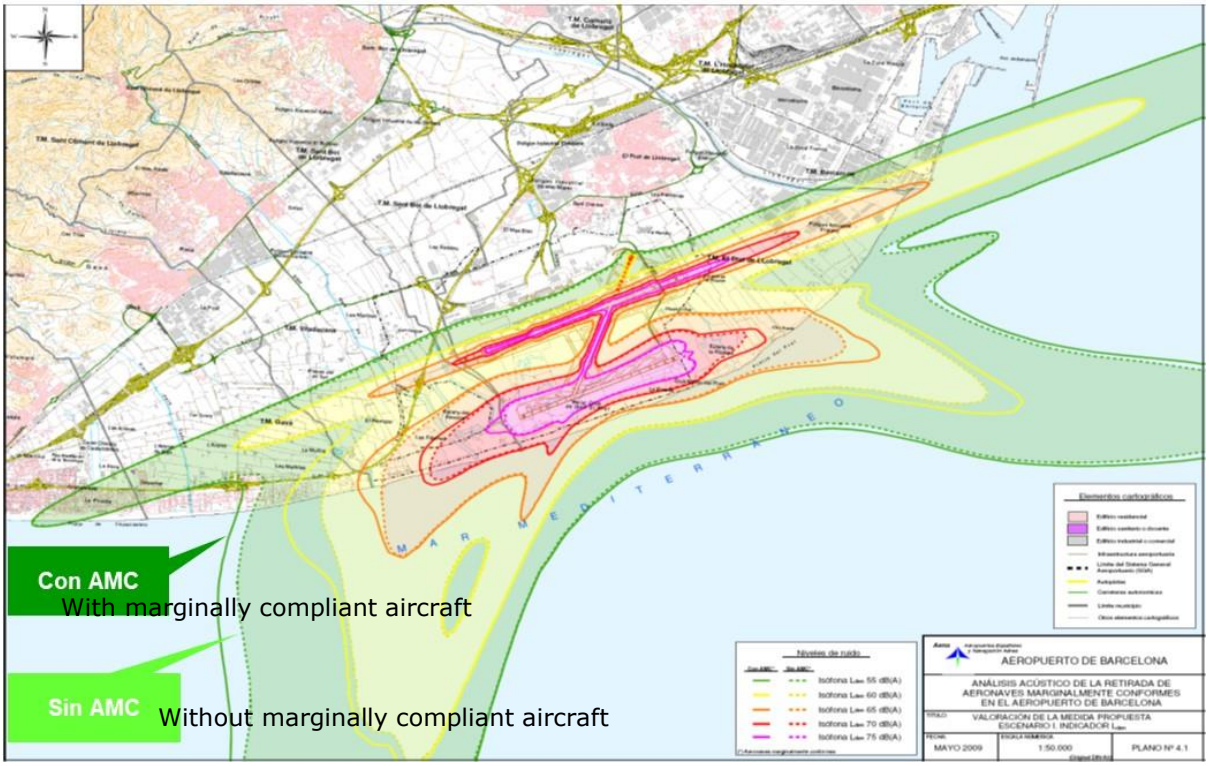
Areas affected and number of people affected by aircraft noise (current situation and 2025 forecast)

3. Assessment of additional measures
    - Measure definition;
    - Measure assessment (with/without operating restrictions);
    - Cost-Benefit analysis.

The noise objective of the ENV is to keep or reduce noise emitted by the major sources (that include major airports) and the evolution presented an increase in number of annoyed people and areas affected.
The third part of the study defined and assessed different scenarios with and without marginally compliant aircraft in terms of L_{den} and L_{night} and areas and people exposed to each level.

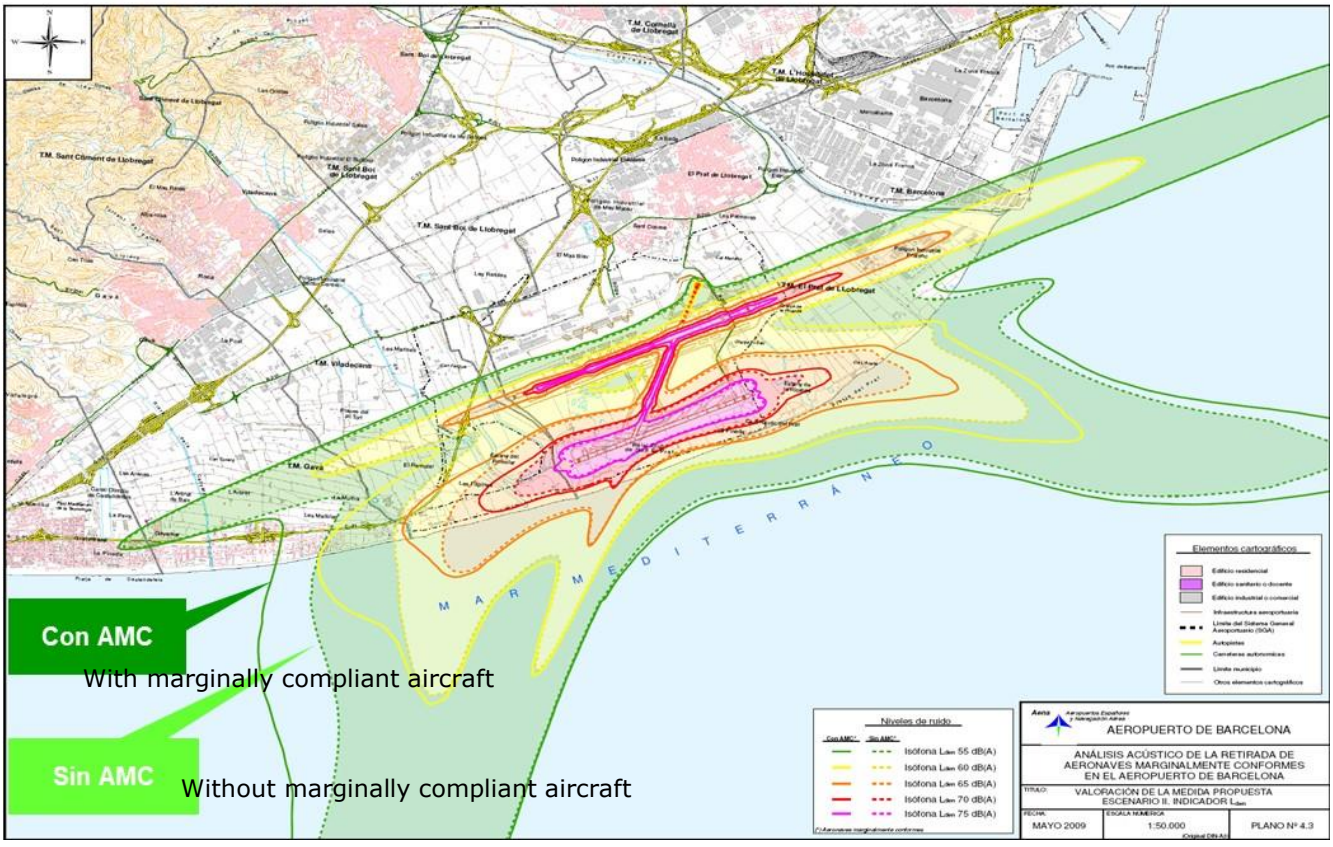
ESCENARIO I

L_{den}

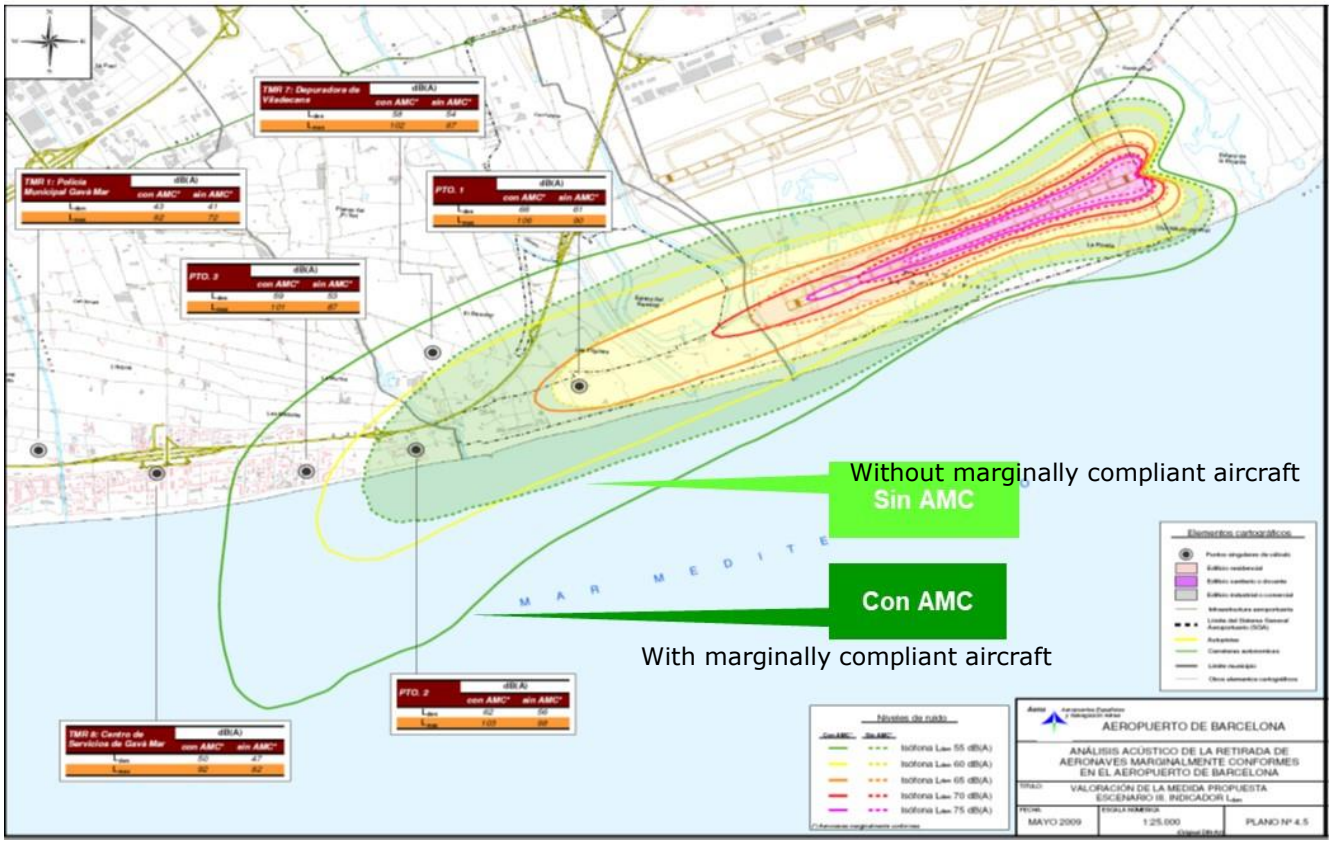


ESCENARIO II

L_{den}

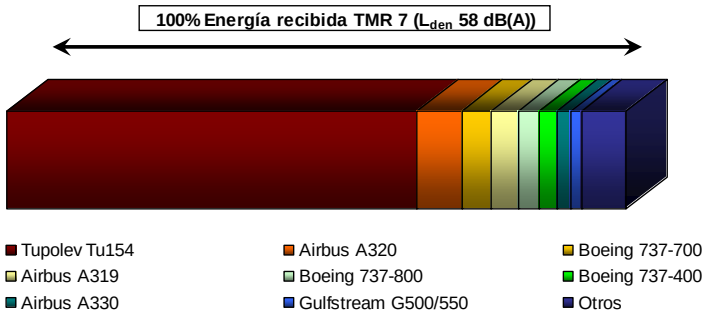


ESCENARIO III — **L_{den}**



Nevertheless, those assessments were not enough to implement a restriction and the study selected some points in populated areas to be analysed more deeply.

Identificador	Coordenada UTM		Localización
	X	Y	
1	*421.003*	*4.570.014*	
2	*419.812*	*4.569.475*	
3	*419.014*	*4.569.291*	
TMR1	*417.061*	*4.569.469*	
TMR7	*419.932*	*4.570.300*	
TMR8	*417.919*	*4.569.274*	



On each singular point (1, 2, 3, TMR1, TMR7 and TMR8) the study calculated the noise energy contribution of each aircraft type into L_{den} and L_{night}.

Modelo de aeronave	% ops E. III	Puntos de control					
		1	2	3	TMR1	TMR7	TMR8
Escenario desarrollo previsible		L_{den} = 66 dB(A)	L_{den} = 62 dB(A)	L_{den} = 59 dB(A)	L_{den} = 43 dB(A)	L_{den} = 58 dB(A)	L_{den} = 50 dB(A)
Tupolev TU-154 (AMC)	*1,6%*	72%	75%	74%	37%	64%	49%
Airbus A320	*14,9%*	6%	4%	4%	11%	7%	9%
Canadair Regional Jet	*17,3%*	1%	1%	1%	2%	1%	2%
Mc Donnell Douglas MD-88	*0,23%*	-	1%	1%	1%	1%	1%

Furthermore, the L_{max} study per operations and per each singular point.

Aircraft type		Operation's number 2008		Singular points					
				1	2	3	TMR1	TMR7	TMR8
Marginally Compliant (MC)	*Tupolev TU-154*	*Day*	*178*	*106*	*103*	*101*	*82*	*102*	*92*
		Eve	*54*						
		Night	*3*						
Chapter 3 no MC	*Mc Donnell Douglas MD-88*	*D*	*14*	*90*	*88*	*87*	*72*	*87*	*82*
		E	*20*						
		N	-						
	Airbus A320	*D*	*1.491*	*83*	*76*	*74*	*63*	*78*	*70*
		E	*573*						
		N	*107*						

Conclusions

- Clear benefits in terms of number of people affected by noise annoyance (under noise insulated levels) and less awakeness due to the aircraft noise;
- Lack of data from some airlines to be presented during the hearing procedure;
- Only one airline was affected at significant levels.

The study was presented firstly to the GTTR and after its approval started the legal process to implement the operating restrictions.

Legal Processing

- Hearing procedure;
- Necessary adjustments;
- Stakeholders communication;
- BOE publication;
- AIP publication.

The lack of noise data certificates from some airlines were solved during the hearing procedures. In general, most airlines understood the measures and made their best efforts to re-schedule aircraft (other times, offered less noisy aircraft). Some problems with International Agreements (Cubana, for instance) and state flights were managed, and some exemptions were applied.

Implementation

- Operations reduction according to the directive's rules and exceptions;
- Inspection and Control.

After all efforts were implemented, the environmental department received less complaints because of sleep disturbance due to aircraft noise. In 2014, Barcelona had not marginally compliant flights.

Lesson learned

- Assessment of different scenarios with and without marginally compliant aircraft, in terms of L_{den} and L_{night} and areas and people exposed to each level, are not enough to implement a restriction and the study had to select some points in populated areas to be analysed more deeply in terms of L_{Amax} (and frequency) and in terms of the noise energy contribution of each aircraft type into L_{den} and L_{night} in those points;
- Clear benefits in terms of number of people affected by noise annoyance (under noise insulated levels) and less awakeness due to aircraft noise during the night period;
- The lack of noise data certificates from some airlines was solved during the hearing procedures. In general, most airlines understood the measures and made their best efforts to re-schedule aircraft (other times, other less noisy aircraft). Nevertheless, this is still missing in many airports. EASA has a database without registration numbers, and there are still some issues to be solved;
- Inspection and control, giving detailed information to the companies and following the infringements.

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6. AENA website Barcelona airport. Environmental website : Strategic maps, Environmental report 2015, PAA, Action plan, DIA, Servidumbres and so on