/Aircraft Noise and Aircraft Noise Abatement

The environment at Munich Airport

Living ideas – Connecting lives

Go CO_2 neutral

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Foreword

Dear Reader,

Air traffic is a major factor in societal development. It helps to secure Germany's economic place in the face of international competition and has immense significance in times of increasing globalization. It makes a substantial contribution not only to exports, but also to the needs of the population in terms of mobility and well-being. Air traffic also means noise, however.

The subject of aircraft noise and complete protection for residents is a chief concern for Munich Airport in dialog with the neighborhood. We, together with the airlines and air traffic control, have for many years been actively engaged in all areas of noise abatement in order to take account of the local residents' need for rest.

Aircraft noise must also be considered and assessed against traffic noise as a whole. The figures show air traffic as a whole to cause the least traffic noise by far, and no other mode of transport has achieved as much success in reducing noise through technological innovations over the past decades as air traffic.

We want to find the right balance based on the legal situation between the interests of residents and the environment and the requirements of industry and people's needs for mobility. To do so we are holding open discussions with all parties concerned.

The aim of this brochure is to look objectively at this issue in the public sphere and to continue discussions with all interested parties.

Dr. Michael Kerkloh
President and CEO, Personnel
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Chief Commercial
and Security Officer

Thomas Weyer
Chief Financial Officer,
Chief Infrastructure Officer


Munich
Berlin-Tegel
Cologne-Bonn
Frankfurt am Main
Noise disturbance: major local differences
Approximately
413,000
aircraft movements in 2018

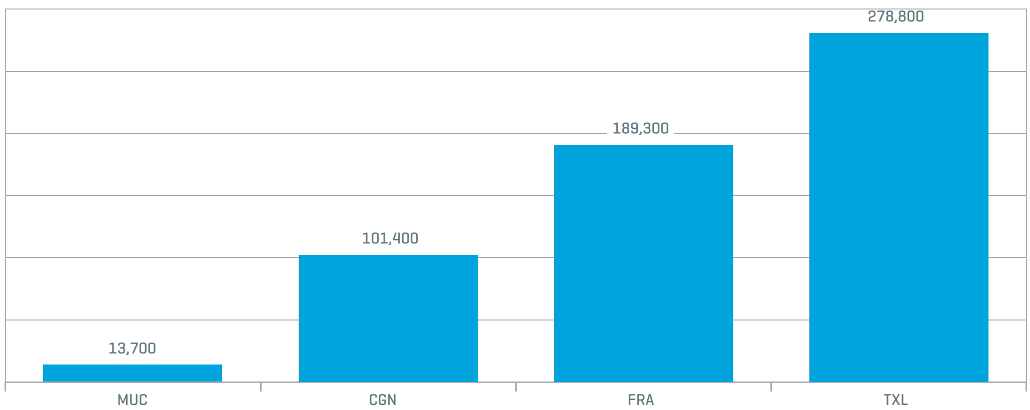
Munich Airport in comparison

Facts and figures
With 46.3 million passengers and 413,500 aircraft movements in 2018, Munich Airport is one of the most important and busiest airports in Europe. It is the second largest German airport and a significant hub connecting Germany to international air traffic. Munich Airport is not only Bavaria's gate to the entire world, but also offers secure jobs to some 38,000 employees. It is one of the key factors for the economic revival of an entire region.

Noise disturbance
When it comes to the number of people directly affected by aircraft noise at major airports, the proportion at Munich is relatively low. Around 7 percent of people are affected in Munich to the same extent as those in Frankfurt. This in no way means that aircraft noise is not an issue for Munich Airport, but rather that the location selected is particularly favorable.

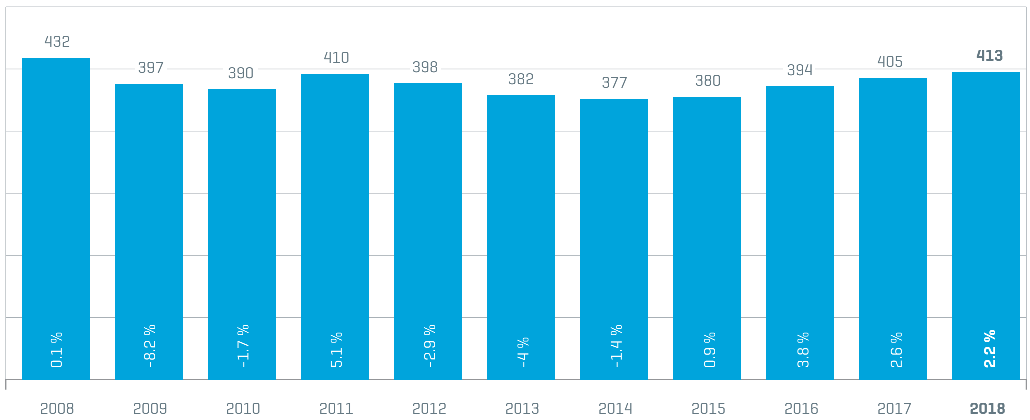
The facts and figures have also been published on the Munich Airport website. www.munich-airport.com/traffic-figures-263342

Noise disturbance



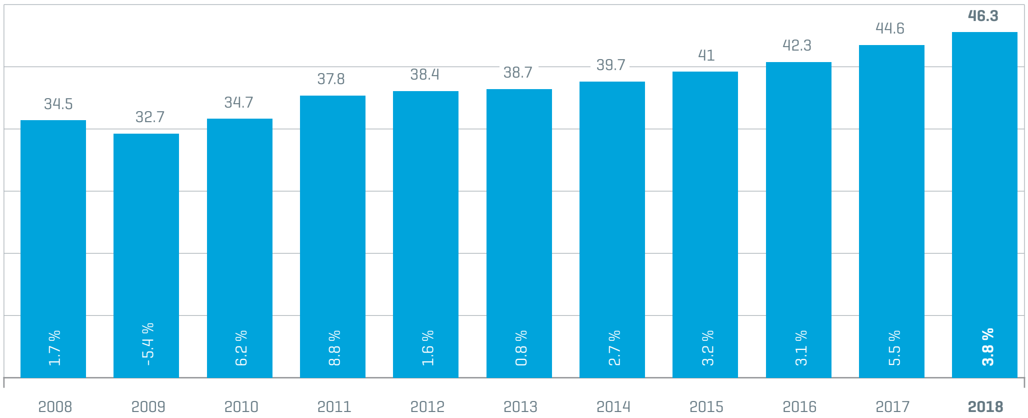
Number of people affected by noise in excess of 55 dB(A) (L_{DEN}) during the day (24 hours); Environmental Noise Directive Source: Federal Environment Agency

Total aircraft movements



2008 – 2018
Take-offs and landings in thousands

Passenger volume in commercial traffic

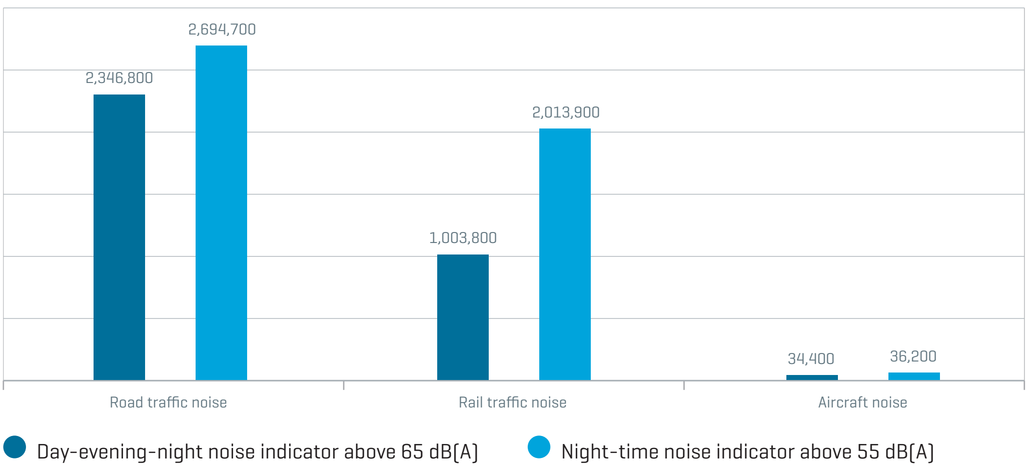


2008 – 2018
Commercial passengers
in millions

www.umweltbundesamt.de/en/indicator-population-exposure-to-traffic-noise

Aircraft noise is also of lesser significance in terms of noise disturbance when compared to other modes of transport. The principal source of noise by far is road traffic.
Rail traffic tends to be a problem at night. Few people as a whole are affected by aircraft noise. This is shown by investigations into exposure to environmental noise using noise mapping in accordance with the Environmental Noise Directive, implemented by § 47c Federal Emissions Control Act (Bundesimmissionsschutzgesetz – BImSchG). For this, the day-evening-night noise indicator L_{DEN} and the night-time noise indicator L_{NIGHT} measured in dB(A) are used to determine exposure to noise in accordance with «COMMISSION DIRECTIVE (EU) 2015/996 of 19 May establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council».

Population exposed to traffic noise around main roads, main train routes, major airports and conurbations (in accordance with the Environmental Noise Directive)



Source:
Federal Environment Agency 2018, noise mapping data 2017, compilation of the notifications of Federal States and Federal Railway Authority pursuant to § 47c BImSchG (date: 30.12.2018)


Approximately
46.3 m
passengers
in 2018
Impact on the population
Road traffic noise
Rail traffic noise
Aircraft noise
Lufthansa
MAX SPAN 30.5m

Causes of noise

Subjective perception – objective measurement

Noise describes any undesired sound that is perceived as disturbing, annoying and loud. The perception of noise is extremely subjective, meaning that everybody experiences sounds differently: some people enjoy loud music, others find it a disturbance.

Sounds are produced by vibrations and are transmitted through the air in the form of sonic waves and perceived by the human ear as sound pressure fluctuations. Sound travels at different speeds depending on the medium, and in the air at around 340 meters per second (m/s). There is a very broad range of perception of sound pressure fluctuations, and sound pressure at the pain threshold is around three million times as high as the hearing threshold. A logarithmic numerical scale specified in ↗decibels (dB) is therefore used to simplify the presentation of sound. With the linear Pascal unit, the scale extends from the hearing threshold at around 20 Micro Pascal (= 20 µP = 20 x 10^{-6} Pascal), which corresponds to 0 dB, through to the pain threshold of almost 100,000,000 Micro Pascal or 130 dB. In the abbreviation dB(A), the (A) stands for an additional filter that takes into account the varying sensitivity of the human ear to high and low tones (frequency), referred to as the A-filter.

↗ Decibel
see Glossary, pp 36-37

The logarithmic principle of the decibel scale requires special calculation rules: doubling the traffic volume leads to a 3 dB increase in noise emissions, however the volume is only perceived to be twice as loud when there is an increase of 10 dB.

From the point of view of physics, aircraft noise are also sound pressure levels of differing amount, duration and frequency. When they are perceived as disturbing or annoying, they are referred to as aircraft noise. Unlike road and rail noise, aircraft noise does not predominantly occur along the complete journey but is rather concentrated on the direct surroundings of the airport in the area of the arrival and departure routes.

Sources of aircraft noise

There are two principal causes of aircraft noise: the engines and the aerodynamic components. The engine noise is made up of the noise created when the jet meets the surrounding air as well as from the noise made by the rotating air blades and kerosene combustion inside the engine.

The aerodynamic noise results from the displaced air flowing around the body of the aircraft and swirling against contact surfaces.

In the past aerodynamic noise was less important. The aerodynamic component has become relevant due to the success in reducing engine noise.

Sources of road noise

Exposure to road noise is mainly determined by the traffic intensity and the noise emissions from the vehicles. The behavior of the driver (especially regarding speed and engine speed) is pivotal. Another important influencing factor is the combination of tires and road surface.

The noise made by motor vehicles are mainly caused by the engine (motor, the air intake and exhaust tract and the gears) and tire contact with the road surface. They primarily depend on the engine speed, the vehicle speed and the condition of tires and the road.

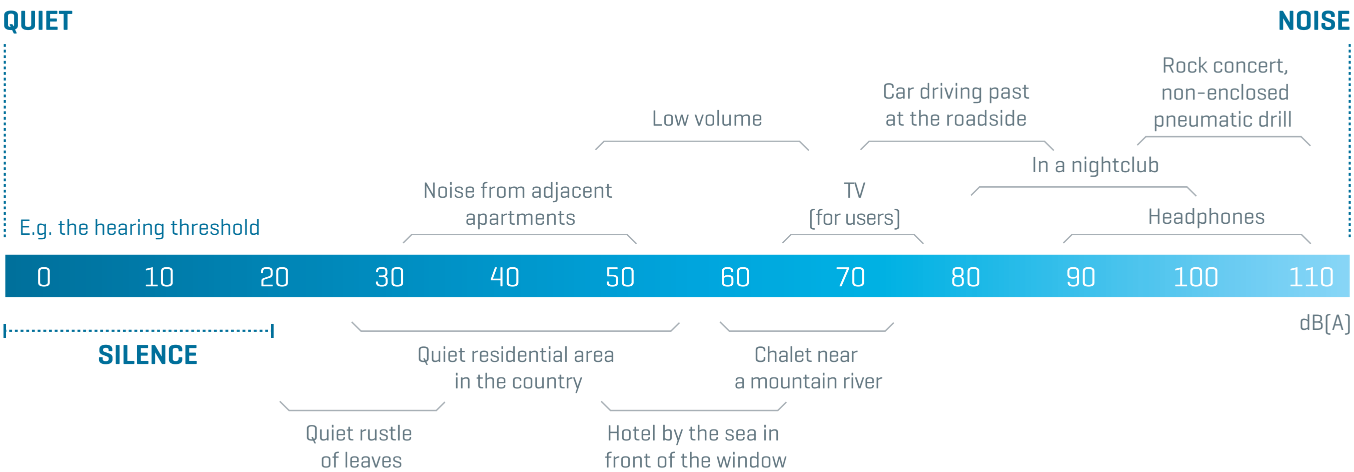
Sources of rail noise

The main sources of noise from rail traffic are as follows:

- Rolling noise from wheel/rail contact
- Aerodynamic noise at speeds exceeding 200 kilometers per hour
- Noise made by the engine and auxiliary power units at low speeds (local public transport (**ÖPNV**), shunting and train station operation)
- Cornering squeal or screeching (**ÖPNV**, area of the (shunting) train station)
- Brake noise, starting noise and shunting noise (**ÖPNV**, area of the (shunting) train station)
- Acoustic signals (for example whistles at level crossings without gates)

The dominant noise on the line is the **rolling noise**. Its intensity largely depends on the speed, the roughness of wheel and rail surfaces and the type of track (rail type, rail mountings and intermediate layers, as well as any rail dampers used). Freight trains mainly run at night and have longer transit times, therefore rail freight **traffic constitutes** the biggest problem for the railways.

Examples of the sound pressure level for various sources of noise



Noise research

One subject of noise research is the degree to which people are disturbed by aircraft noise. This is defined in different ways, and unlike objectively measurable exposure to noise, depends heavily on personal sensitivity to noise.

«What all of these definitions of disturbance have in common is that they are based on a subjective perception that can be neither physically measured nor objectively calculated. The term noise disturbance as well as the survey methods used to determine it are therefore divorced from the measurable physical burden ... All definitions furthermore share the fact that the term disturbance only covers impairments that are below the threshold for detrimental effects on health.»

Surveys also show that the disturbance from aircraft noise is much lower than that caused by road traffic, neighbors or trade and industry.

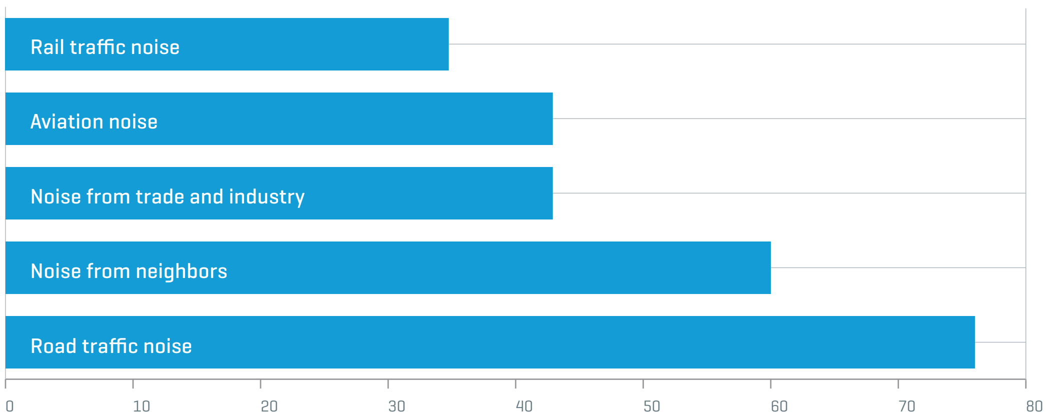
NORAH study

Information about the effects of aircraft, rail traffic and road traffic noise on the health and quality of life of residents affected is contained in the NORAH study into the effects of noise («Noise-Related Annoyance, Cognition, and Health»). This study, headed by Ruhr-University in Bochum, was conducted between 2011 and 2015 at Frankfurt, Berlin, Cologne-Bonn and Stuttgart airports. The study showed that aircraft noise impaired the health of residents near Frankfurt airport to a lesser degree than feared. No significant correlations were identified for risks such as heart attacks, strokes or high blood pressure. The only area where a significant correlation to noise was seen for all modes of transport was in the case of depression and cardiac insufficiency.

www.umweltbundesamt.de/en/topics/transport-noise/noise-effects/noise-annoyance

Source:
Dr. Christian Giesecke
Zeitschrift für Luft- und Weltraumrecht [ZLW] 2018, 1

Exposure to noise in Germany in percent



Source:
Federal Environment Agency 2019

The study results also confirm that the disturbance reaction is greater than had previously been thought. Whether and the extent to which people find noise disturbing can only partially be identified by means of physical indicators, however. Individual perception fluctuates substantially and is influenced by a number of non-acoustic factors such as one's personal attitude to the source of the noise.

Evaluation of research into the effect of aircraft noise on people

Headed by the interdisciplinary sleep center at the Charité-Universitätsmedizin Berlin, experts from the areas of medicine, psychology, epidemiology, statistics and economics have examined the current state of research into the effect of aircraft noise on people. To do so they evaluated scientific literature from journals and

reference books as well as other publications from the years 1970 to 2015 and the NORAH study. This evaluation confirmed findings about the effect of aircraft noise on disturbance perception, the cardiovascular system, sleep and on children's reading comprehension.

Possible effects on other organ systems and diseases have yet to be documented with sufficient accuracy according to the current state of research. Insufficient data is available regarding many questions concerning the link between aircraft noise and health ramifications, and more research is needed.

Air traffic basics

The runway in use is determined by the wind and weather

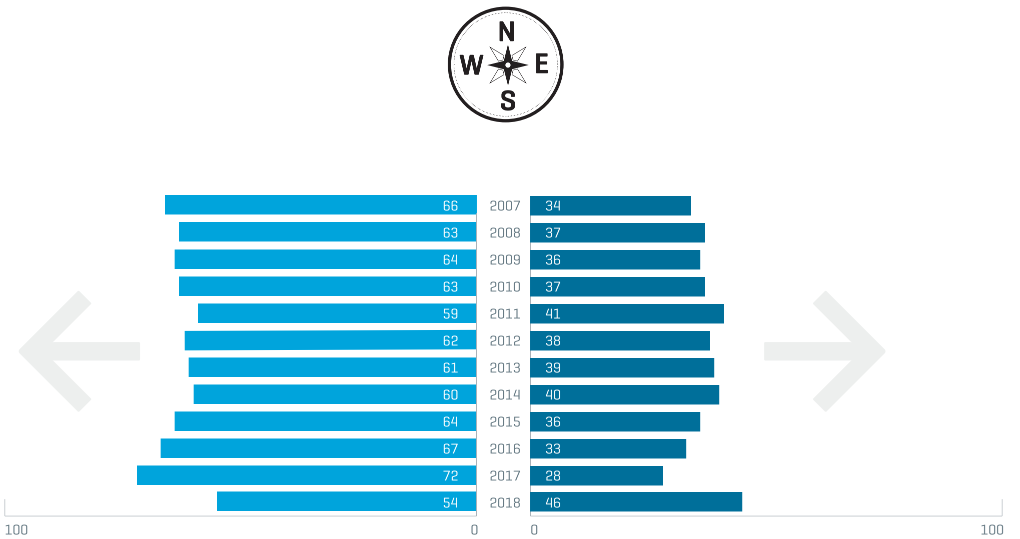
§ Legal clauses
see Legal requirements
pp 32–34

For reasons of flight safety, aircraft always take off and land against the wind. The parallel east/west position of the two runways at Munich Airport produce two ↗ runways in use (operating directions): take-off and landing in a westerly direction is used for two-thirds of the operating time as an annual average, while the eastern operating direction is used for one-third. Different exposure to aircraft noise arises for the surroundings of Munich Airport depending on the runway in use.

↗ Runway in use
(operating direction)
↗ Deutsche Air traffic
control GmbH
see Glossary pp 36–37

Meteorological events such as snow, rain or fog may result in delays at airports. Aircraft movements may then have to take place at times when they will be perceived as more disturbing by those affected. Certain meteorological conditions such as thunderstorms are fundamentally bypassed for safety reasons. This, too, can subsequently lead to aircraft being positioned differently to the published flight procedures. Decisions are based on corresponding air traffic control clearance (see § 31 (3) Air Traffic Ordinance – Luftverkehrsordnung) issued by the air traffic controller responsible (↗ Deutsche Flugsicherung GmbH (DFS)).

Distribution of the operating directions in use in percent



Approaches

During landing, the wind is used firstly for a shortened delay line and secondly to enable the machines to glide in without extending the landing flaps and landing gear prematurely for reasons of speed. In this way as little noise as possible is generated. Especially aircraft approaching Munich Airport opposite the final approach course are initially led parallel to the runway (for example with an approach from the west using the western operating direction).

This generally occurs using transition procedures (↗ Transition to Final Approach). This concerns flight procedures which among other things are parallel to the runways and whose routes are defined by navigation points, referred to as waypoints. Aircraft making a downwind approach are then guided by means of a 180° curve onto the final approach course or extended runway centerline. This takes place at different distances from the airport depending on factors such as traffic volume. If the aircraft are on their final approach, the remaining approach up to touchdown is generally conducted with the help of the ↗ instrument landing system. This system specifies both the approach line (centerline) and the glide slope.

Departures

Departures against the wind have a positive influence on the noise generated: the aircraft climbs more steeply and faster due to the headwind and gains height more rapidly so that the greater distance from the ground leads to a faster reduction in the aircraft noise reaching it. The departure procedures are planned according to the following assumptions:

- Departure procedures must enable the DFS to handle air traffic in a safe, orderly and expeditious manner.
- During planning it must be taken into consideration that aviation authorities and the air traffic control organization must work towards protecting people from unreasonable aircraft noise (see § 29b (2) Air Traffic Act [LuftVG]).

The length of the flight procedure must be acceptable, taking account of all points. During normal operation it is not permitted to abort departure procedures without prior clearance by air traffic controllers.

In the course of safe, orderly and expeditious traffic handling there is, for example, the opportunity using individual clearances (see § 26 (2) Sentence 2 LuftVO) to guide departing jets over 5,000 ↗ feet (1,524 meters) above ground and propeller aircraft over 3,000 feet (914 meters) above ground to individual routes also outside of published departure procedures. Among other things this can contribute to reducing negative environmental effects. Shorter flight routes result in lower kerosene consumption, for example. This fundamentally also reduces CO_2 emissions.

Thunderstorms in the area of departure procedures may be a reason for crews to ask air traffic control for clearance to enable them to avoid these storms. The air traffic controllers will accede to this request where there are no flight safety arguments against doing so. The altered route may mean flying over individual towns or villages although no storm can be seen there (from the ground).

§ Legal clauses
see Legal requirements pp 32-34

↗ Transition to final approach
↗ Instrument landing system
↗ Foot
see Glossary pp 36-37

Planning flight procedures

Planning process

§ Legal clauses
see Legal requirements
pp 32-34

Based on DFS flight procedure planning, the Federal Supervisory Authority for Air Navigation Services (BAF) stipulates flight procedures by means of a legal ordinance. It does so following advice from the Aircraft Noise Commission with the involvement of the Federal Environment Agency (UBA) where applicable and after an examination of compliance with legal requirements by the Federal Ministry of Justice and Consumer Protection (BMJV). If the responsible air traffic control unit issues no contrary air traffic control clearance in accordance with § 31 (3) LuftVO, the pilot must follow the prescribed flight procedures for flights within the control zones, for approaches and departures to and from airports with an air traffic control unit and for flights in accordance with Standard Instrument Departure, (see § 33 (1) LuftVO). According to § 27c (1) LuftVG, air traffic control serves the safe, orderly and expeditious handling of air traffic.

Under § 1 (1) LuftVG, aircraft are free to use airspace «… insofar as use is not limited by this Act, by legal provisions enacted to implement this Act, by international law applicable domestically, by legal acts of the European Union and legal provisions enacted to implement these provisions».

- Strict national regulations and international standards and recommendations, including the International Civil Aviation Organization (ICAO, a sub-organization of the United Nations), must fundamentally be taken into consideration when planning flight procedures. The approach and departure procedures («flight routes») are consequently «tailored» to every runway and operating direction.
- Aviation authorities and the DFS must work towards protecting the general public from unreasonable aircraft noise in accordance with § 29b (2) LuftVG.
- In order to be able to give sound consideration to aspects of exposure to noise during planning, the DFS operates the ↗NIROS planning tool (Noise Impact Reduction and Optimization System), using which departure procedures for flights are optimized in accordance with ↗Standard Instrument Departure or SID for short with respect to the public noise disturbance they cause. The aim of NIROS is to identify minimum noise routings based on scientific findings.

↗ NIROS
↗ Standard Instrument Departure
see Glossary pp 36-37

Coordination with the Aircraft Noise Commission

Planned approach or departure procedures are firstly presented to the local Aircraft Noise Commission (FLK) and discussed there. The staffing of the Aircraft Noise Commission is set out in § 32b (4) LuftVG. The approval authority for the commercial airport concerned – which for Munich Airport is the Bavarian State Ministry for Housing, Construction and Transport (BayStMB) – appoints the members. For the Aircraft Noise Commission for Munich Airport these are representatives of the municipalities and administrative districts affected by aircraft noise in the vicinity of the Airport (as a rule of the mayors), representatives of the airlines, of the Airport operator and of the Bavarian State Ministry for the Environment and Consumer Protection (BayStMUV) and BayStMB. The Commission is entitled to propose measures to protect the public from aircraft noise or reduce air pollution by aircraft in the area of the airport to the

approval authority, the BAF and the DFS. If these institutions consider the proposed measures to be unsuitable or impracticable, they inform the Commission, giving reasons (see § 32b (3) LuftVG). This provides a full explanation if proposals cannot be implemented. Residents have the opportunity through their local representatives to make suggestions on the issues being dealt with by the Aircraft Noise Commission.

Once the DFS has weighed up all proposals and variants, it presents its result to the BAF. If the flight procedure planning is of particular importance for protecting the public against aircraft noise, the BAF refers it to the UBA for examination. The BAF finally lays down the flight procedure as a legal regulation on the basis of a comprehensive impact assessment, taking the positions of the UBA and Aircraft Noise Commission into consideration.

Once the examination of compliance with legal requirements has been conducted by the BMJV, flight procedures are announced in the Federal Gazette and published in the «Nachrichten für Luftfahrer» (Notices to Airmen), the official journal for aviation in the Federal Republic of Germany.

§ Legal clauses
see Legal requirements
pp 32-34

Aircraft noise monitoring

Comprehensive measurements

Under § 19a LuftVG, airport operators are required to set up and continuously operate «equipment to measure and record the noise levels of inbound and outbound aircraft at their airports and in surrounding areas».

↗ Flughafen München GmbH (FMG) currently operates 16 stationary monitoring points which, in agreement with the Aircraft Noise Commission, are within a 20-kilometer radius of the Airport. The monitoring points are mainly close to the publicized approach and departure routes or are near towns and villages affected by the aircraft noise, and have been ideally situated to produce meaningful results:

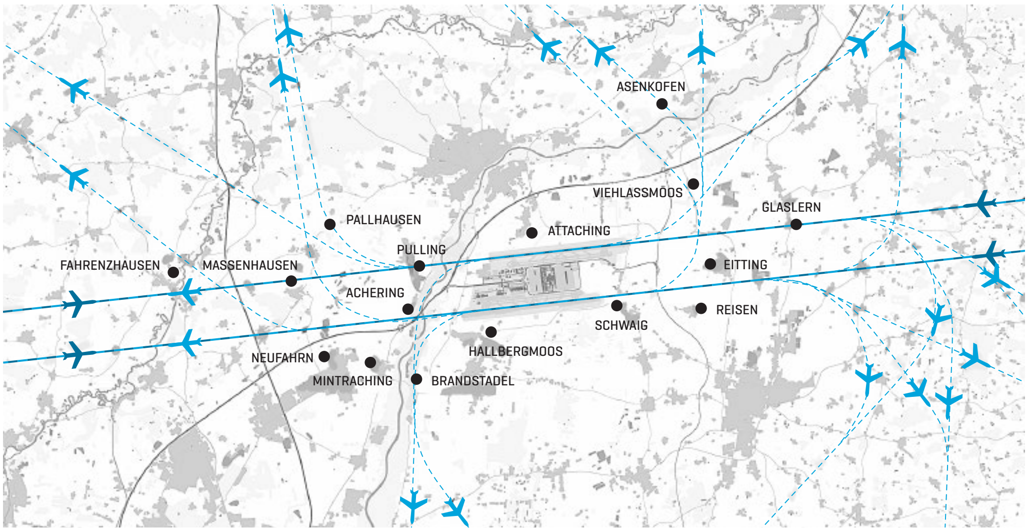
- Close distance to publicized approach and departure routes to register as many noise events caused by overflying aircraft as possible
- Close to housing so as to correctly map the impact on the population
- Avoiding extraneous noise, for example from road traffic, agricultural traffic

Three mobile monitoring points are also used at places where no information on exposure to aircraft noise is provided by stationary monitoring equipment. The use of mobile monitoring points is a voluntary additional service provided by FMG and may be applied for by the Aircraft Noise Commission and the communities affected by aircraft noise.

Here too, the most modern environmental technology is deployed. One monitoring point was fitted with a solar panel in spring 2019. A combination of photovoltaic and fuel cell supplies the station fully independently with electricity. As soon as the solar system is unable to supply sufficient power (batteries are empty), the fuel cell turns on automatically, supplying the system with power and charging the batteries.

§ Legal clauses
see Legal requirements pp 32-34

↗ Flughafen München GmbH (FMG)
see Glossary pp 36-37



Aircraft noise monitoring – sites of the Flughafen München GmbH stationary monitoring points

Quality-assured readings

All FMG noise measurements meet the requirements in DIN 45643 «Measurement and assessment of aircraft sound». Every monitoring point and all meteorological components meet the highest electro-acoustic specifications and use sound level meters rated precision class 1. Every monitoring point is inspected daily to ensure the aircraft noise monitoring equipment is in full working order, with acoustic calibration during an interim inspection every six months. The measuring components are calibrated at prescribed intervals by an external and certified calibration laboratory.

Each monitoring point records sound levels every second, thereby producing a noise level curve. Using aircraft noise parameters, aircraft noise events can be identified as such, guaranteeing the greatest possible number of measured aircraft movements or aircraft noise events. At the same time this method enables possible extraneous noise to be filtered out.

NB: Only the continuous sound level is used in assessments of all other modes of transport such as road or rail traffic.

The readings or aircraft noise events are assigned to the flight movements causing them. Since April 2002, DFS radar data has been used for the correlation, and this allows an extremely accurate assignment and high automatic correlation rate.
To avoid distortions, there are checks for whether there were any prevailing extreme weather events during the measurement period (for example wind speeds > 10 m/s). Meteorological data is used here, which is recorded by three monitoring points at the same time as the aircraft noise events. Because high wind speeds can distort the noise levels measured (the wind itself causes notable sound pressure levels on the microphone at high wind speeds), the aircraft noise events recorded under these conditions are not taken into consideration in the statistical analyses. This also occurs where very high levels of extraneous noise are superimposed on aircraft noise, so preventing a correct measurement of the aircraft noise.

↗ Continuous sound level
↗ Individual noise event
see Glossary pp 36-37

Only after the following manual check and correlation of each individual aircraft noise event acoustic parameters such as the ↗ continuous sound level are calculated and saved together with all acoustic and meteorological readings and indices for subsequent evaluations.

In addition to its use in general aircraft noise monitoring, this quality-assured data forms the basis for reports to the Aircraft Noise Commission, for the regularly published emissions reports, for noise-related take-off and landing charge calculations and when responding to complaints about aircraft noise.

Individual noise events and continuous sound level

Two variables are used as a benchmark for noise disturbance: ↗ individual noise events $L_{p,AS,max}$ and the continuous sound level $L_{p,A,eq,T}$ each expressed in dB(A).

An individual noise event $L_{p,AS,max}$ describes the maximum sound pressure level of a noise event, for example produced by a single passing or overhead plane. The continuous sound level $L_{p,A,eq,T}$ (frequently referred to as the average sound level) indicates sound levels that vary over time using just one figure. The intensity and duration of each individual noise over a specific evaluation period is incorporated in the continuous sound level – with disproportionate intensity due to the logarithmic principle.

The equivalent continuous sound level $L_{p,A,eq,Fl,day}$ and $L_{p,A,eq,Fl,night}$, are decisive when assessing aircraft noise. The 'day' assessment period covers the time from 6 a.m. to 10 p.m., and the 'night' assessment period from 10 p.m. to 6 a.m.

Transparent communication of the readings

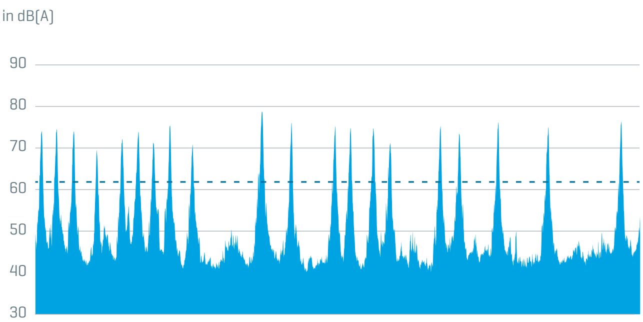
The measurement results are published in web reporting on the FMG website. In addition to the monthly measurement reports for the 16 stationary monitoring points, this service also includes individual reports from mobile measurements and further information on the distribution of the runways in use, route allocation, night flights or model mix and annual comparisons of aircraft noise trends. The results are presented at the meetings of the Aircraft Noise Commission which are held at least twice a year.

Following aircraft movements live

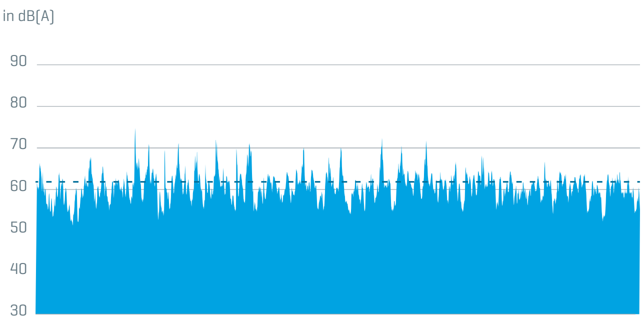
Current aircraft movements can be accessed with a delay of a few minutes on the FMG website. The model of aircraft, airline, the starting point or destination, altitude and the angle of approach or ascent are displayed. The map can be marked at a desired point to see the altitude of planes flying over it or the lateral clearance they have to the approach or take-off line. Data from the aircraft noise monitoring points is likewise displayed with a click of the mouse.

Further information can be found using the following link: www.munich-airport.com/noise-protection-264207

Air traffic
Continuous sound level/average sound level = 62 dB(A)



Road traffic
Continuous sound level/average sound level = 62 dB(A)



Typical noise level curve for air and road traffic: equally high continuous sound levels can arise despite different progressions (noise breaks and higher individual noise levels for air traffic).

Bigger, more economical and quieter: The Airbus A350-900 is the most modern and environmentally friendly long-haul aircraft in the world. Lufthansa has stationed 15 of this model of aircraft at Munich Airport.

Reducing aircraft noise

Noise certification for aircraft

The permitted noise emissions from aircraft are regulated internationally in Annex 16, Volume I of the International Civil Aviation Organization (ICAO) aviation agreement. This noise regulation contains detailed provisions for measuring noise emissions and evaluating the results, as well as for granting noise approvals for aircraft. ↗ ICAO Annex 16 is subdivided into various chapters dealing with the noise certification provisions and noise limit values for different aircraft. The majority of civil subsonic jet aircraft currently in use are certified in accordance with Chapter 3. The provisions, instructions and procedures under ICAO Annex 16 have been transposed into German law by means of the «Noise regulations for aircraft (Lärmvorschriften für Luftfahrzeuge – LVL)».

Noise approval is granted according to a standardized procedure in which the noise emissions of the aircraft are measured at three defined monitoring points during a flyover.

In 2001, the ICAO agreed to tighten the exposure limits for civil subsonic jet aircraft and heavy propeller aircraft. A noise threshold was set that is 10 EPNdB below the total of the three noise thresholds regulated in Chapter 3 of ICAO Annex 16. The noise thresholds apply from 1 January 2006 to the approval of new models of aircraft. These aircraft are designated Chapter 4 planes because the noise regulations are stipulated in Chapter 4 of ICAO Annex 16. Many aircraft already fall below the Chapter 4 noise thresholds at Munich Airport.

With the further developments in engine technology and changes to aircraft design, a further reduction of around 10 EPNdB has already been achieved, and airlines increasingly opt for this new and quieter engine technology when ordering new aircraft.

↗ ICAO-Annex 16
see Glossary pp 36-37

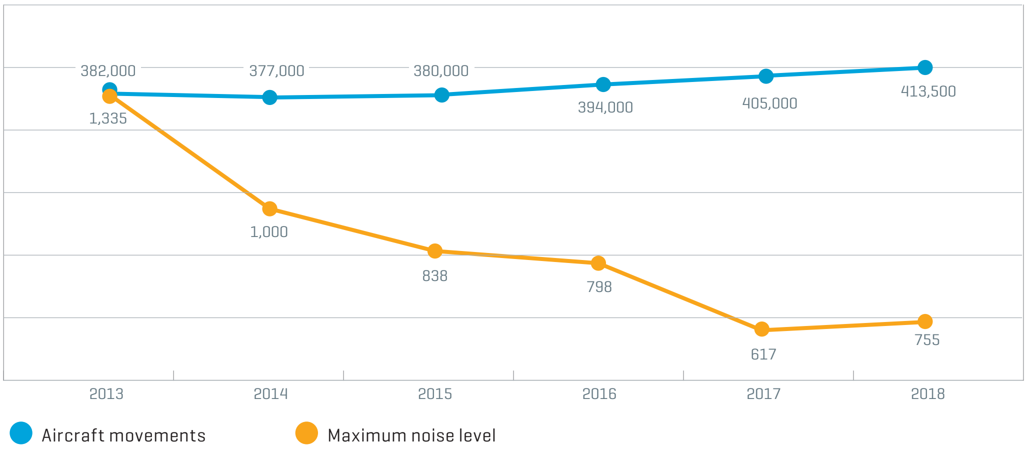
New models of aircraft at Munich Airport which already fall below the Chapter 4 limit value by more than 10 EPNdB

Model of aircraft	Falling below the Chapter 4 limit value by EPNdB	Aircraft movements in 2018
Airbus 350-900	-22	7,029
Airbus A320neo	-20	2,090
Boeing 787-9	-19	1,458

This also complies with the objectives of the EU's ACARE-Council (Advisory Council for Aeronautic Research in Europe) which in its Vision 2020 aims to halve the perception of external noise (a noise reduction of 10 dB[A]). The aim of the EU «Flight Path 2050» is to reduce noise emissions by 65 percent by 2050.

Reducing the maximum noise level

Through the deployment of quiet models of aircraft, the number of high individual noise events with $L_{p,AS,max}$ > 85 dB(A) has decreased in the past five years despite increasing aircraft movement figures.



Bonus list

The former Federal Ministry for Transport, Building and Urban Development (BMVBS) devised the so-called list procedure to differentiate charges for Chapter 3 aircraft under ICAO Annex 16. According to this procedure that is based on current noise measurements for the airports, models of aircraft that are particularly quiet during take-off and landing are incorporated in the «bonus list».

Emissions-related take-off and landing charges

Munich Airport influences the aircraft deployed through the use of noise differentiated landing charges. Airlines using quiet aircraft benefit from a graduated, widely differing charge system. The noise charge is determined using fixed noise classes based on the average noise level during landing and take-off.

The noise-related take-off and landing charges can be eight times as high for a loud model of aircraft as for a quiet one. At the start of 2009, FMG increased this part of the charge by 60 percent, thereby creating a further economic incentive for airlines to deploy modern and quiet planes.

Strict regulations for night flights

The regulations governing night flight traffic at Munich Airport were changed in March 2001 by an amendment to the aviation law permit issued by the District Government of Upper Bavaria (ROB).

Only night airmail and calibration flights by the DFS are permitted during the so-called core period (from midnight to 5 a.m.). The only exceptions to this are emergency and aid relief flights, landings essential for reasons of flight safety and flights for which special dispensations have been granted by Bavaria's Ministry of the Interior (BayStMI) or the aviation supervisory authority to avoid major disruptions in air traffic or for other reasons of special public interest.

In the marginal night hours (from 10 p.m. to midnight and from 5 – 6 a.m.), flights are only permitted by aircraft that are set out in the «bonus list» of the Federal Ministry of the BMVBS. This excludes delayed flight movements or early landings of aircraft with noise certifications that at least correspond to the requirements in ICAO Chapter 3.

The flight movements must also meet one of the following approval criteria:

- Scheduled aircraft movements in regular and charter transport (maximum of 28 per night)
- Flights by airlines that maintain a home base in Munich
- Aircraft which on average do not generate any individual noise events louder than 75 dB(A) at the noise monitoring points near Munich Airport
- Training and practice flights

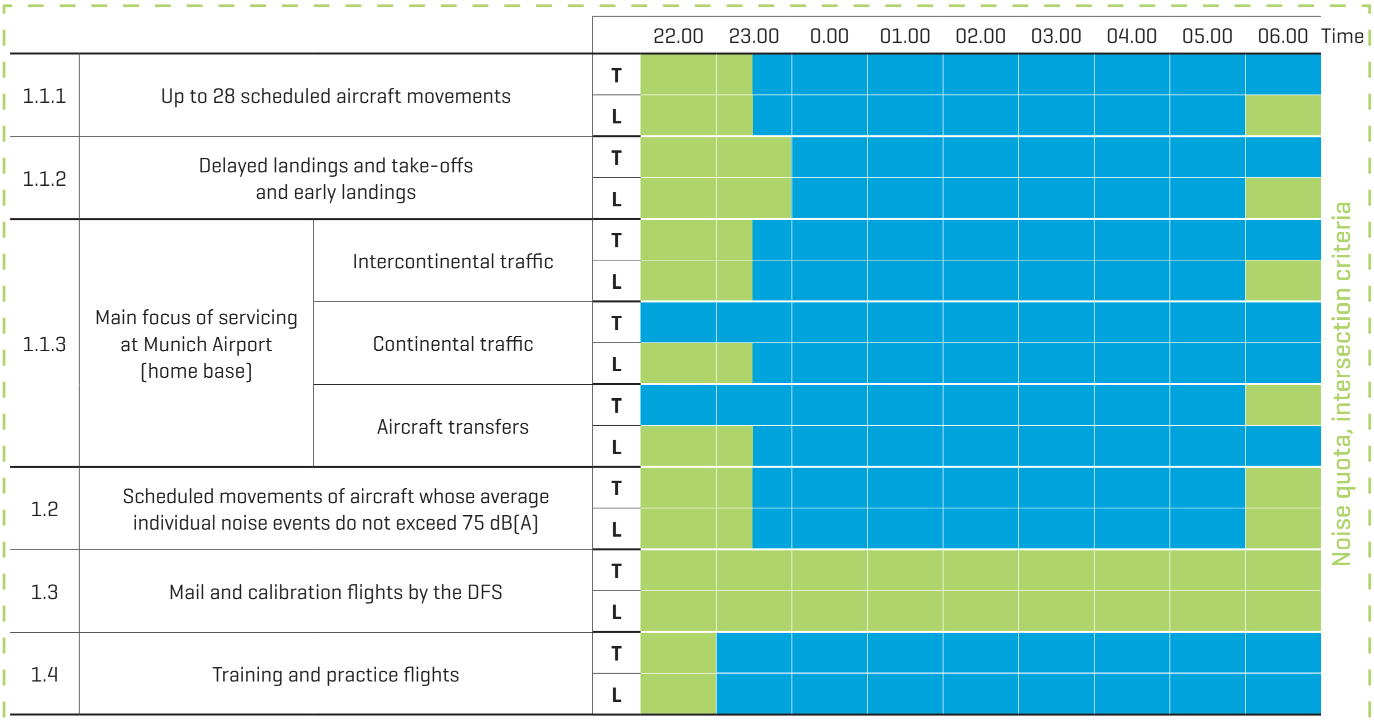
Night flight operations at Munich Airport are furthermore only permitted where the aircraft noise generated by all night flights does not exceed a fixed annual noise quota.

The use of quieter aircraft therefore permits a larger number of night-time flight movements, while only fewer aircraft movements are possible when louder aircraft are used. Moreover, the equivalent continuous noise level L_{eq} calculated during the average night of a calendar year at the intersections of flight paths with the boundary of the combined day and night protection zone must not exceed 50 dB(A). Compliance with the noise quota and continuous sound level must be demonstrated annually to the aviation authorities and the Aircraft Noise Commission. This also ensures that the correct implementation of the night flight regulation and the development of night flight operations is transparent and understandable for the general public.

Passive noise protection measures

When opening Munich Airport, FMG implemented an extensive noise protection program. When the regulations governing night flights were amended on 23 March 2001, the night protection area was expanded once more, and a combined day and night protection area designated with the existing daytime protection area. People living in this area had the opportunity to assert claims for noise protection in living rooms and bedrooms. FMG has carried out considerable

Summary of the night flight regulations at Munich Airport
in accordance with Change Authorization Number A.I. dated 23.3.2001



Exceptions: Restrictions in A.I.1 do not apply to
2.1 Relief flights during emergencies and disasters and when executing police duties
2.2 Landings for meteorological, technical and other flight safety reasons
2.3 Flights authorized by BayStMB or the aviation supervisory authority for which special dispensations have been granted to avoid substantial disruptions in air traffic or for other reasons of special public interest

T Take-off
L Landing
permitted
not permitted

noise protection measures to ensure that, as a rule, no individual noise events exceeding 55 dB(A) occur inside rooms where windows are closed. Since then, FMG has installed around 21,000 soundproof windows and some 20,000 fans.

FMG has taken further measures in subsequent years to support citizens with the care and upkeep of guaranteed noise protection measures. In particular, as part of a voluntary service program FMG has serviced windows or replaced misted insulated cast resin panes. Since 1992, FMG has invested a total of € 62 million in soundproofing.

Flight ban for loud aircraft

With the phasing out regulations (Directive 92/14/EEC of 2 March 1992 – Limitation of the operation of Chapter 2 aircraft covered by ICAO Annex 16), Chapter 2 aircraft have been banned from operating since 1 April 2002. Exceptions to this rule only apply to aircraft with a maximum take-off mass of 34 tons or fewer than 19 seats. The BMVI can also grant exceptions to airlines from former Warsaw Pact states.

Engine technology with ever new findings

Technologies currently being developed may be expected to produce further advances in future because reducing aircraft noise is also a key concern and development objective for aircraft and engine manufacturers. This is not merely because certain noise reduction measures reduce kerosene consumption, but also because in recent years in particular there has been increasing political pressure to reduce aircraft noise. Technical measures to reduce aircraft noise are expensive, time-consuming and usually decided and implemented at an international level. One extremely successful approach is the geared turbofan, an aircraft engine which by isolating the fan and low-pressure turbine helps to considerably reduce noise. Future plans for further significant noise reductions include the use of temperature-resistant lightweight materials and a fast-running, highly efficient expansion system with very high bypass ratios. Two-shaft engines with high bypass ratio, referred to as LEAP engines (Leading-Edge-Aviation-Propulsion), are also designed to reduce noise.

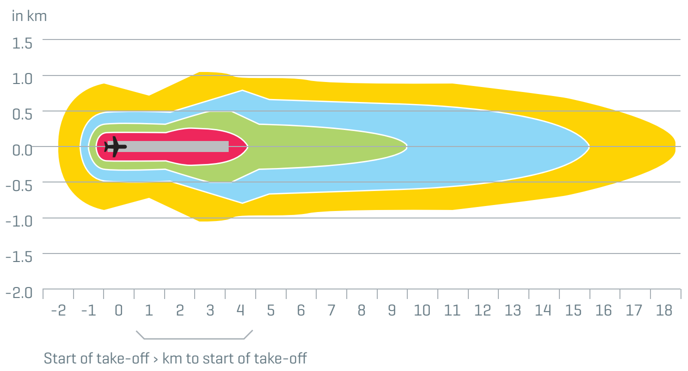
A350: high-flyer from Airbus halves noise

The Airbus A350-900 is the most modern and environmentally friendly long-haul aircraft in the world. It causes much lower noise levels compared to its predecessor, the A340 – on take-off up to 7 dB(A) lower and on landing up to 3 dB(A) lower. The noise contour of the A350-900 is 40 to 50 percent smaller compared to the A340, and it has no level exceeding 85 dB(A) outside the airport. This results in lower exposure to aircraft noise in the airport surroundings. Thanks to the most up-to-date engines and special aircraft design, the A350-900 uses 50 percent less kerosene in total and therefore emits 50 percent less CO_2. Lufthansa stations 15 A350-900 long-haul planes at its Munich hub. The Airbus A320neo, currently the most efficient and quietest aircraft for short and medium-haul routes, also serves Munich Airport. It is fitted with the latest generation of engines that reduce fuel consumption by 15 percent. This is accompanied by reduced carbon dioxide emissions and noise.

Facts about the Airbus A350-900

Length	66.8 m
Wingspan	64.8 m
Height	17.1 m
Speed	910 km/h
Range	15,000 km

Comparison of take-off footprint of the 75 dB(A) contours



- Chapter 2, Annex 16 model of aircraft (banned in the EU since 2002), e.g.: B737–200
- First generation Chapter 3, Annex 16 model of aircraft, e.g.: MD80, B737–200 Hush Kit
- Model of aircraft with current Chapter 4, Annex 16 engines, e.g.: A320, B737–800
- Modern models of aircraft with geared turbofan engines, e.g.: A320neo

Engine test facility minimizes noise impact

Engine test runs can be associated with high noise emissions. These are always necessary when systems need to be checked and/or the performance of engines has to be tested following maintenance work or if there are any irregularities. Frequently the only time available for these inspections is at night. To enable tests to be conducted at that time, FMG has erected a noise protection system designed specifically for this.

Although the hangar is open to the east and west, 20-centimeter-thick reinforced concrete walls, 10-centimeter thick acoustic panels on the internal walls and ceiling as well as its conical shape guarantee consistent sound refraction. Despite a peak noise level of more than 120 dB(A) inside the hangar, hardly anything can be heard beyond the premises of the Airport. Just 1,400 meters away, and therefore close to the nearest residential area, the exterior noise level does not exceed 55 dB(A).

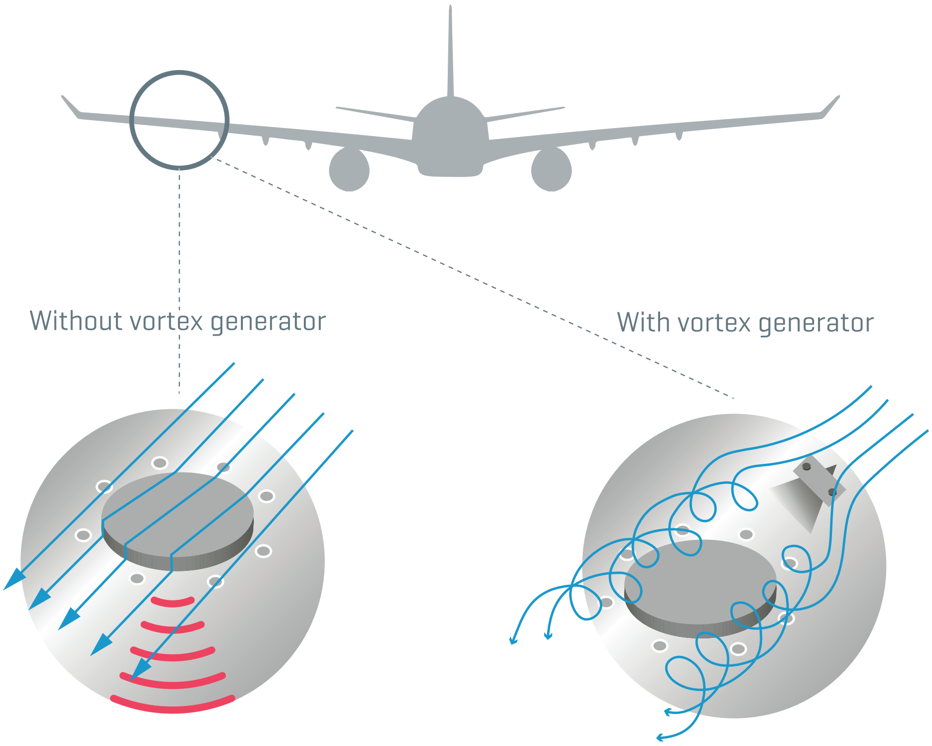
Optimized flight procedures

Continuous Descent Operations (also referred to as Continuous Descent Approach, CDA) describes a flight procedure where the aircraft descends with minimal engine power (ideally at idle thrust) and avoids horizontal flight phases, which reduces fuel consumption and CO_2 emissions. A reduction in noise may also be anticipated in some areas. These flight procedures have also been published for Munich Airport.

Pre-conditioned air systems

Pre-conditioned air systems (PCA) have been used at aircraft stands near the building since 2016. These systems supply aircraft with pre-conditioned air during the ground handling process and replace the aircraft's own auxiliary power units that had been used previously. The new systems substantially reduce exposure to noise on the apron.

Reducing noise at its source



Vortex generators

Openings, gaps and grooves on the aircraft generate air turbulence during the flight, and these in turn lead to pressure fluctuations. This creates sounds similar to bubbles above the opening to a gas cylinder. Vortex generators generate horizontal vortices that alter the airflow above the openings in a way that prevents these sounds occurring.

Artificial «shark's skin»

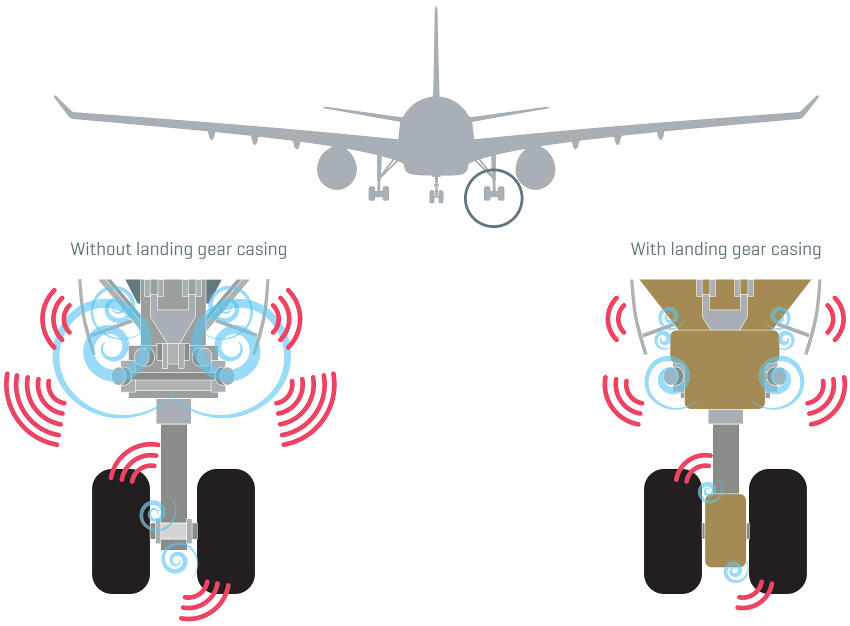
Ribbed surface structures have better aerodynamics.

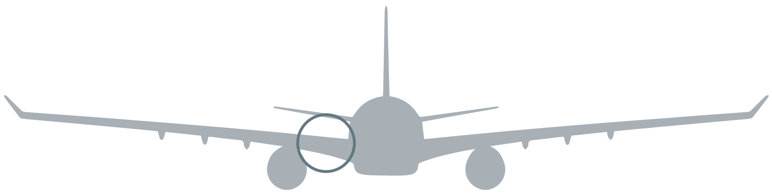
Source: Lufthansa Technik

Wing tips: Winglets indirectly ensure less noise

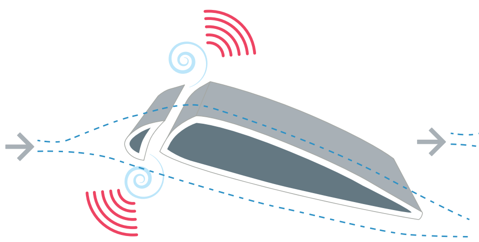
Aircraft are able to fly because different air pressure is generated above and beneath the wings, which results in air turbulence primarily on the wings. Ever since the 1970s, scientists have been working on reducing the resultant air resistance, because the greater the air resistance, the more energy is needed to fly. One solution to the problem is for the wing tips to be curved upwards. Engineers have dubbed these Winglets or Sharklets.

Less aircraft noise due to wind-protected landing gear

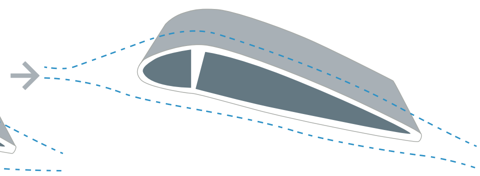




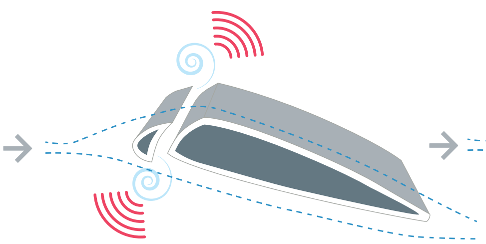
Wing cross-section
when landing



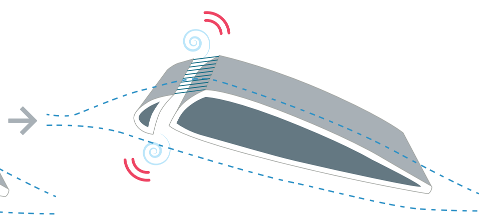
Conventional slats



Droop nose



Conventional slats



Slats with brushes

Front edge of the wings: droop nose for less noise

Industry and research have also looked into how noise can be reduced on the slats. Slats are moving and normally concealed parts on the wings. They are extended during take-off and landing to support the required lift or braking action. A gap between the slats and the actual wings opens up and causes air turbulence – and thus noise. The German Aerospace Center (Deutsche Zentrum für Luft- and Raumfahrt – DLR) has further developed the conventional, separate slat to produce a kind of droop nose on the wing. Getting rid of the gap that occurs when extending conventional slats considerably reduces turbulence and noise. The droop nose is now being used on the Airbus A380 and A350 XWB.

Slats: brushes break up the air flow

The brush solution offers another way to reduce noise on the slats. DLR researchers are now looking into how to minimize the air turbulence created when extending the slats. With the brush solution, the air no longer flows over an edge, but is divided into lots of small airflows by the hairs on the brushes. The scientists believe that aircraft noise can be reduced by 4 decibels in this way.

§

Legal requirements

Air Traffic Noise Act

With the amended Air Traffic Noise Act (FluLärmG) which came into force on 31 October 2007 the legislator greatly improved the incorporation of legitimate noise protection interests of people living near airports and fundamentally modernized protection against aircraft noise. The law in particular takes account of current findings regarding the impact of noise and the relevant operating limits. A number of regulations in the Air Traffic Act concerning aircraft noise abatement were also amended and advanced, principally guaranteeing better information for those affected, greater consideration of noise protection matters and the relevance of the applicable FluLärmG aircraft noise protection thresholds when setting up noise protection areas during aircraft noise related decisions. The amendment to the law introduced applicable thresholds to define noise protection areas and, for the first time, a night protection zone for airports with relevant night flight operations.

According to § 1 FluLärmG, the purpose of the law is «to ensure there are structural limitations and structural noise protection in the area of airports to protect the general public and neighborhood from danger, major disadvantages and major disturbance caused by aircraft noise».

The principal content of the FluLärmG concerns the following:

- Identifying protection zones
  - Daytime protection zone 1
  - Daytime protection zone 2
  - Night protection zone
- Reimbursement of structural sound insulation measures in daytime protection zone 1 and in the night protection zone
- Compensation for impairments to the outdoor living area in daytime protection zone 1
- Bans on building and limitations on structural use

An evaluation of the FluLärmG is currently being carried out, the legal basis for which was provided under § 2 (3) FluLärmG. According to this, the Federal Government is required to report back to the German Bundestag by 2017 at the latest regarding a review of the key noise values when defining the protection zones inside the noise abatement area, taking consideration of the state of research into noise impact and of aeronautical engineering.

EU-Environmental Noise Directive

Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise (Environmental Noise Directive) was adopted on 25 June 2002. Environmental noise within the meaning of the Directive is caused principally by road, rail and air traffic and by industrial areas in conurbations.

In accordance with the EC Environmental Noise Directive, noise mapping was required to be drawn up for major conurbations on the busiest main roads and for the larger airports for the years 2007, 2012 and most recently 2017. Among other things it stipulates the identification of exposure near airports with a traffic volume exceeding 50,000 movements per year and the presentation of data in the form of noise mapping.

The Federal Ordinance on Strategic Noise Mapping (34th Federal Emissions Control Act – BImSchV) in conjunction with the «Provisional Calculation Methods for Environmental Noise at Airports (VBUF)» currently regulates the calculation details and sets out the requirements for presenting the exposure in the noise mapping. New, uniform EU-wide criteria will apply as from the next mapping cycle, and in 2015 the EU Commission published new assessment methods to this end (Common Noise Assessment Methods in EU, CNOSSOS-EU). Member states must apply these methods from 31 December 2018.

The Bavarian Environment Agency (LfU) is responsible for mapping Munich Airport. The aim of the Directive is to define a pan-European concept for evaluating and combatting environmental noise. It therefore obliges member states to record exposure to noise by means of noise mapping, to provide public information using the noise mapping, to prepare plans for action in the event of problematic noise situations («noise hot spots») with the participation of the public (Munich Airport is not a hot spot of this kind) and to notify the EU Commission about the results of mapping and plan of action in their territory.

Statutory framework conditions

Extracts from the German «Air Traffic Act in the version published on 10 May 2007 (BGBl. I p 698), most recently amended by Article 2 (11) of the law dated 20 July 2917 (BGBl. I p 2808; 2018 I 472)»:

§ 1 Air traffic Act (LuftVG)
(1) The use of airspace by aircraft is free insofar as use is not limited by this Act, by legal provisions enacted to implement this Act, by international law applicable domestically, by legal acts of the European Union and legal provisions enacted to implement these provisions.

§ 19a Air traffic Act (LuftVG)
Within a period determined by the approval authority, operators of an airport or landing site within the meaning of § 4 (1) No. 1 and 2 Air Traffic Noise Act are required to set up and continuously operate equipment to measure and record the noise levels of inbound and outbound aircraft at their airports and in surrounding areas. The measurement and evaluation results must be communicated to the approval authority and the Commission pursuant to § 32b and to other authorities if required to do so by the approval authority and must be published periodically. The approval authority may grant exemptions where there is no need to procure and operate equipment pursuant to Sentence 1.

§ 27c Air traffic Act (LuftVG)
(1) Air traffic control serves the safe, orderly and expeditious handling of air traffic.

§ 29b Air traffic Act (LuftVG)
(1) When operating aircraft in the air and on the ground, airport operators, aircraft operators and pilots are required to prevent avoidable noise and where noise is necessary to minimize the spread of unavoidable noise in order to protect the general public from danger, major disadvantages and major disturbance caused by aircraft noise. Particular consideration must be paid to peace at nighttime.

www

https://ec.europa.eu/jrc/en/publication/common-noise-assessment-methods-europe-cnossos-eu-implementation-challenges-context-eu-noise-policy

(2) Aviation authorities and the air traffic control organization must work towards protecting the general public from unreasonable aircraft noise.

§ 32a Air traffic Act (LuftVG)
(1) An Advisory Committee shall be established by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry for Transport, Building and Urban Development that pursuant to this Act must be heard prior to the adoption of statutory ordinances and general administrative provisions insofar as these are aimed at protection against aircraft noise and against air pollution caused by aircraft. The Advisory Committee may make recommendations for protection against aircraft noise and against air pollution caused by aircraft. The Advisory Committee should comprise representatives of science, technology, airport operators and airlines, local authority associations, noise abatement and environmental associations, the commissions pursuant to § 32b, aviation authorities as well as supreme aviation authorities appointed by the federal states and the Federal Environment Agency. Membership is honorary.

§ 32b Air traffic Act (LuftVG)
(1) A commission to advise the approval authority and Federal Supervisory Authority for Air Navigation Services and air traffic control organization shall be convened for every passenger airport connected to airline traffic and for which a noise protection area is to be specified in accordance with the Air Traffic Noise Act to advise on measures for protection against aircraft noise and against air pollution caused by aircraft. If a new airport is planned, the commission shall be formed before initiating the approval procedure.

- The noise indicators L_{DEN} and L_{Night} are used as measures of general nuisance and sleep disturbance respectively. The L_{DEN} level reflects emissions averaged over 24 hours and determined according to certain specifications from the L_{Day}, $L_{Evening}$ and L_{Night} levels for the evaluation times day, evening and night.

- Noise maps are graphical and numerical representations of the existing exposure to noise in an area. These must be drawn up separately for each type of noise, i.e. for road, rail and air traffic.

- The noise maps for Munich Airport can be viewed on the website of the Bayerisches Landesamt für Umwelt.

Appendix

Contact information

FMG
A great deal of information about the subject of noise is available on the FMG website. The monthly emissions reports and a contact form can also be found there. The telephone number for complaints about noise issues at Munich Airport is: **+49 89 975-4 04 10**.

DFS website, in particular ↗STANLY_Track
The southern branch of the DFS Center can be contacted if you have any questions concerning «Flight procedures and the handling of air traffic» by calling **+49 89 9780-123** or **-124**.

ROB, Southern Bavaria Aviation Office (Luftamt Südbayern)
The Aircraft Noise Abatement Officer for Upper Bavaria, Lower Bavaria and Schwaben at the ROB, Southern Bavaria Aviation Office can be contacted on **+49 89 21 76-25 87**.

German Air Force (Luftwaffe) for military flight operations Luftwaffe
The Luftwaffe is responsible for questions concerning military flight operations: **+49 800 8 62 07 30**.

Police (helicopter squadron)
The helicopter squadron for the Bavarian riot squad can be contacted on **+49 89 9 73 02-0**.

Further information can be found using the following link: www.munich-airport.com/noise-protection-264207

↗ STANLY_Track
see Glossary pp 36-37

Glossary

Runway in use	The runway in use (operating direction) essentially depends on the current wind direction and wind speed, because aircraft always take off and land against the wind. Internationally it is identified according to the direction of the runway. For the parallel runway system at Munich Airport there is operating direction 26 (which rounded off corresponds to 260 degrees on the compass rose and denotes a westerly wind) and 08 (which rounded off corresponds to 80 degrees on the compass rose and denotes an easterly wind).
Continuous sound level (L_{eq})	Since both intensity and duration are considered when assessing noise, individual noise events occurring at a place over a specific period are converted to a uniform noise throughout this period. The noise level determined in this way is the equivalent continuous sound level $L_{p,A,eq,T}$ (in accordance with DIN 45643-2011-02), which characterizes aircraft noise disturbance during an assessment period.
Decibel	The sound pressure level is physically measured and specified in decibels (dB). The level is evaluated using an A filter which takes account of the varying sensitivity of the human ear to high and low tones, hence dB(A).
Deutsche Flugsicherung GmbH (DFS)	The DFS is largely responsible for air traffic control in Germany. The company headquarters of the DFS are in Langen, Hesse.
Individual noise event	An individual noise event $L_{p,AS,max}$ (in accordance with DIN 45643-2011-02) is the maximum sound pressure level of a noise event. This reading makes it possible to assess a route in terms of the noise generated by different models of aircraft.
Flughafen München GmbH (FMG)	FMG is the company that operates Munich Airport.
Foot	British measurement used as standard to describe altitude in global aviation. 1 foot (ft) = 0.3048 meters (m)
ICAO Annex 16	ICAO is the global organization for civil aviation and sets out provisions and standards for international aviation, for example noise thresholds and measurement. These provisions have been incorporated into ICAO regulations Annex 16.
Instrument landing system (ILS)	The highly accurate instrument landing system (ILS) guides pilots on approaching aircraft safely to the runway even when visibility is poor. It uses horizontal and vertical beams, shown on the navigation display in the cockpit. The glide slope on the ILS is three degrees at almost all major passenger airports. The rate of descent depends on the aircraft speed. A pointer instrument gives pilots information throughout the final approach about whether they are heading accurately towards the runway (course information) and descending at the ideal angle (glide slope information).

NIROS – Noise Impact Reduction and Optimization System	NIROS simulates the departure of aircraft that use a flight management system (FMS) on a standard departure route. The speeds during individual flight phases are used to calculate how much time the aircraft requires to cross a certain spot on the ground, for example. This information is then used to calculate the duration of the noise at this spot. When calculating sound transmission and the resulting noise emission level, variable atmospheric properties may also be considered. The noise emissions calculated by NIROS (Leq). are then weighted against the population density of the surface that the aircraft flies over to give a noise exposure parameter for each surface element. The surface elements or grid cells measure 100 x 100 meters. Integrating the exposure parameters produces an exposure factor for the area examined, referred to as the nuisance indicator.
Standard Instrument Departures (SID)	The standardized departure procedure routes for aircraft based on instrument flight rules may also be defined using waypoints.
STANLY_Track	STANLY_Track among other things allows the DFS to plot and display the course and altitude of approaches and departures based on standard instrument departures to or from German airports online. Radar data is only kept for 14 days. Flight paths can be downloaded for this period.
Transition to Final Approach	This refers to flight procedures that can be assigned completely or in segments to approaches based on standard instrument departures. The routes in the transition procedure are defined by means of waypoints and based on satellite assisted navigation.

Source: http://www.dfs.de/dfs_homepage/en/Air%20navigation%20services/Glossary/

Imprint

Published by
Flughafen München GmbH
P.O. Box 23 17 55
85326 Munich
www.munich-airport.de

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Dr. Joseph Schwendner
Chief Representative and Senior Vice President
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Text
Group Environmental Unit –
Noise and Noise Protection Team

Editorial Office
Corporate communication / Corporate Media

Design
© SPARKS CONSULTING, Munich

Photos and graphics
Flughafen München GmbH

Printers
G. Peschke Druckerei GmbH

Paper
Enviro Top

Production
Munich Airports aims to minimize its impact on the environment, and this also applies to its printed products. This publication has been printed according to an ecologically efficient standard. Environmentally friendly inks, additives and paper, combined with ideal recyclability with excellent quality are components of the individual «formula» in this Airport printing standard.

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October 2019

munich-airport.de