Case Study – Frankfurt Airport

1. Overview

Frankfurt Airport (FRA) served more than 69.5 million passengers in 2018, thus posting a new record in the airport's history. Compared to 2017, traffic at Germany's largest airport grew by approximately 5 million passengers or by 7.8%. It also increased by 5.1% to some 31.6 million metric tons.

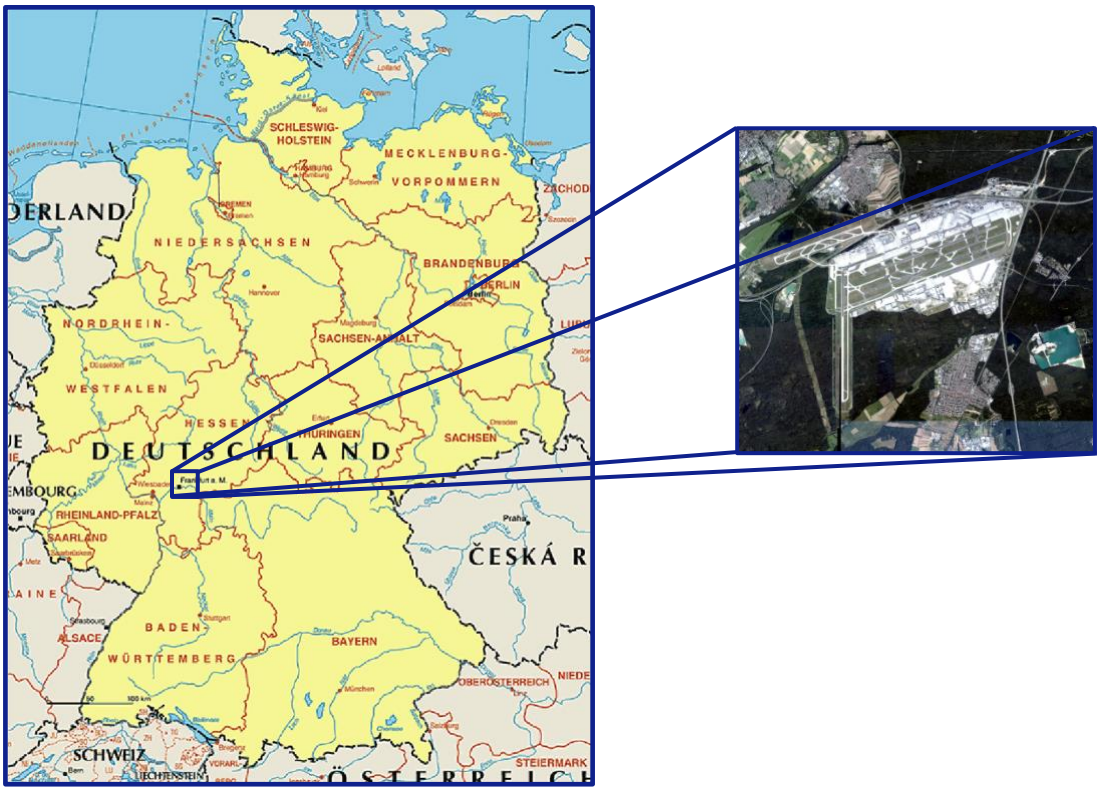


Figure 7.1 – Location of Frankfurt Airport

For the last winter timetable, Frankfurt was served by 89 passenger airlines flying to 262 destinations in 100 countries worldwide. With 128 intercontinental destinations, almost half of all destinations were intercontinental.[1]

In Europe, Frankfurt Airport ranks second in terms of cargo tonnage and is the fourth busiest airport for passenger traffic. With about 55% of all passengers using Frankfurt as a connecting hub, Frankfurt also has the highest transfer rate among the major European hubs. [1]

Frankfurt Airport City has become Germany's largest job complex at a single location, employing approximately 81,000 people at some 450 companies and organisations on site. Almost half of Germany's population lives within a 200 km radius of the Frankfurt intermodal travel hub – the largest airport catchment area in Europe. [1]

History

1924	Opening of Airfield at Rebstock Site in Frankfurt/Main, operated by "Südwestdeutsche Luftverkehrs AG"
1936	Start of flight operations at today's airport site in Frankfurt: "FRA"
1939-'45	World War II: Construction of first Runway
1945	End of WW II: 77% of airport destroyed, US took over airport control
1949	2nd FRA Runway "South" constructed in less than 1 year during Berlin airlift
1954-'55	Resumption of civil aviation businesses by "Flughafen Frankfurt/Main AG"
1972	Inauguration of FRA Terminal 1
1984	3rd FRA Runway "West" goes into service
1994	Inauguration of FRA Terminal 2
2001	Initial Public Offering: new company name "Fraport AG"
1997 until today	Focus on international expansion: asset deals such as Hanover and Xi'an; concessions, a. o., in Delhi, Antalya, Lima, Varna & Burgas, St. Petersburg; as well as management contracts in Cairo, Dakar, Riyadh & Jeddah
2011	4th FRA Runway "Northwest" goes into service
2014	International portfolio expanded with Ljubljana airport and AMU Holdings
2015	Construction start of FRA Terminal 3
2016	FRA JV with Gebr. Heinemann founded to operate 27 retail stores
2017	Take over of airport concessions for 14 airports in Greece
2018	Jan: take over of Fortaleza and Porto Alegre airport concessions in Brazil Apr: take over of JFK T5 master retail concession

2. Context and background: new runway (2011) [7] [8]

In 1997, Lufthansa recommended the expansion of Frankfurt airport due to an expected lack of capacity. One year later, Prime Minister of the state of Hessen initialised a mediation process over 15 months, 24 meetings and three working groups (which had 35 more meetings). The mediation group consisted of three mediators (assisted by the three working groups) and 21 members: four representatives of towns and cities, four representatives of NGO, two representatives of economy and one representative each of airport, Lufthansa, ATC, Federal Ministry of Transport, Hessian Ministry of Environment, Hessian Ministry of Transport, Board of Airline Representatives in Germany. During that time, a total of 129 expert opinions were received, 20 studies were assigned, and 15 hearings were carried out. The mediation was needed because of the bad experience (protest demonstrations, non-peaceful clashes and complaints) before, while and after building the West runway (in service since 1984).

As a result of the mediation process there was a "mediation report" which included a series of recommendations and proposals which had no legally binding force but carried a lot of weight. The report confirmed the need to expand the infrastructure but recommended a **ban on night flights (23:00h to 05:00h)** and an agreement on a "noise pact", as well as setting up a permanent Regional Dialogue Forum ("Regionales Dialogforum") as follow-up of the mediation throughout the entire process.

The period of Regional Dialogue Forum was between 2000 and 2008. Its main goals were continuation of the dialogue, objectification of the discussion by information and expertise, guidance to the approved procedures and keeping of the mediation results. It was composed of 33 members, representatives of towns and cities, NGOs, industry, airport, airlines and air traffic control, churches and trade unions. There were 57 meetings to discuss and decide on the outcome of the project teams' work (five project teams – Night

Flight Ban, Anti-Noise Pact, Optimisation, Ecology-Health and Long-term Perspectives – they had 289 meetings), 19 studies were ordered and 20 hearings took place. A Citizen's Advice Bureau was built up as a liaison agency and information centre.

There were two planned approval procedures in which the airport operator applied not only for an expansion but also for a night flight ban (like the mediation process agreed), but finally in December 2007, the decision of the Hessian Ministry for Transport on the plan approval procedure included a permission to have 17 movements per day between 23:00h and 05:00h and 150 movements from 22:00h to 06:00h. The public debate was served to decide if it is a violation of mediation agreements or not.

Figure 7.3 – Planned expansion of the Frankfurt Airport

In 2008 the Forum of Airport and Region (Forum Flughafen und Region – FFR) was established as a successor of the Regional Dialogue Forum and finally after almost 14 years since the beginning of the mediation process, on 21 October 2011, the new landing runway started its operations.

Less than ten days later, on 30 October 2011, the night flights were banned from 23:00h to 05:00h due to a decision of the higher administrative court in Hessen. On 4 April 2012 the final decision of the Federal Administrative Court established – night flight ban from 23:00h to 05:00h, a maximum of 133 flights in total from 22:00h to 23:00h and from 05:00h to 06:00h (average per night/year).

- Exceptions for landings: possible until 0:00h local time, but not more than average of 7,5 per night/year. Moreover, the operations should be planned between 22:00h and 23:00h and their delay cannot result from the scheduling;
- Exceptions for take-offs: only possible if the reason for delay could not be influenced by airline, needs prior permission by HMWEVW (Hessian Ministry of Economics, Energy, Transport and Housing);
- Exceptions for special cases (medical, safety etc.);
- Only chapter aircraft.

3. "Balanced Approach" in Frankfurt [6]

Firstly, by Directive 2002/30/EC of the European Parliament and of the Council of 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 of 15 February 2008 entitled "Noise Operation Restrictions at EU Airports" pointed to the need to clarify in the text of Directive 2002/30/EC the allocation of responsibilities and the precise rights and obligations of interested parties during the noise assessment process so as to guarantee that cost-effective measures are taken to achieve the noise abatement objectives for each airport.

After 12 years, an update on how to use operating restriction measures is required to enable the authorities to deal with the current noisiest aircraft in order 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 of 16 April 2014 was published on the establishment of rules and procedures regarding the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC.

3.1 Reduction of Noise at Source [1]

Measures for active noise abatement are directed towards avoiding or reducing the noise directly at the source, or at least achieving a better distribution. The expert committee "Active Noise Abatement" of the Airport and Region Forum (FFR) has formulated appropriate proposals.

Frankfurt airport operator (Fraport AG) continuously contributes to aircraft noise reduction efforts. Starting with the 1990s, Fraport has been taking account of aircraft noise in its airport charges and in 2001 Frankfurt Airport was the first airport in Germany to introduce airport charges based on effectively measured noise.

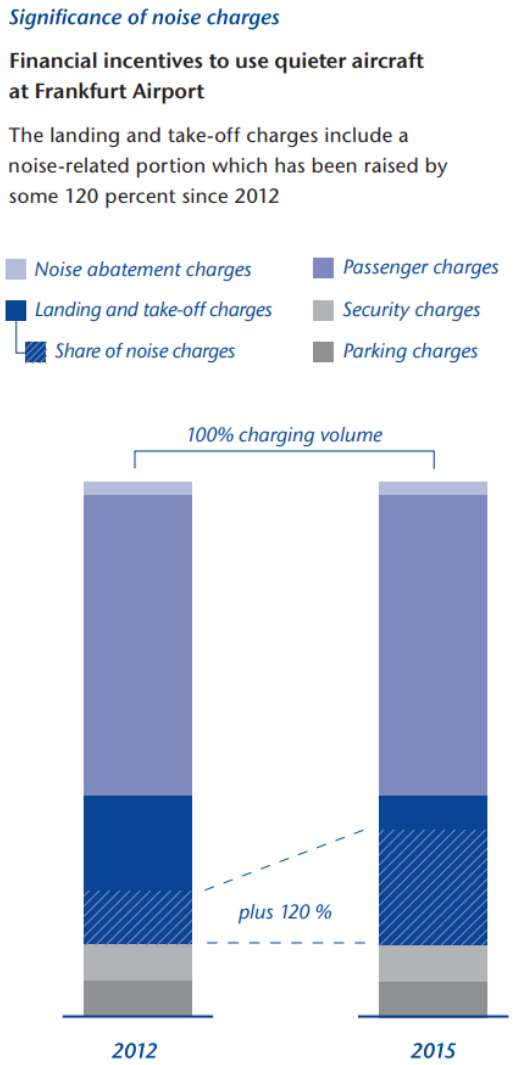


Figure 7.3 – Charging structure at Frankfurt Airport

Back in 2010, these noise charges were spread even further – using a noisy aircraft became more expensive for the carriers. This charge component was then further differentiated in the years 2013, 2014 and 2015 (120% in three years). Every charge calculation is based on the aircraft type being allocated in one of 16 noise categories measured at Frankfurt. Higher charges for aircraft movements operated during the late

evening or early morning hours serve as an incentive to shift these movements into the daytime. A night curfew takes place at Frankfurt between 23:00h and 05:00h.

3.1.1 Noise abatement charges

- Per departing passenger or per 100 kg of freight on landing and take-off;
- Depending on the noise category of aircraft and the time of arrival/departure;
- Legal noise abatement measures in the vicinity of the airport.

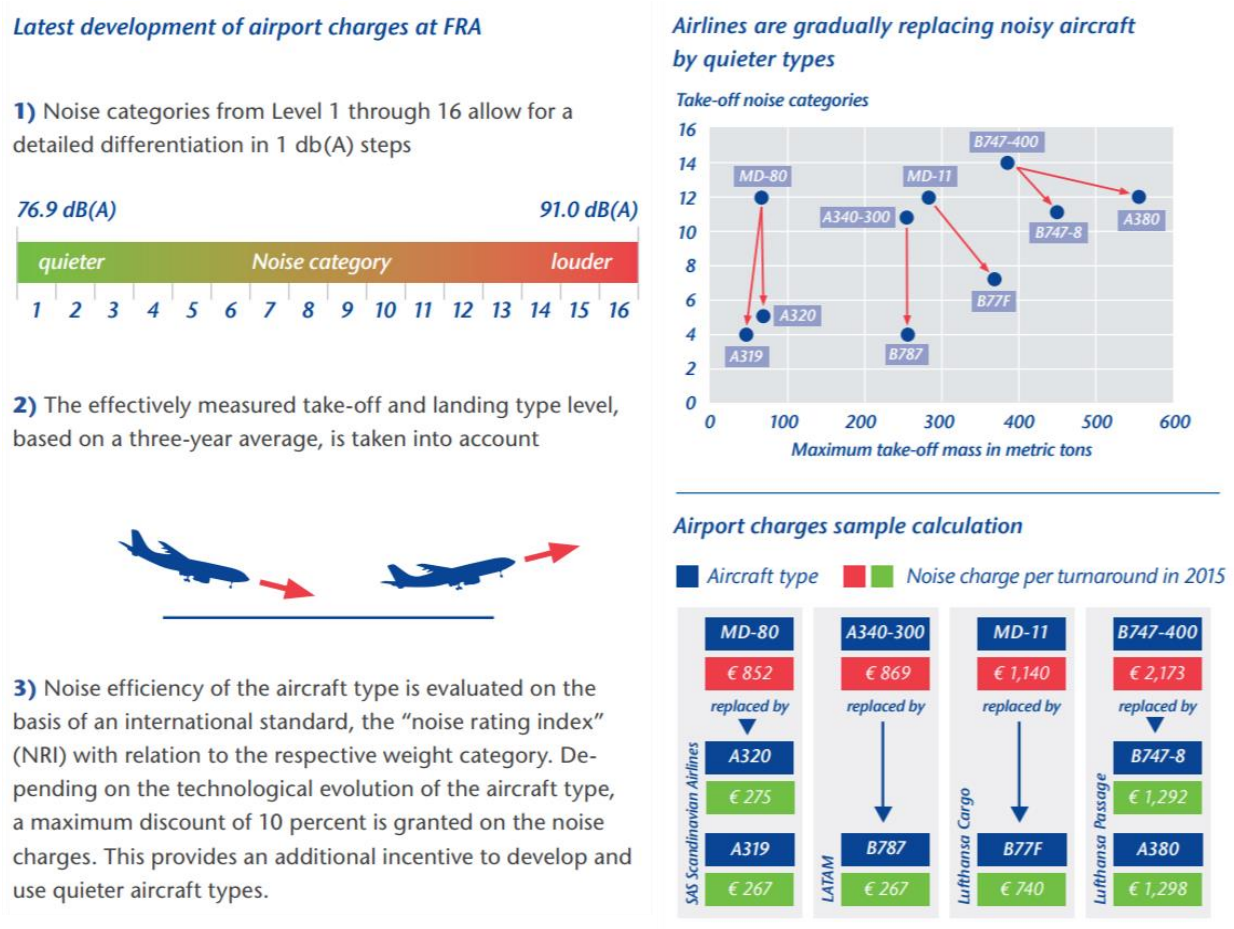


Figure 7.4 – Latest development of Frankfurt Airport charges

Further innovation was the introduction of a Noise Rating Index (NRI) with the aim of incentivising airlines to use technologically advanced aircraft. Depending on how the individual aircraft is classified, a reduction of up to 10% on noise-related charges is granted.

3.1.2 The New Incentive Model GBAS

(Ground-Based Augmentation System – new navigation system enabling aircraft to make satellite-assisted precision approaches).

Frankfurt Airport was the first international hub in Europe to introduce the Airport Charges Regulation and to offer regular GBAS-CAT I approaches since September 2014. Since March 2017, Frankfurt Airport can be approached at a steeper glide path angle, GBAS 3.2°. In this way, the new GBAS technology will make a significant contribution to noise abatement and to protecting people and the environment in the vicinity of the airport. Fraport AG is supporting the equipping of aircraft with GBAS technology. It applies to

aircraft that are newly licensed in 2019 and equipped with GBAS, including its activation, and aircraft that are retrofitted with GBAS in 2019 or whose GBAS is activated in 2019. Consequently, the flight crews of the airline need to be licensed for GBAS landings (OPS approval). Airlines will then receive €100 per landing for each aircraft that has been equipped with GBAS in 2019. This incentive applies for the first 100 landings of the GBAS equipped aircraft, resulting in a maximum total incentive per aircraft of €10,000. [1]

3.1.3 Vortex generator reduces noise emission – upgrading the A320 Family

A circular pressure equalisation opening of the tank on the underside of the aircraft wing generates tonal sounds during the course of the flight. The noise produced during this process is comparable with the noise that arises when air flows over the opening of a glass bottle. The faster the air flows over the opening, the louder the noise becomes. These characteristic sounds for the A320 Family are particularly noticeable in the approach phase when engine power is low. The new component causes the oncoming air to swirl in front of the opening and this prevents the generation of noise. In February 2014, the first Airbus A320 was supplied with vortex generators and since October 2014 the Airbus A319, A320 and A321 aircraft in operation have been gradually upgraded with vortex generators. Evaluation of the measurement results indicates that the vortex generators reduce the level of noise during approach by up to 4 dB.

3.1.4 Fitting the engines of Lufthansa's B737 fleet with acoustic panels

This is a noise reduction measure for Boeing 737 jetliners with CFM-56-3 engines. Replacing twelve acoustic panels at the engine inlet reduces the aircraft noise both during take-off and landing. Lufthansa implemented this measure for the B-737 aircraft stationed at Frankfurt Airport already at the end of 2011. This has led to a recertification for the B737 fleet into the quietest noise category.

3.1.5 Withdrawal of Lufthansa's B737 fleet

All B-737s have been replaced by newer aircraft. Noise reduction was possible in all take-off and departure flight phases.

3.1.6 Modernisation of fleets

In 2014, Lufthansa placed a large order for modern long-haul aircraft. Along with the use of Boeing B 777-9X and Airbus A 350-900 jetliners, it is expected that kerosene consumption, and thus also CO_2 emissions, can be reduced even further and that acoustic emissions will decrease, too. However, not all the new aircraft are destined to be part of Frankfurt fleet, and Frankfurt still has a few A 340 flying around.

3.2 Land use planning and management

3.2.1 Planning instruments: [3] [10]

Land-use planning is a further important measure or the reduction of noise. This instrument is included in the German Act of Protection against Aircraft Noise, October 2007. This act requires the establishment of noise protection areas at commercial airports as well as military airfields with the operation of jet or heavy transport aircraft. The noise protection area is subdivided into two daytime protection zones and one night-time protection zone. The act contains different limit values for the individual zones. A distinction is made between existing and new or significant expanded airports. Furthermore, there are different limit values for airports and military airfields, which are displayed in tables 7.1 and 7.2.

Table 7.1: Overview of the limit values for existing airports or airfields according to the Act for Protection against Aircraft Noise

Type of airport/airfield	Daytime protection zone 1	Daytime protection zone 2	Nighttime protection zone	
	$L_{Aeq\ day}$	$L_{Aeq\ day}$	$L_{Aeq\ night}$	N x L_{Amax}
Civil airport	65 dB(A)	60 dB(A)	55 dB(A)	6 x 57 dB(A)
Military airport	68 dB(A)	63 dB(A)	55 dB(A)	6 x 57 dB(A)

Table 7.2: Overview of the limit values for new or substantially expanded airports or airfields according to the Act for Protection against Aircraft Noise

Type of airport/ airfield	Daytime protection zone 1	Daytime protection zone 2	Night-time protection zone			
			Until 31.12.2010		From 01.01.2011	
	$L_{Aeq\ day}$	$L_{Aeq\ day}$	$L_{Aeq\ night}$	N x L_{Amax}	$L_{Aeq\ night}$	N x L_{Amax}
Civil airport	60 dB(A)	55 dB(A)	53 dB(A)	6 x 57 dB(A)	50 dB(A)	6 x 53 dB(A)
Military airport	63 dB(A)	58 dB(A)	53 dB(A)	6 x 57 dB(A)	50 dB(A)	6 x 53 dB(A)

The calculation of the noise protection area is carried out based on a prediction on the future flight operations as well as on the description of the flight routes in the surroundings of the airport[1].

In the whole noise protection area, the construction of noise-sensitive buildings (e.g. hospitals, schools) is generally prohibited. In the daytime protection zone 1 as well as in the night-time zone, the construction of new dwellings is also not allowed.

For existing residential buildings located in these zones, the Act of the Protection against Aircraft Noise contains provisions that oblige the airport operator to cover the costs for constructional soundproofing measures at these buildings. Moreover, the expenses for the installation of ventilation systems in rooms that are predominantly used for sleeping, are to be reimbursed by the airport operator for buildings in the night-time protection zone. Expenses incurred for constructional soundproofing measures including the ventilation systems are reimbursed to a maximum amount of 150€ per square meter of living space. The noise insulation requirements are specified in the statutory decree[2].

In the case of construction of new or the expansion of existing airports, these regulations are supplemented by compensation arrangements for deterioration of the quality of outdoor living space (terraces, balconies, etc.) in daytime protection zone 1. Further

[1] First Decree on the Implementation of the Act on Protection against Aircraft Noise, Decree on the Acquisition of Data and the Calculation Procedure for the Establishment of Noise Protection Areas of 27 December 2008. Amended 2015. Instructions on the Acquisition of Data on Flight Operations and the Calculation of Noise Protection Areas. December 2008

[2] Second Decree on the Implementation of the Act on Protection against Aircraft Noise, Decree on noise insulation measures of 8 September 2009

details such as the extent of the outside living area that requires protection and the compensation for impairment in this area are also laid down in a statutory decree[3]. The compensation has to be paid by the airport operator.

3.2.2 Building restrictions

- Zone 1 and night zone: all building is prohibited, except if the Regional Government gives its explicit authorisation in cases of major public interest (section 34 of the German Federal Building Code). The exceptions are a controversial point;
- Zone 2: there is no ban on housing. However, public buildings such as schools, hospitals and retirement homes need a specific authorisation by the Regional Government.

3.2.3 Mitigation instruments [1]

Financial resources are provided for structural noise abatement measures. Measures directed towards passive noise abatement aim to reduce the noise level in rooms inside the buildings by carrying out adjustments to building structures. Frankfurt Airport (Fraport) has comprehensive obligations for around 86,000 households in Frankfurt area under statutory legislation. Their entitlement to submit claims is defined by a noise abatement zone which was established by the Hessen Government on the basis of the very strict rules of the Aircraft Noise Abatement Act (Fluglärmgesetz). Furthermore, Fraport AG has set up a Regional Fund of 270 million euros together with the Hessian Government, and this fund is used to finance additional measures. Statutory payments for passive noise abatement and payments from the Regional Fund can only be granted on application.

Fraport maintains a comprehensive package of information and services on the company's website https://www.fraport.com/noise-abatement in order to provide assistance to the residents in order to determine their claims and support the application. In 2013, the Compensation for Outdoor Living Areas Regulation pursuant to the Aircraft Noise Law came into force. For the first time, this regulation introduced as a statutory requirement compensation for the impaired use of the outdoor living area in the Day Protection Zone 1 of Frankfurt Airport. This affects approximately 12,500 households, primarily in Flörsheim, Frankfurt, Nauheim, Neu-Isenburg, Rüsselsheim und Raunheim. The level of the compensation is either determined based on a statutory flat-rate amount, depending on the type of property or by means of an expert report on the marketable value of the property. Applications for this compensation can be submitted to Darmstadt Regional Council. The outdoor living area includes lawns, gardens, terraces, balconies, roof gardens, and similar communal outdoor facilities such as playgrounds at an apartment block. The buildings can be houses and apartments used for residential living or institutions like nurseries or schools. However, the entitlement only applies to plots of land on which building structures were erected before 13 October 2011 – the day when the noise abatement zone was defined – or when planning approval has been obtained prior to this date. The entitlement is phased according to the strength of the noise pollution. Since 13 October 2016, Day Protection Zone 1 has qualified for entitlement. 2,700 applications had already been submitted to Fraport up to the start of the submission period in October 2016. The period for application submissions ends on 12 October 2021.

3.2.4 Financial instruments [1]

As part of its voluntary Casa program, Fraport AG was buying residential properties that are flown over at especially low altitudes, i.e. beneath 350 m, or compensated the owners

[3] Third Decree on the Implementation of the Act on Protection against Aircraft Noise, Decree on compensation for impairment of the outside living area of 20 August 2013.

financially. The application deadline for the program was on October 1 2014. This offered an alternative to homeowners who had purchased or built a property before the plans of the airport's expansion were discussed and who now found their house right under the entry line to the airport.

Within the context of the noise-abating package of measures "Together for the Region - Alliance for Noise Abatement 2012" Fraport AG had significantly upgraded the Casa program in 2012 ("Casa 2"). Altogether, the volume of measures taken within the Casa program amounted to over 100 million euros.

Households may make claims for passive noise abatement protection for their homes in the framework of the Passive Noise Protection Program. These noise abatement protection measures are meant to reduce the noise level within buildings.

Within the framework of the current "Passive Noise Abatement" program, corresponding measures are being brought forward beyond the statutory regulations and are given extra budgetary resources from the Regional Fund. The budget comprises of 150 million euros for the Passive Noise Abatement Program and 265 to 2570 million euros for the Regional Fund. The Regional Fund is part of the "Alliance for Noise Abatement 2012", launched on February 29, 2012.

The program differentiates between four protected zones, which were created in compliance with the applicable limit values shown in the amended noise protection laws. The noise protection areas thus determined are composed of two daytime protection zones and one night-time protection zone and since 2013 also of one area covered by the Regional Fund.

3.3 Operational procedures [1]

3.3.1 Noise abatement flight procedures

- Continuous Descent Operations (CDO), referred to in the past as Continuous Descent Arrival or Approach (CDA); more frequent Continuous Descent Operations;
- Noise Abatement Departure Procedures (NADP); RNAV SIDs. Improving departure procedures, limiting the speed at a certain point in the departure. Continuous Climb Operations (still under development);
- Modified approach angles, staggered, or displaced landing thresholds; gliding angle of up to 3.2 degrees on the runway northwest became standard on December 19 2014 after more than two years of testing this measure. The results of the test operation had been completely positive. Measurements made by the German Aerospace Centre during the entire test phase at seven noise measurement stations at Frankfurt Airport showed a reduction of the maximum noise level from 0.5 to 1,5 dB(A) depending on the site of the measurement station and the type of aircraft.

  Steeper Approach procedures. In this procedure, the approach flight is initiated from a relatively high altitude at about 2,400 m using an angle of 4.49 degrees. Once approximately 600 m have been reached, the light beacon of the instrument landing system (ILS) is geared to from above in a 3.0 or 3.2 angle.

  Point Merge procedure is a novel method for sequencing arrival flows. Instead of using the current flight paths, arrivals are bundled into funnel-type structures and guided towards final approach. The technique is to support continuous descent operations in higher altitudes for a longer time span.

  Modified Arrival Routes. By raising the minimum altitude of arrival sectors, approaches will be kept in higher flight altitudes for a longer period of time.

- Low power/low drag approach profiles; raising the minimum downwind approach angle by 304 m on the northern and on the southern. Raising the altitude for starting final approach up to 1524 m. The altitude for aircraft coming from the south and turning to start final approach is raised from 300 m difference. In the parallel independent operation, the turning operations from the south must continue to be 304 m lower than from the north, thus 1219 m in the south and at least 1524 m in the north. Lengthening the Instrument Landing System (under development) – the vision is to raise the altitude for approach flights turning to start final approach by 300 m. When turning from the north, this will be accomplished by gearing to the ILS approach light beacon at 1828 m and when turning from the south at 1524 m. In order to implement this measure, the range of the instrument landing system (ILS) needs to be expanded;
- Minimum use of reverse thrust after landing, monitoring the use of reverse thrust. An acoustic monitoring system was implemented at Runway Northwest for westerly operations (runway designator 25) in May 2015. This system is now being tested and optimised. Reverse thrust with higher load levels represents a disturbing noise event in the nearby residential areas. Reducing such cases of use equals means less disturbances.

3.3.1.1 Introduction of a Ground Based Augmentation System (GBAS)

GBAS is a satellite-based precision landing aid that is additionally supported by a ground station. This technology considerably improves the accuracy of satellite navigation. Aircraft equipped with GBAS receivers may determine their own position so accurately that precision landings are possible without requiring an ILS. The new landing system is capable:

- To raise the approach angle from 3.0 degrees to 3.2 degrees on Runway South and on Runway Centre (25L/C and 07 R/C), a measure that had so far only been possible using conventional ILS technology (instrument landing system) on the Runway Northwest, and here they have already been integrated into regular operations;
- The GBAS technology provides the possibility to use curved, segmented approach procedures without affecting capacity. Such procedures make it possible to direct arrivals around densely populated areas.

The installation of "Ground Based Augmentation System" (GBAS) navigation made Frankfurt Airport the first international air traffic hub in Europe to host satellite-based precision approaches for appropriately equipped aircraft.

Since the second quarter of 2017, the steeper approaches using GBAS navigation are being tested on the South and Centre Runway. Up to 49 different approach routes can be supported with a single GBAS ground station. The new airport charges introduced in early 2017 incentivised the use of GBAS to make application of the GBAS navigation system even more attractive for airlines.

3.3.2 Spatial management

- Noise preferred arrival and departure routes; increased use of westerly direction. Some residential areas in the western part of the airport are directly adjacent to the airport premises, which means that they are flown over in the landing direction 07 at very low altitudes. This is the reason why operation direction 25 is the preferred scenario at Frankfurt Airport. On a yearly average this direction is used at some 70%[4] of all days.

[4] In 2018 it was 50%

Fewer take-offs via Frankfurt and Offenbach during easterly operations. Relocating the take-offs from the 07-N (long) to 07-0 departure route to relieve the urban areas located below the 07-N (long), in particular Frankfurt and Offenbach;

- Flight track dispersion or concentration; flying around densely populated metropolitan areas. No aircraft can start final approach above the residential areas of Mainz and Offenbach;
- Noise preferred runways; procedure for alternate use of runways permits noise respites. From 23 April 2015, the noise respite model 4 recommended for testing by the Frankfurt Aircraft Noise Committee (FLK) and by the Airport and Region Forum (FFR) 2016 underwent testing for flights routed in a westerly direction, which is the main operating direction for the airport. This means that specific take-off runways are not used alternately in the early morning and late evening hours. Frankfurt is the first major international airport to support an operational restriction on night-time flights including a preferred runway usage concept. This extends the night-time quiet period by one hour in the approach corridors. The main beneficiaries from bundling landings in the evening hour between 22:00h and 23:00h on the South Runway are the people living in the south of Frankfurt and to the north of Offenbach. However, Neu-Isenburg and southern Offenbach experience more noise pollution by the exclusive use of this runway during this hour. Nevertheless, the nighttime quiet period here is extended beyond the core time between 23:00h and 05:00h because the South Runway is not used for landings between 05:00h and 06:00h. Morning approaches are then scheduled on the Runway Northwest and the Centre Runway, all morning take-offs are scheduled for the South Runway. The monitoring results obtained during the test phase confirmed the potential for reducing noise pollution that had previously been calculated, such that the "noise respite" concept was incorporated into regular operations after a year of testing.

3.3.3 Ground management

- Hush houses and engine run up management (location/aircraft orientation, time of day, maximum thrust level): noise-reducing screening walls. An engine test-run facility reduces the noise emissions towards nearby residential areas. The facility built at Frankfurt Airport was the subject of a zoning request by Fraport. This facility allows reducing the peak level from engine test runs by up to 5 dB(A) thus affecting the residential areas considerably less.
- Auxiliary power-unit (APU) management: provision of Pre-Conditions Air Units. Both with a view to noise emissions and pollutant emissions, stationary units operate considerably more efficiently than auxiliary power units. Consequently, this measure allows reducing ground noise in the immediate surroundings.
- Taxi and queue management; towing; taxi power control (taxi with fewer than all engines operating). Reducing ground-level engine noise by using electrically driven aircraft tractors (TaxiBot/E-taxi) thanks to electrical drives, taxiing movements of aircraft performed at the airport with running engines should be reduced or made without the airplane's own engines. One way to accomplish this is to use electrically driven aircraft tractors, controlled in the cockpit of the towed aircraft (TaxiBot). Another way consists of fitting a wheel hub motor to an aircraft's main landing gear serving as an electrical drive (E-Taxi).

3.4 Operating restrictions

Restrictions have been implemented related to the type of aircraft.

3.4.1 Specific bans

- MD11, B747 and A380 are banned from the new runway.

3.4.2 Night flight

- Between 22:00h and 08:00h, marginally compliant aircraft are banned;
- Between 22:00h and 06:00h, only chapter 4 compliant planes are authorised;

- Since October 2011, a curfew is applied between 23:00h and 05:00h.

3.5 Community engagement

3.5.1 Noise Monitoring System

The German Civil Aviation Law (Section 19a) obliges the operators of civil airports which are served by airline traffic to set up and operate installations for the measurement of air traffic noise near the airport. The operation of these installations is regulated in more detail by a German standard which is called DIN 45643 "Measurement and Assessment of Aircraft Noise". The measurement results are correlated with radar data at different airports in order to determine the exact correlation between passing aircraft and air traffic noise incident. Pursuant to the Civil Aviation Law, the measurement results must be transmitted to the competent aeronautical authorities and to the Commission on Aircraft Noise. Many German airports publish the results of the air traffic noise measurements on a regular basis.

Monitoring aircraft noise Fraport AG operates a total of 29 stationary measuring stations and three additional mobile measurement containers in the neighbourhood of the airport. The data from the measuring stations provide continuous monitoring of aircraft noise development. They are used to categorise aircraft types for noise-dependent take-off and landing fees, and for documentation of unusual aircraft noise events.

Forum Flughafen und Region, throughout its environment and communication centre (UNH - Umwelt- und Nachbarschaftshaus "Environmental and Neighbourhood House") manages a network of nine fixed monitoring stations and two mobile ones. The Environment and Neighbourhood House is an observer of developments in the region, a neutral information service provider and a mediator between the conflicting parties. A central task for them is to carry out independent aircraft noise measurements and to make the results available to the public. The UNH also offers municipalities to become a location for a mobile measuring station for a period of about three months.

3.5.2 Advisory Committee pursuant to the German Civil Aviation Acts

A committee for all German airports advising the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety and the Federal Ministry of Transport and Digital Infrastructure prior to the adoption of legal provisions on aircraft noise or emissions of pollutants from aircraft was formed on the basis of the German Civil Aviation Law (Section 32a). The committee issues recommendations on measures for protection against air traffic noise. It consists of both representatives of the aviation industry and citizens affected by air traffic noise as well as various other institutions.

3.5.3 Commissions on Aircraft Noise at the civil airports

Pursuant to the German Civil Aviation Act (Section 32b) commission is advising the aviation authority on measures for the protection against aircraft noise and against air pollution from aircraft and it has been established at all major civil airports. The Commission on Aircraft Noise meets on a regular basis to discuss local problems concerning aircraft noise and to elaborate proposals for improvements. The Commission is made up of both representatives of the aviation industry and citizens affected by aircraft noise as well as various other institutions. Usually, not more than 15 members: representatives of towns and cities affected by aircraft noise, an NGO against aircraft noise, airlines, airport operator, supreme federal state authorities and in individual cases additional members. It must be informed and consulted on issues regarding noise protection and measures against air pollution. The Commission holds a veto right. It is important to note that this kind of body was created because of the first contestations against airport developments and in order to enhance the transparency of the decision-making process. It advises the permit authority and the German air navigation service

provider on mitigation of noise and air pollution and works closely with the Airport and Region Forum.

3.5.4 The Airport and Region Forum (Forum Flughafen und Region, FFR) [7] [8]

The Airport and Region Forum (Forum Flughafen und Region, FFR) was established in 2008. This forum continues the work of the previous Regional Dialogue Forum (RDF), brings together representatives of the aviation industry, municipalities, relevant authorities, practitioners and researchers and aims, above all, to implement active noise abatement measures. The main tasks are:

- Provide information neutrally, correctly and transparently;
- Improve communication and cooperation between Frankfurt Airport, its users and the residents;
- Noise monitoring;
- Environmental monitoring;
- Social monitoring.

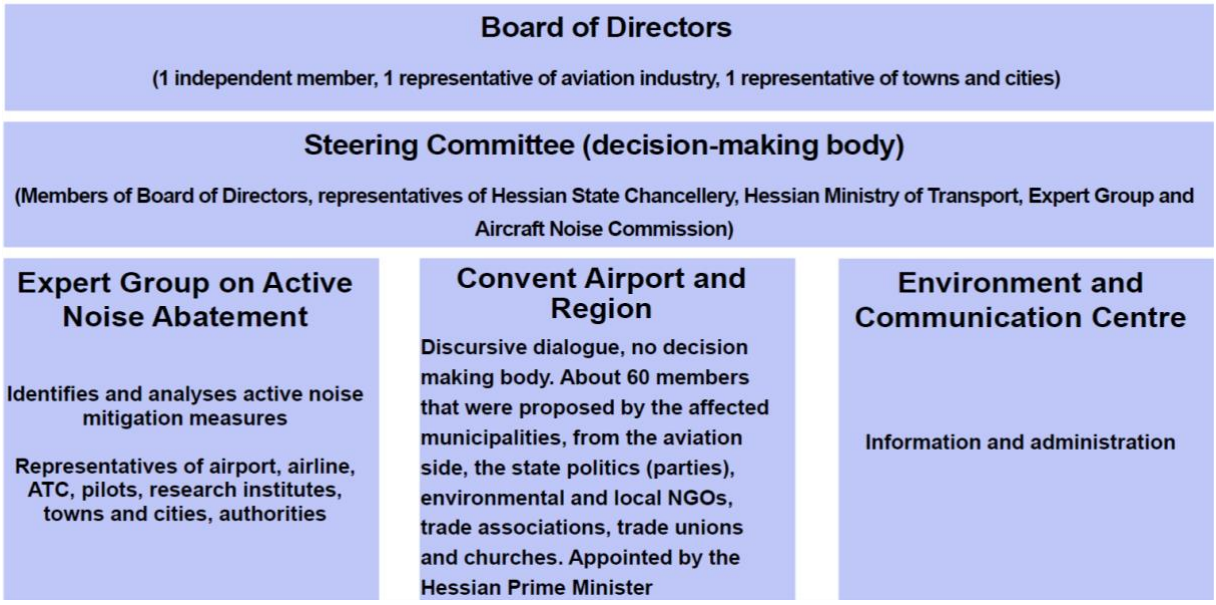


Figure 7.5 – Region Forum organisational chart at Frankfurt Airport

The Expert Group on "Active Noise Abatement" of the Airport and Region Forum (FFR) is in charge of:

- Identifying measures for active noise abatement and verifying them for suitability, applicability and ICAO conformity;
- Checking and creating the preconditions for approvability;
- Calculation of noise impact.

The Basic conditions for work are:

- Safety and capacity requirements are met;
- Noise reduction is achievable;
- Technical and operational feasibility at Frankfurt airport;
- No legal approval in advance.

This Group included Fraport AG and other partners from the airline industry, German Air Navigation Services (DFS), the State Government and the region to develop the last action plan comprising 19 new measures. These include noise-reducing approach and take-off procedures, a concept involving alternating use of runways and financial incentives to promote the use of maximum quiet aircraft. The success of the measures is monitored using comprehensive monitoring and the results are posted on the website of the Environmental and Neighbourhood House.

Environment and Communication Centre is in charge of:

- Provide information neutrally, correctly and transparently;
- Improve communication and cooperation between Frankfurt airport, its users and the residents;
- Noise monitoring;
- Environmental monitoring;
- Social monitoring.

3.5.5 Investigation of the impacts of aircraft noise on health and quality of life [11]

In 2011, the Forum launched the NORAH Noise Impact Study (Noise-Related Annoyance, Cognition and Health) primarily financed by the State of Hessen (later by the Umwelt- und Nachbarschaftshaus) with the aim of conducting more detailed research on the effects of aircraft noise on health and quality of life. NORAH is the most extensive investigation into the effects of exposure to aircraft, road and rail traffic noise that has ever been carried out in Germany. It was conducted by nine independent scientific institutes from all over Germany, under the management of the Ruhr University Bochum and it has been divided into three modules. The study was concluded in October 2015 and the results were published throughout Germany. The first module of the study deals with potential noise pollution and the associated impairment of quality of life. The second module addressed the health risks that could be linked to all traffic noise modes. The learning performance for children was the subject of the study's third module.

4. Land Use Planning case study

4.1 Spatial Planning System in Germany [9]

Despite the federal nature of the country, spatial planning systems are fairly uniform. At the local level the "Federal Building Code" (Baugesetzbuch, BauGB) and the "Federal land use Ordinance" (Baunutzungsverdordnung, BauNVO) apply all over Germany, making detailed land use planning very homogeneous.

Länder (except city states) have adopted "state-wide" spatial plans where airports are outlined but not regulated. "Regional Plans" covering several districts are adopted in many of the Länder. These plans include a more detailed delimitation of the airport grounds and may define "settlement restriction areas" based on noise, but do not regulate airport uses.

Local framework plans and regulatory plans, covering only part of a municipality, are adopted by local authorities or local planning associations but must be approved by a higher administrative authority, usually the district. Regular spatial plans are not used to regulate airport creation or development. The spatial planning legislation provides for special planning instruments to plan and implement large infrastructural projects, including airports.

4.2 Regulations and permits [9]

4.2.1 Construction permits

In principle all construction works require a building permit issued by the local authorities. There is no generalised exclusion of infrastructure projects from the building permit requirement.

Large infrastructural projects, however, usually follow special planning procedures which do not lead to an ordinary "building permit" and are not handled by the local authorities.

4.2.2 Environmental permits

Environmental Impact Assessment (EIA) is regulated in accordance with EU legislation, including the evaluation of plans and programs, but also applies to a larger number of projects. Airports require an EIA when runway length exceeds 1,500 m and the approval of the German National Parliament.
A specific evaluation is conducted for projects which may affect protected areas.
All potentially contaminating activities require either an EIA or an environmental permit, but airports are excluded from this requisite.
Environmental permits are integrated with the building permit. Regional authorities in charge of environmental permits issue this integrated permission after consultation with the local authority. Water related permits are processed separately.

4.3 Airport planning and construction [9]

4.3.1 Policy and planning

The Federal government has a general competence regarding aviation but all competences with respect to airports are in the hands of the Länder.

- **National**
  The "Federal Transport Infrastructure Plan" (BundesVerkehrswegePlan, BVWP), which is adopted by Parliament, is basically an infrastructure investment program oriented essentially towards rail, road and waterways, but does not include airport projects since these are not within the competence of the federation. It includes only some very broad statements about enhancing the competitiveness of German airports. The "Airport Concept of the Federal Government" (Flughafenkonzept der Bundesregierung), adopted in 2000, analyses investment requirements needed to accommodate demand, lists proposed actions, including the modification of noise legislation and puts air transport in perspective with other modes but does not go into details.

- **Airport**
  There are no statutory airport plans. Each airport may prepare its own internal development strategy but in order to create a new airport or expand an existing one it is necessary to go through a special "planning decision procedure" (Planfeststellung) and will often require a "spatial planning procedure" (Raumordnungsverfahren) in order to determine the impact on spatial plans and define the spatial framework for the new project. Both procedures require an environmental impact assessment.

4.3.2 Spatial impact

- **Implementation of ICAO Annex 14 requirements**
  Safeguarded areas are implemented by defining a construction restricted area (Bauschutzbereich) formed by a series of concentric circles and a widening inclined plane beginning 500 m from the end of the runway. In the inner areas (1.5 km radius) all constructions, trees, power lines, etc. must be authorised by the aviation

authority, in the outer areas such authorisation is only necessary when building heights exceed between 25 m and 100 m depending on the distance.
All construction within these areas must be authorised by the Land's aviation administration. The limits of safeguarded areas are made public but not integrated into spatial plans. Affected property owners are notified.

- **Noise Impact**
  The noise impact of airports was regulated in 1971 by The German Act of Protection against Aircraft Noise (Gesetz zum Schutz gegen Fluglärm). The Act defined two land use restriction areas where residential use buildings such as hospitals and schools are restricted. An important modification in October 2007 came into force as it was mentioned before, establishing new and more restricted limits.

- **Risk prevention**
  There are no legal provisions concerning risk analysis, but in Frankfurt risk has been the object of specific evaluations.

- **Land reserve for future construction**
  Land for future construction can be reserved in ordinary spatial planning documents or by means of the specific planning instruments (Planfeststellung), which must be used for airport development.

4.3.3 Construction

All new airports or substantial modifications must be authorised following a "planning decision procedure" (Planfeststellungverfahren), which serves both as planning and building permission. The permit is issued by the aviation authorities in each Land.
The "planning decision" replaces all permits, authorisation or licenses that may be required by law, it covers both airport construction and operations.
A regular building permit is needed for airport buildings, since the "planning decision" covers only the infrastructure.

- **Operation**
  A permission of the local Government is required.

4.3.4 Airport noise and air quality

- **Noise**
  Air traffic noise is regulated under specific legislation, requiring the delimitation of noise protection zones where land use restrictions are posed, and some insulation measures receive financial assistance.
  Night curfews, quota count systems and noise charges are used in many airports to contain airport noise.

- **Air quality**
  Clean Air Plans and action plans must be adopted when certain levels are attained for a number of days. Polluting activities may be restricted or banned in contaminated areas.
  Air pollution is taken into account in the special planning procedures used for the construction or enlargement of airports.
  Information from monitoring stations does not justify aviation related problems with air quality in or around airports.

4.4 Frankfurt airport

Frankfurt airport expanded between 1997-2011 and provided a good example of how the German system operates for the construction or expansion of airports, how it relates to spatial planning and how environmental concerns (especially, noise) are taken into consideration.

When the airport operator, Fraport AG, decided in 1997 that it was necessary to undertake a major expansion, the "Minister President" of the Land of Hessen indicated that it would be convenient to carry out a mediation process firstly in which all interested parties could be heard in order to reach a consensus on the major options for the future airport development, as well as to build a closer relationship between the airport and its neighbours as it was mentioned previously.

At the end of the process this process, the "mediation report" included a series of recommendations and proposals which had no legal force but carried a lot of weight. The report confirmed the need to expand the infrastructure but recommended a ban on night flights and an agreement on a "noise pact", as well as setting up a permanent Regional Dialogue Forum throughout the entire process.

On the basis of the outcome of the mediation process and the work of the Regional Dialogue Forum, the operator prepared the documents needed to initiate the "spatial planning procedure" (Raumordnungsverfahren) and filed the application in October 2001. The documents included three possible alternatives, which were evaluated in detail from all points of view – technical, economic and environmental. It focused on the compatibility with existing spatial plans and with environmental planning and legislation. The documents were then examined by the administration and submitted to all affected local authorities as well as citizen organisations, trade associations and public interest organisations. Any interested citizen was able to examine the documents and submit an opinion.

At the end of the "spatial planning procedure" the President of the Darmstadt district issued a "regional planning statement" (Landesplanerische Beurteilung) on 10 June 2002, pointing out the need to amend the objectives of the regional plan for South Hessen in order to achieve compatibility of the north west alternative with the requirements of regional planning. Moreover, the statement set a number of conditions to be met by the operator in order to insure compatibility with regional planning.

Due to the Hessen-wide importance of the expansion of Frankfurt Airport, the development plan of the Land of Hessen was amended in order to include regional planning objectives and principles for the airport's development.

The airport operator prepared the detailed project documentation required to initiate the "planning decision procedure" (Planfeststellungsverfahren) and filed the application in the Darmstadt district administration on 9 September 2003 and after several requests for additional documents and clarifications, the district administration considered the application to be complete. On 24 November 2004 the documentation was put on public display and it was announced that comments could be submitted for a month.

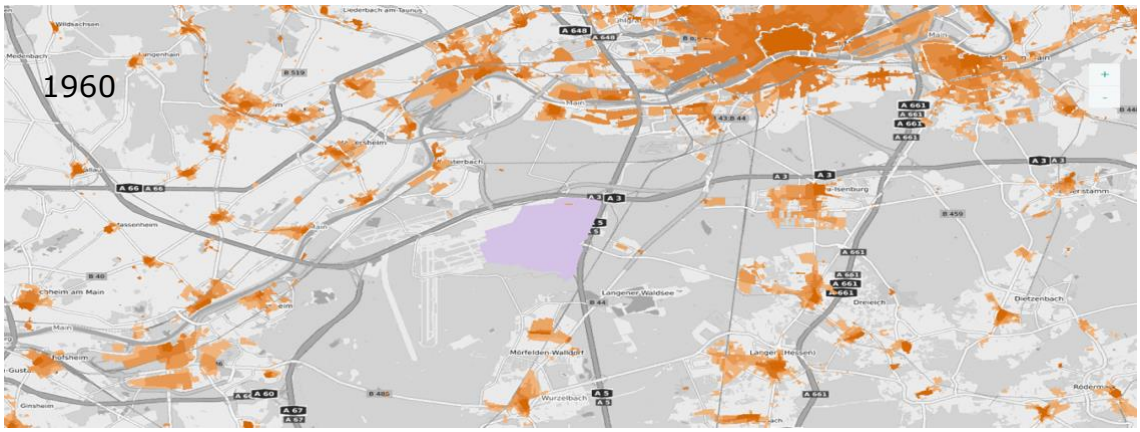
The documentation was made available to 57 local communities and 327 public authorities were invited to comment on the proposal. The participation process resulted in over 120,000 written submissions.

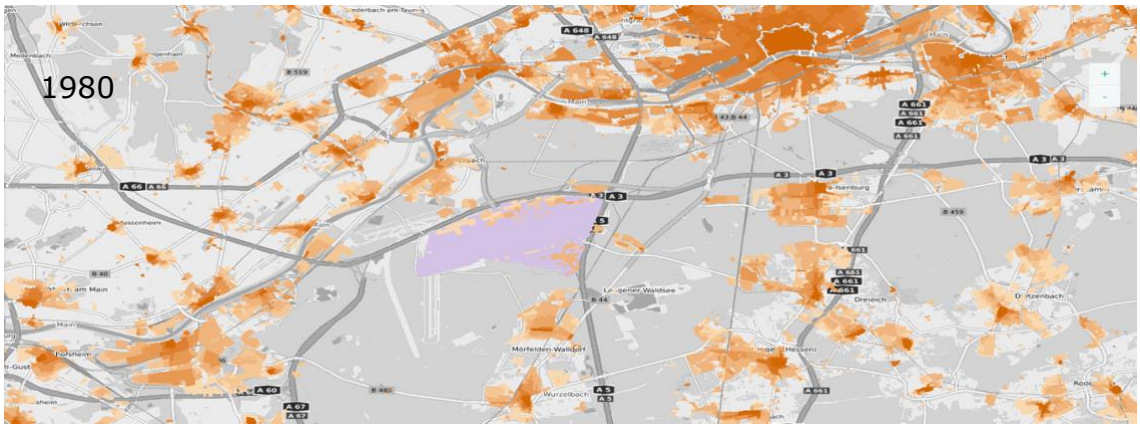
The final decision (Planfeststellungsbeschluss) was reached in December 2007, when the Hessian Ministry of Transport granted the approval procedure including all the necessary permits for the beginning of the construction of the new infrastructure, as well as a decision on all the operational restrictions. It authorised having 17 movements per day between

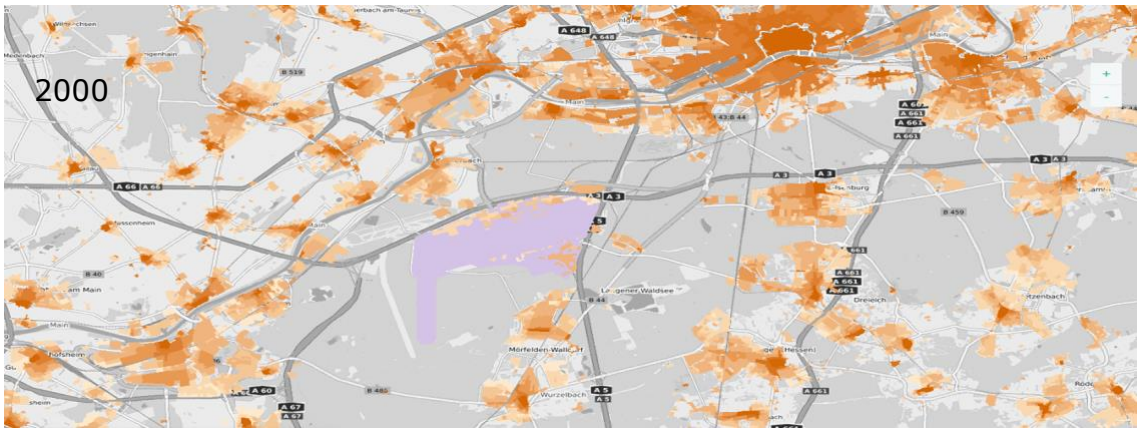
23:00h and 05:00h and 150 movements from 22:00h to 06:00h, as it was mentioned before.

4.5 Management effectiveness in Land Use Planning around Frankfurt

Nevertheless, the next pictures show the land evolution of the last 60 years:







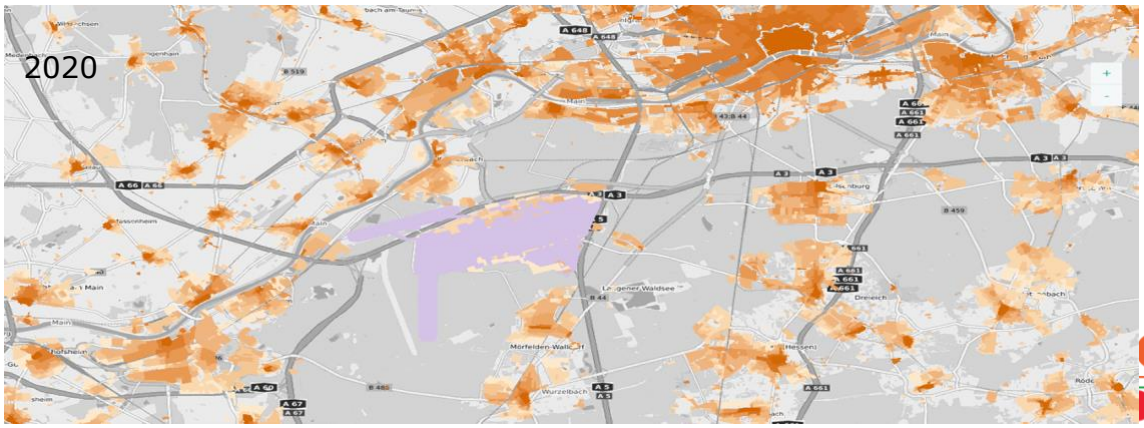


Figure 7.6 - Land evolution of the last 60 years around Frankfurt Airport

In the previous figures, in purple the evolution of the airport is visible, in brown – the evolution of the residential areas is marked (darker brown is for the older the residential areas). The residential areas inside the protection zones have remained mostly frozen, but in some cases, there are densification and consolidation of existing residential areas and some new residential areas.

A recent study: "SiedlungsflächenentwicklungimFlughafenumfeld" ("Development of residential areas in the vicinity of airports"), carried out by University of Bonn (Prof. Wiegandt et. al.) / RWTH Aachen (Prof. Selleet al.) on behalf of BDL (German Aviation Association) about six airport regions: CGN, DUS, FRA, HAJ, HAM, MUC shows interesting outcomes.

Findings of the study [3]:

- Buildings are getting closer and closer to airports; above-average development of residential areas in the vicinity of Frankfurt Airport;
- Closing of gaps between buildings; densification and consolidation of existing residential areas; building of some new residential areas;
- Consequence – increase in the number of people affected by aircraft noise; new conflicts can be expected;
- Growth pressure in thriving regions –partly triggered by airports;
- Planning tools have not been exhausted; instead, building permits with no land use plan (section 34 of the German Federal Building Code);
- Higher-level regional and state planning frequently acts with caution (topical example: residential restriction zone in the new Hessen regional development plan scaled down significantly).

Recommendations of the study [3]:

- Manage residential development activity based on land use plans instead of on building permits on the basis of Section 34 of the German Federal Building Code in order to broach the issue of conflicts and balance interests in a better way;
- Preventive conflict mitigation and mediation of interests in the regional and state planning through consistent designation of residential restriction zones;
- Continue confidence-building measures (discussion groups, joint data collection);
- Strengthening of inter-municipal cooperation (e.g. joint land use planning/ projects, partly in cooperation with airport; example Mönchhof Logistics Park);
- Objective: noise abatement through residential development management.

4.6 What were the problems? [5]

Before the new version came into force in 2007, the Federal Air Traffic Noise Act from 1971 mainly regulated noise insulation. In some Länder additional regulations were introduced to avoid future conflicts due to aircraft noise. In the Land of Hessen, different noise zones were established through spatial plans. The current regulation is that no new residential areas and no new mixed used areas should be planned within noise zone L_{DN} 60 dB(A) (settlement restriction area - 'Siedlungsbeschränkungsgebiet');

- The noise zones were based on forecasts that are not always true. Noise zones changed significantly in shape and size over the years (forecasts did not come true). As a result, residential areas were developed in zones which were not expected to become as noisy.

- For different towns and cities noise zones meant that there is no or very limited opportunity for further development. Therefore, they requested a compensation.

It is important to note that in Frankfurt region there is a lack of affordable housing, which leads to a big pressure to build dwellings.

4.7 New regulations [5]

The Hessian regulation on regional equalisation of burdens ('Gesetz über den Regionalen Lastenausgleich') came into force on 1 January 2018. Land provides 21 towns and cities, which are highly affected by aircraft noise, with 22.6 million euros until 2021 (money comes from dividend of the Land's company shares of Fraport).
The amount of money for towns/cities depends on a number of affected inhabitants and extent of noise pollution.
Money is spent for social matters, education, childcare, employment and apprenticeship initiatives, improvement of public building's noise insulation and air conditioning, building and maintenance of public recreation areas.

'Lärmobergrenze' (Upper noise limit)

The Hessian Minister of Economics, Energy, Transport and Housing, Lufthansa, Condor, BARIG (Board of Airline Representatives in Germany), Fraport AG, Forum Airport and Region and Aircraft Noise Commission developed a Voluntary agreement about an upper noise limit:

- area within LD = 55 dB(A) should not become bigger than 22.193 ha (16.955 ha in 2017);
- area within LD = 60 dB(A) should not become bigger than 8.815 ha (6.911 ha in 2017).

Noise monitoring takes place every year. Measures to be taken if noise areas are exceeded. By doing this, it may help to establish a lasting noise zone.

Some towns are adopting:

- Voluntary commitment of town to stabilise number of inhabitants;
- Using the revision of the existing binding land-use plans;
- Plan to limit building density.

4.8 Conclusions and lesson learned

- Land-use planning can contribute to avoiding future noise problems, but noise insulation rules and additional regulations bidding new residential areas are not enough. Local Authorities and Communities requested a compensation scheme for outdoor living areas (implemented by a new law in 2013) and for regional equalisation of burdens (implemented by the change of the law in 2018). Moreover, there are voluntary programs like CASA to rebuy dwellings;
- For establishing noise zones, reliable forecasts are needed in order for noise zones to last. Long tradition of establishment of noise zones around the airport is meant to reduce future conflicts due to aircraft noise. However, previous noise zones were based on forecasts that did not turn out to be accurate. Noise zones changed significantly in shape and size over the years, as a result, residential areas were developed in zones which were not expected to become as noisy. Since 2017, there is a new voluntary agreement concerning the area and its noise footprints per year;
- The interest of growth of airport and surrounding towns/cities must be deeply studied and balanced. Land use planning is a global problem that must be treated jointly by different stakeholders – it is a shared responsibility. There are voluntary agreements

with the airport for specific areas and voluntary commitments of some towns to stabilise the number of inhabitants;

- Usually additional noise mitigation measures are required;
- Night-flight ban, noise mitigation package, noise respite, regulation on regional equalisation of burdens and 'Lärmobergrenze' (upper noise limit) in Frankfurt-Rhein-Main region are the outcome of the mediation process and structures that helped to achieve tailor-made mitigation measures, knowledge, transparency and understanding for problems and constraints for the other parties.

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