Quality of Life
Health
Development

NORAH
Knowledge No. 2

NORAH noise impact study

Sound and noise

The basic principles of acoustics

forum flughafen & region
umwelt- und nachbarschaftshaus

NORAH Knowledge No. 2

Sound and noise:
The basic principles of acoustics

"NORAH Knowledge" provides information at irregular intervals about the methods and results of the NORAH noise impact study. The aim of this publication is to communicate to as many people as possible what exactly NORAH does. This why you will find an explanation in the glossary at the end of this edition for all items marked with an "▤ Glossary". If you would like to receive further editions of "NORAH Knowledge", please use the attached order form.

In various parts of the study NORAH examines the long-term impact of traffic noise on health, quality of life and early childhood development in the Rhine-Main Region. Such a complex task confronts the acoustic experts involved with major challenges. On the one hand they have to determine various types of noise exposure in very large investigation areas as precisely as possible: the exposure to traffic noise differs considerably from town to town and from street to street, and even the storey of the building, the position of the bedrooms in the apartment, the type of walls and the glazing have an influence on just how much noise from aviation, road and rail traffic actually reaches the ear of each individual study subject.

NORAH ("Noise Related Annoyance, Cognition, and Health") is the most extensive investigation into the effects of exposure to aviation, road and rail noise that has ever been carried out in Germany. It is being conducted by nine independent scientific institutes from all over Germany. The client is the Umwelt- und Nachbarschaftshaus, a subsidiary of the Land of Hessen and part of the Forum Frankfurt Airport and Region. Communities, Fraport AG and Lufthansa are also involved in the financing.

The second big challenge consists in NORAH's aspiration to also take into account the noise exposures which the individual study subjects were subjected to in the past. It is only with this information that the scientists can gain objective, well-founded insights into the long-term effects of noise – for example into the links with the occurrence of chronic diseases. In this issue of "NORAH Knowledge" we present the methods which the acoustic experts on the NORAH team used to calculate address-specific values for the aviation, road and rail traffic noise exposure in the whole investigation area around Frankfurt Airport and at the airports Berlin-Brandenburg, Cologne-Bonn and Stuttgart – and not only for the current situation, but also in some cases (at Frankfurt Airport) going back over the last 18 years.

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Further information on NORAH can be found on
→ Page 12 and on the Internet at
www.laermstudie.de

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The task

In order to precisely investigate the effect of noise (Glossary), the NORAH Study scientists need **exact data on the exposure** of each individual study subject to aviation, road and rail noise. Not only the current exposures, but also noise exposures in the past play a role. This is because, in particular for the occurrence of chronic disorders, observation over long periods is decisive. Noise levels measured or calculated only for the current situation are not sufficient because chronic diseases do not develop "overnight", but over a prolonged period. This is why the scientists also take into account the respective noise exposure of the surveyed persons in the last 18 years.
Moves of the study subjects also go into the calculations: someone who has not been living long near the airport could possibly respond differently to a long-term resident.

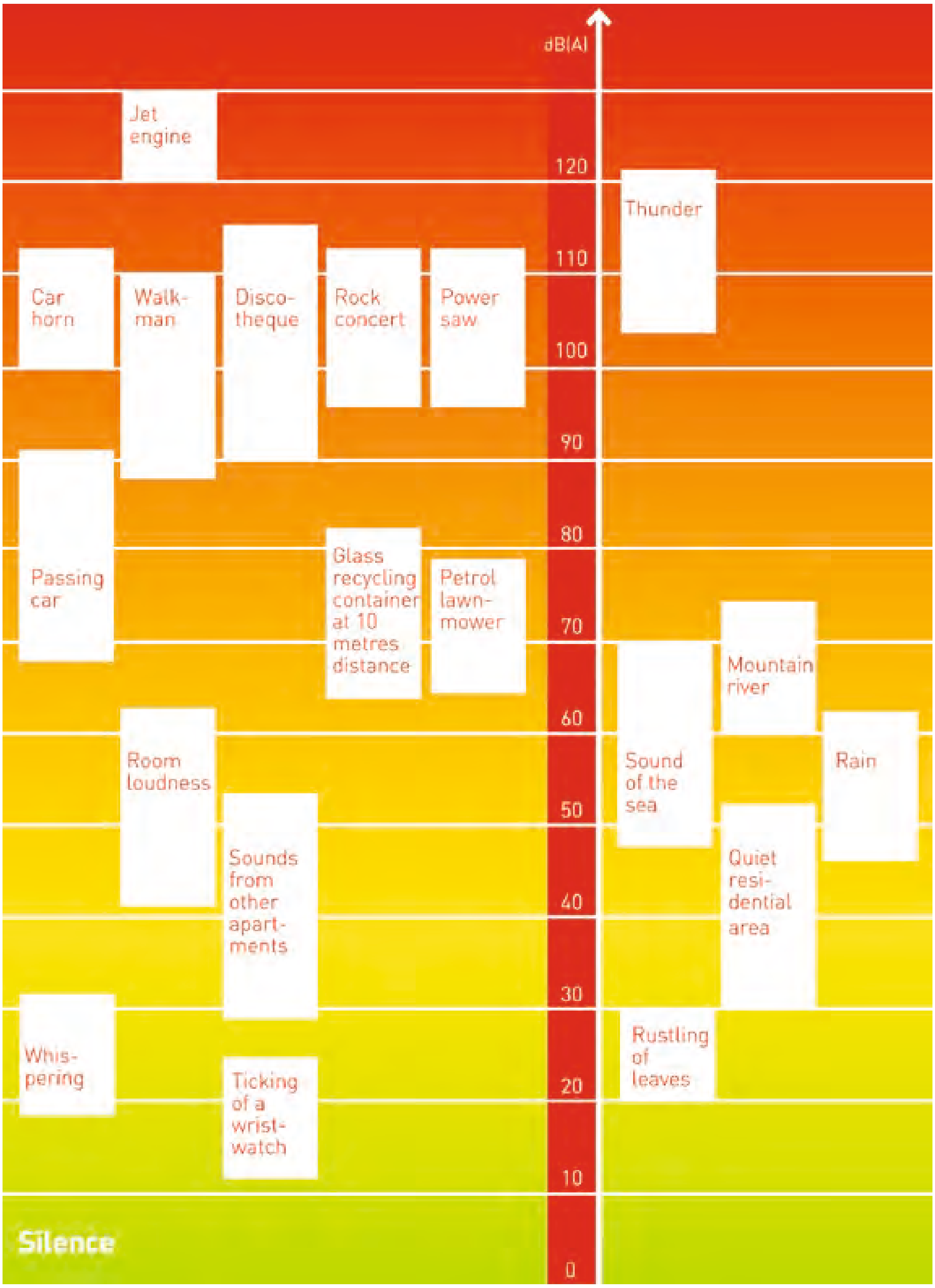
NORAH takes account **not only of aviation noise, but also rail and road noise (total traffic noise observation)**, and that alone at Frankfurt Airport for around 900,000 buildings in the investigation area and at **different times of the day and night.** For the NORAH sub-study on childhood development this means, for example, that not only the aviation noise at school, but also at home is taken into account. In order to include all of these factors, the scientists draw up an enormous amount of different acoustics data. For example, they also measure the room acoustics of the classrooms and look at the insulation of the buildings.

In order to generate comparisons with other airport locations, the scientists in the quality of life sub-study investigated the effects of noise on around 5,000 residents at Berlin-Brandenburg Airport before it begins operations, and on 2,500 residents in the areas of both Cologne-Bonn Airport and Stuttgart Airport.

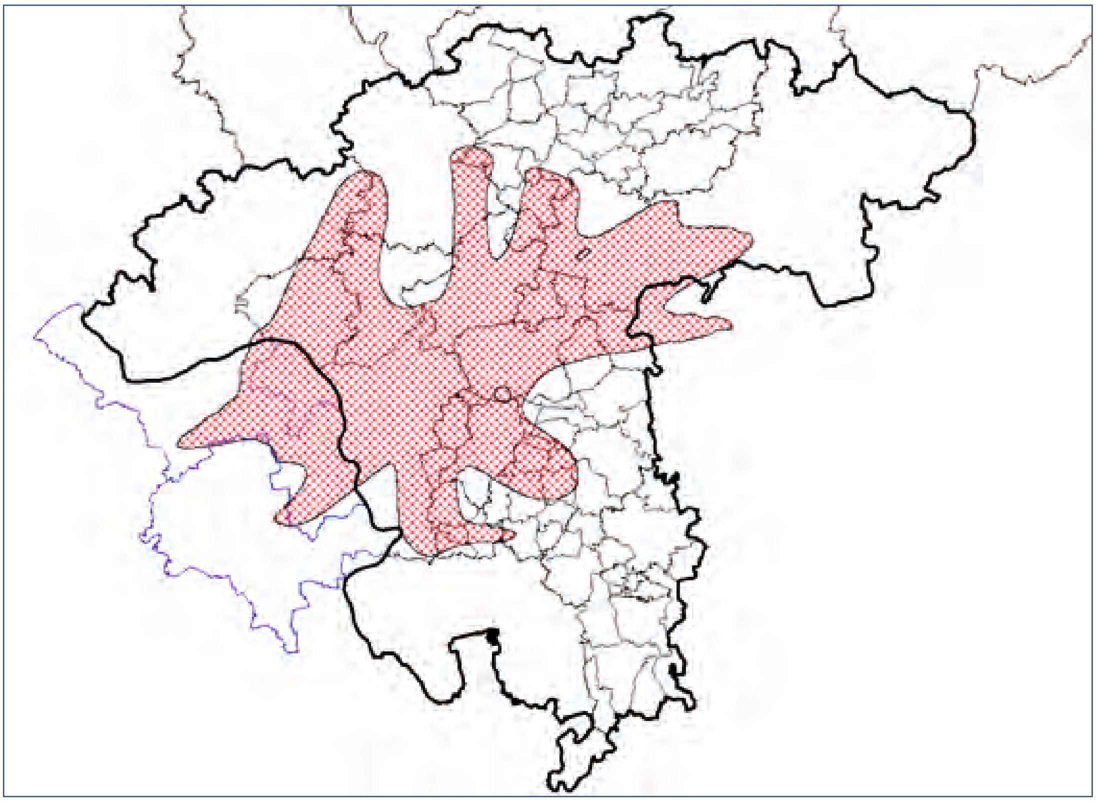
Sound and noise are not the same. To understand the following pages, it helps to know the difference: **Sound** (Glossary) is a term from physics, and refers generally and neutrally to noises emitted by a cause (source). These sounds are propagated in the air by pressure and density fluctuations (vibrations). These fluctuations can be determined using the sound pressure level (Glossary). The unit of measurement for the sound pressure level is the decibel (dB) (Glossary). How loud we perceive a sound to be varies from person to person.
Noise (Glossary) generally refers to undesired sound that is perceived as an annoyance, impairs wellbeing and, depending on loudness and duration, can even make people ill. Unlike sound, noise is not objectively measureable but **purely subjective**. This means that every person perceives sounds differently. Some people are hardly bothered, while others find even relatively low sound pressure levels a considerable burden.

One of the central values in acoustics is the **sound pressure level or, more simply, sound level.** It describes the loudness of the sound. The human ear can process a value range from 0 to 120 dB. The so-called **absolute threshold of hearing** is at 0 dB. **The pain range** begins at around 125 dB. As the decibel scale is a logarithmic scale, special rules apply here: an increase of the sound output of a machine by 10 dB means a multiplication of the sound intensity by 10, an increase of 20 dB a multiplication by 100 and of 30 dB by one thousand.

Everyday noises – the noise thermometer



Deutsche Gesellschaft für Akustik (German society for acoustics – DEGA), Brochure "Lärm im Alltag" (Noise in Everyday Life)



The map shows "overlaps" of the investigation areas per study module. The red hatching delineates the investigation area of the study modules quality of life and development. The thick black line shows the border of the administrative district of Darmstadt. The thin blue lines on the left enclose four regional districts in Rhineland-Palatinate (Worms, Alzey-Worms, Mainz and Mainz-Bingen). In connection with the borders of the administrative district of Darmstadt, these four regional districts form the investigation area for the study module on health.

Team

For the execution of the NORAH Study a research consortium from nine institutions was formed under the overall coordination of Prof. Dr. Rainer Guski (Ruhr University of Bochum) and Dirk Schreckenberg (ZEUS GmbH). The noise calculations for aviation, rail and road traffic in the Rhine-Main Region, as well as the calculation of the aviation noise exposure at the three other airports Berlin-Brandenburg, Cologne-Bonn and Stuttgart, were carried out by the engineering consultants Möhler + Partner Ingenieure AG as well as the company AVIA Consult.

Continuous sound level (Glossary)
The energy-equivalent continuous sound level (in short: L_{eq}) is a measure for the average noise exposure over a certain period (e.g. day or night). It is thus a measure for the average noise exposures in a certain period. It is made up of frequency, duration and level of the individual sound events. The L_{eq} is the basis for the determination of noise protection zones pursuant to the aviation noise act – separated according to day (6 – 22 hrs) and night (22 – 6 hrs). The measurement unit for the L_{eq} is the same as that for the sound pressure level: decibel (dB).

Investigation area at Frankfurt Airport

The investigation area of the NORAH Study is based on the level of noise exposure: it includes the area around Frankfurt Airport in which the continuous sound level from aviation in the reference year 2007 was over 40 dB. This area extends around 100 km from east to west and around 65 km in the north-south direction.

As well as aviation noise, the scientists are also investigating the effects of road and rail noise here, and carrying out the sub-studies on quality of life, blood pressure, sleep quality and on childhood development.

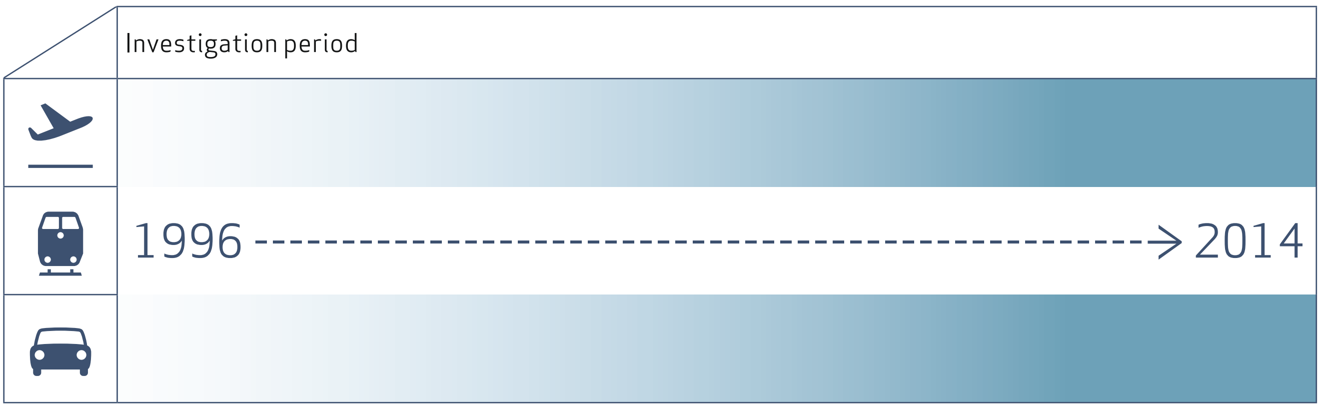
The health sub-studies extend even beyond this boundary. They are investigating all residential areas in the administrative district of Darmstadt as well as in Mainz and Rhine-Hessen. The investigation area is around 150 km from east to west and around 120 km from north to south. The aim of these two sub-studies is to survey a cross-section of the population in the entire Rhine-Main Region in order to be able to evaluate their state of health in relation to traffic noise. The acoustics experts also provide noise data for these sub-studies.

The same applies at Berlin-Brandenburg, Cologne-Bonn and Stuttgart as at Frankfurt Airport: in each case the investigation area includes the area around the airport in which the aviation-related continuous noise level lies above 40 dB (A).

Maximum noise level (Glossary)
The parameter which has the greatest influence on the irritation factor of a noise is the maximum sound level. It determines how strongly the noise stands out from the existing background noises. The maximum sound level is used for the calculation of another aviation noise evaluation measure (continuous noise level), but is also an independent criterion in itself for the evaluation of the aviation noise situation. The irritation effect depends on the level and the frequency of occurring maximum sound levels. The maximum sound (pressure) level is the highest measurement value that a sound level meter measures during a measurement.

Investigation period

The investigation period in which the scientists examined and calculated the acoustic data within the framework of the NORAH Study extends from 1996 to 2014.



WHERE DO THE AVIATION NOISE DATA COME FROM?

Data Acquisition System (DAS) – the aviation noise measurements

Aviation noise can be investigated in two ways: either it is calculated or it is measured. With a measurement it is only possible to register the current status at a point; with calculations, however, it is possible to represent noise exposure over large areas in the future. The present-day noise calculation programs allow experts to model complex situations. If they want to calculate the aviation noise, they need information on the incoming and outgoing flights: number, size, weight and technical equipment of the aircrafts as well as the type of operation, i.e. flight altitude and flight routes. The acoustics experts feed these data into mathematic formulae to calculate the noise exposure.

In Germany aviation noise is subject to statutory regulation: airports are obliged to save data on incoming and outgoing aircraft. According to an established formula, the acoustics experts can calculate where in the area of the airport how much aviation noise is being generated. The core of the calculations is the so-called Data Acquisition System (DAS) (Glossary). It contains information on the airport such as the orientation, length and geographical location of the runways and landing strips, the incoming and outgoing routes, and the number and type of takeoffs and landings. The DAS also contains the respective aircraft class and the information on the noise development of the aircraft. Day and night flights are registered separately. On the basis of this information a software program uses a legally established formula, the "Guide to the Calculation of Aviation Noise" (AzB08) to calculate where, when and how much noise is generated.

Nonetheless, the DAS data for Frankfurt Airport were not sufficient to answer the research questions of the NORAH scientists: for one thing, the stored flight routes were too short to allow conclusions to be drawn about the whole investigation area. In addition to this, the data from the previous years was not as detailed as necessary.

Aviation noise calculation by NORAH

How can you reconstruct sound events which occurred up to 18 years ago? The answer of the NORAH experts: in the case of flight noise you can use radar data or, to be more precise, the radar records of Deutsche Flugsicherung, the company in charge of air traffic control for Germany. For decades the state-owned company has been collecting and storing the "flight courses" of every single plane flying in German air space. The radar data used in the NORAH Study are provided by Deutsche Flugsicherung.

From radio traces to the noise database

Unlike the "flight corridors" stored in the Data Acquisition System, the radar data provides precise information on the route flown and altitude for every flight – like a line in three-dimensional space. In order to compile a noise database for the Rhine-Main Region from these radio traces, a special software is necessary. This is why the NORAH acoustics experts upgraded the software that normally works with the data of the DAS in such a way that it can also calculate the aviation noise exposure with radar data in accordance with the calculation regulation AzB08 (Glossary). With success: with the aid of comparisons with aviation noise measurement values, the acoustics experts of the NORAH research team were able to show that the aviation noise levels calculated using radar data provide a very good representation of the actual aviation noise exposure.

Aviation noise calculations over all modules	
Individual continuous noise level	The NORAH acoustics database contains for each study subject around 30 "acoustic indicators", including the so-called equivalent continuous sound level by day (6 – 22 hrs) and night (22 – 6 hrs), average maximum sound levels as well as maximum sound level statistics. From these data the researchers can calculate which sound levels from aviation, road and rail noise each individual study subject was exposed to in the various annual periods between 1996 and 2014. All of the data are, of course, anonymized according to the data protection regulations.
Acoustic indicator	The continuous sound level (L_{eq}) and the maximum sound level (L_{max}) are used as acoustic indicators. The continuous sound level refers to the mean noise exposure in a time range. The maximum sound level refers to the maximum sound level occurring in a time range. The maximum sound level is, therefore, always above the mean level.
Time ranges	The continuous sound level can fluctuate greatly over the course of the day. This is why the levels are stated separately for different time ranges: e.g. hourly 5 to 6 hrs, day 6 to 18 hrs, evening 18 to 22 hrs and night 22 to 6 hrs. Alongside the continuous sound level, the maximum levels are also stated for these time ranges.
Quality of life study Continuous sound level over the course of time	The continuous sound level can change over the course of time. For example, the traffic volume distribution on workdays can differ from that on the weekends. In order to take account of these changes, the continuous sound level is measured for individual weeks and months and for the half year and the whole year.
Health study 1997 to the present Reference year 2005	Within the long period from 1997 to the present, the traffic volumes and traffic routes can have changed starkly, with effects on the noise exposure of the residents. For this purpose, precise calculations were made for the reference year 2005 and estimates made for the other years.
Child study Home address Schools – exterior level Schools – interior level	The sound exposure of the children concerned changes depending on where they are. The noise exposure is lower indoors than outdoors. The noise exposure in the school can also differ from that in the home. This is why the levels for the different locations were calculated separately.
Overall view	The NORAH scientists calculated the noise exposure in a differentiated manner: according to daily, monthly and yearly changes, and depending on the location. This provides extensive information on the noise exposure of the individuals concerned. Depending on the questions addressed by the individual parts of the study, the acoustic indicators can be precisely selected which best describe the respective effect.

Calculating road and rail noise

Just like the aviation noise, the road and rail noise is nowadays mainly calculated rather than measured. The reason for this is that in the case of measurements, the weather conditions, for example, background noise or also difficult-to-register fluctuations of the traffic frequency over time can influence the measurement values. Accordingly, measurements are only ever a snapshot. For the objectives of the NORAH Study it is also important to know the noise exposure in the past. These values cannot be calculated, of course, by measurements, but only by calculation.

In Germany, the observation of road traffic is one of the tasks of the public administration. The observation of the roads within a community is the responsibility of the local authorities, while the federal authorities are responsible for the motorways. Not only for noise protection measures, but also, for example, for traffic planning, it is important to know how many vehicles are driving on a road at which times of the day. This is why the traffic authorities regularly carry out traffic surveys. The NORAH acoustics experts were able to use this information for their calculations. Other information was also used for the calculations, including the permissible top speeds and the various types of road surface. The scientists even took into account whether a road is sloped or level.

The NORAH scientists received information about rail traffic from the Federal Railway Authority and from the Bahnumweltzentrum Berlin. With these data they were able to reconstruct which trains travelled at which speeds and on which routes in the investigation area between 1995 and 2010. These data also provide information on the types of train (passenger trains or goods trains), train lengths and even changes in speed. The NORAH acoustics experts were able to use this to calculate which rail noise is generated when and where.

The road and rail traffic noise was calculated using the same methods as were used for the noise mapping in connection with the EU environmental noise directive.

Sound propagation
From the point of view of the acoustics experts, cars and trains are sound sources. In order to calculate from the strength of a source which sound level applies to a person, the acoustics experts have to follow the path of the sound from the source to the ear. For the calculation of noise it thus makes a big difference whether a train or truck is driving on low ground or on a hill. Buildings or noise protection walls can also influence the propagation of the sound. In the case of aviation noise, the distance and the angle between a building and the aircraft play a role in the propagation of the sound. In order to register such circumstances on site, the scientists use three-dimensional terrain models for their calculations provided by the regional ordinance survey offices. For the area of the administrative district of Darmstadt, for example, the researchers used a digital terrain model accurate to 10 metres provided by the Hessen Regional Office for Soil Management and Geoinformation. This allowed them to take all of the buildings in the investigation area into account.

Site-specific noise calculations

Just like the aviation noise data, the road and rail noise values for all study subjects also go into the NORAH database. Taken together, they can be used to draw up address-specific and time-specific noise exposure profiles for each individual. The database also contains information provided by the study subjects, for example, on the storey or the position of their bedroom. This is because even apparently small influences on the propagation of the sound can have a considerable effect on how much noise actually reaches the ear of a study subject. For example, the doubling of road traffic at a location would only lead to an increase in the continuous noise level of around three decibels. The sound level, however, that can be measured in front of a house on a busy road is around 15 to 20 decibels higher than it is at the back of the house.

“The sound evel in front of a house on a densely frequented street is around 15-20 decibels higher than it is at the back of the house.”

Photo: Deutscher Verkehrssicherheitsrat (DVR)

The role of acoustics in the NORAH Study

How do the NORAH scientists link their findings on noise exposure with the data that they collect on quality of life, health and childhood development?

Just to remind you: the NORAH Study wants to find out what effect noise exposures have on people – whether, for example, the quality of life is reduced, the risk of high blood pressure and cardiovascular disorders is increased, or the intellectual development of children is impaired.

This is why the scientists assign to each study subject an individual data set with the traffic noise exposure at different times of the day and night, and from the present going back in some cases for up to 18 years. This is the only way that they can, for example, establish connections between an earlier traffic noise exposure and a chronic disease.

The scientists compare the acoustic data with data on health and quality of life – both separately for road, rail and aviation noise as well as "overlapped" for the overall noise exposure. To collect the data on health and quality of life, the scientists carried out extensive surveys, tests, blood pressure and sleep measurements in the entre investigation area. They are also analyzing the health insurance data of 1.5 million insured persons.

The noise data already played an important role in the selection of the subjects for the individual sub-studies. On the basis of these data it was possible to examine persons selectively from various "sound level classes". The child study, for example, involved second-class schoolchildren from 29 schools. The schools are divided into three groups of seven exposed to a continuous noise level of 40–45 dB, 45–50 dB and 50–55 dB respectively, and eight schools where a continuous sound level of more than 55 dB prevails during the day. This makes it possible to statistically register differences between the development of the children in the various sound level classes **(for further information on the child study, see NORAH Knowledge No. 1 – "The NORAH Child Study: Effects of aviation noise on children").**

Data protection in the NORAH Study

A study that examines such a wide range of individual health and address-specific information has to be very careful about compliance with data protection regulations. This is why the NORAH scientists have elaborated a system that brings all of the relevant data for each study subject together while preserving the subject's anonymity. Expressed simply, the scientists assign numbers to the study subjects which cannot be traced back to the person. Before the study started, the NORAH scientists had their research project, their methods and their data protection concept thoroughly examined and approved by various ethics committees and the data protection authorities of the federal states concerned.

Photo: Fraport

NORAH overview

The noise impact study NORAH (Noise-Related Annoyance, Cognition, and Health) is one of the most extensive studies internationally on the effects of aviation, rail and road traffic noise on the health, quality of life and development of the population. Several research and development institutions from the fields of medicine, psychology, social science, acoustics and physics have joined to form the NORAH research consortium. The investigations are carried out mainly in the Rhine-Main Region, but also in the regions around the airports Berlin-Brandenburg, Cologne-Bonn and Stuttgart.

Overview of the NORAH sub-studies

Quality of life study

This sub-study investigates over three years how people living in the proximity of an airport suffer from aviation, rail and road traffic noise, which noise levels they are exposed to, what changes in the noise exposure mean to them, and how they assess their health and quality of life. A total of around 27,000 people at four airports are taking part in the surveys.

Sleep study

Very early or very late flights take place when many people are in bed. How well they actually manage to sleep despite the noise is the subject of the sleep study. For this purpose, the sleep of the study subject is electronically monitored over several nights like in a sleep laboratory. Parallel to this, a sound level meter registers every noise in the course of the night directly at the ear of the sleeper.

Health study

Using the health insurance data of 1.5 million insured persons in the Rhine-Main Region, the NORAH team examines how frequently various disorders, including heart disorders and depressions, occur in the region, and which noise the persons concerned were exposed to. There is a special emphasis on cardiovascular disorders: the scientists additionally surveyed study subjects with newly contracted disorders for other risk factors such as obesity or tobacco consumption.

Blood pressure study

Does the blood pressure react to aviation, rail and road traffic noise? What happens when the noise exposure changes? The blood pressure study pursues these questions in monitoring projects. Study subjects from areas with different noise exposures measure their own blood pressure every morning and evening for three weeks. More than 1,300 persons took part in the initial measurement phase. The second one runs until May 2014.

Child study

Does noise have an effect on the development of children? This is what the scientists want to find out in the child study. Investigations with more than 1,200 second-class schoolchildren in the Rhine-Main Region illuminate the connection between noise exposure and intellectual development. Surveys provide information on the quality of life of the children.

Quality of life module
Health module
Development module

Glossary

We feel it is important to explain the main technical terminology of the NORAH noise impact study in a manner that is comprehensible to laypersons. Terms that are not covered by the glossary will soon be available in the WIKI which is currently under construction.
wiki.umwelthaus.org

AzB/AzB08
The "Guide to the Calculation of Noise Abatement Ranges" (Anleitung zur Berechnung von Lärmschutzbereichen) is a calculation method with which the noise abatement ranges can be established in accordance with the law on the protection against aviation noise dated 01.06.2007 and the first implementing ordinance of the aviation noise act dated 2007. This calculation method is also used in the calculation of the aviation noise in the NORAH Study. Wherever AzB08 is mentioned, this refers to the current version from 2008.

DAS
The Data Acquisition System contains data on the airport, the take-off and landing corridors, as well as the number of flight movements. The system also stores the "noise class" to which the respective aircraft type belongs.

Continuous sound level
The equivalent continuous sound level (in short: L_{eq}) is a measure for the average noise exposure over a certain period in which frequency, duration and level of the individual sound events are taken into account. The L_{eq} is measured in decibels (dB). Alongside continuous sound level, acoustic experts use a range of other terms to distinguish different types of sound levels, e.g. the maximum sound level.

Decibel
Decibel is a physical unit of measurement used, among other things, for the sound pressure level.

Digital terrain model
A digital terrain model contains the elevation data for the terrain at several points. These points are arranged in specified, regular grids, e.g. 10 x 10 or 50 x 50 metres.

Noise
Noise is generally described as undesired sound.

Loudness
The loudness is more a matter of perception. Two tones with the same sound level but different frequency are often perceived as being differently loud. The measurement unit of loudness is the "phon" and the definition of phon is based on the subjective comparison of two sound events.

Maximum sound level
The parameter which has the greatest influence on the irritation factor of a noise is the maximum sound level. It determines how strongly the noise stands out from the existing background noises. The maximum sound level is used for the calculation of another aviation noise evaluation measure (continuous noise level), but is also an independent criterion in itself for the evaluation of the aviation noise situation. The irritation effect depends on the level and the frequency of occurring maximum sound levels.

Sound
Sound is generated by vibrations of a sound source.

Sound pressure level
The sound pressure level is stated in decibels "dB (A)" and is a measure for the loudness. The decibel scale from 0 to 120 dB (A) reflects the range from the absolute threshold of hearing to the pain threshold (see graphic: Noise Thermometer, page 7).

Imprint
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Concept, text and design
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Status
April 2014