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Procedures for the assessment and establishment of noise-reducing air routes

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Procedures for the assessment and establishment of noise-reducing air routes

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16. Abstract

For the improvement of the aircraft noise situation it was determined in 2007 by an amendment §32 of the air traffic act that the Federal Environment Agency is to be involved with the definition of air routes and flight procedures. Presently the assessment of proposals for the amendment of air routes rests primarily on operational criteria relevant for safety. Low transparency of the assessment procedure and insufficient consideration of the noise prevention was criticised during the last years by the aircraft noise affected persons. Within the scope of this study a proposal should be worked out for an improved assessment procedure which takes into account these criticized aspects.

First the study presents the current legal bases and the procedure of the definition of air routes and flight procedures. Besides, the involved stakeholders are introduced in case studies to describe the actual activities and judgments. Approach and departure procedure and their potential to decrease aircraft noise are explained and an insight into the actual assessment criteria and assessment procedures is given. A comparative analysis of internationally approved assessment procedures supports the determination of *Best of all Practice-examples*. Besides, actual trends and developments are included in the study.

Main focus of this study is the determination of a criteria catalogue which unites the different capacitive environment-related and operational aspects. In the developed 5-phase model for the assessment of air routes an unequivocal definition of the criteria is met. The quantitative classification and standardisation of the aspects is vital to guarantee an objective assessment. The assessment method is based on the Zurich aircraft noise index. Finally, the practical application is explained along an example.

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Abbreviations & Definitions

ADV	**A**rbeitsgemeinschaft **D**eutscher **V**erkehrsflughäfen
AIP	**A**eronautical **I**nformation **P**ublication (Luftfahrthandbuch)
ATC	**A**ir **T**raffic **C**ontrol
AzB	**A**nleitung **z**ur **B**erechnung von Lärmschutzbereichen
BAF	**B**undes**a**ufsichtsamt für **F**lugsicherung
BASUM	Departure Route (BASUM 1Q, 2A, 6K, etc.) at Bremen Airport via waypoint BASUM
BMU	**B**undes**m**inisterium für **U**mwelt, Naturschutz und Reaktorsicherheit
BMVBS	**B**undes**m**inisterium für **V**erkehr, **B**au- und **S**tadtentwicklung Ministerium
BVerwG	**B**undes**verw**altungs**g**ericht
BvF	**B**undes**v**ereinigung gegen **F**luglärm
CDA	**C**ontiniuous **D**escent **A**pproach
dB	Decibel
DES	**D**aten**e**rfassungs**s**ystem
DFS	**D**eutsche **F**lug**s**icherung GmbH
DLR	**D**eutsches Zentrum für **L**uft- und **R**aumfahrt
DME	**D**istance **M**easuring **E**quipment
EAM	**E**urocontrol **A**irspace **M**odel
EANS	**E**uropean Aircraft **N**oise **S**ervices
ECAC	**E**uropean **C**ivil **A**viation **C**onference
FAF	**F**inal **A**pproach **F**ix
FANOMOS	**F**light Track and **A**ircraft **No**ise **Mo**nitoring **S**ystem
FEG	**F**lug**e**rwartungs**g**ebiet
FLK	**F**lug**l**ärm**k**ommission
FMS	**F**light **M**anagement **S**ystem
Fraport	Operator of Frankfurt/Main Airport
ft	Feet (1 ft = 0,3048 m)
GBAS	**G**round **B**ased **A**ugmentation **S**ystem
GPS	NAVSTAR **G**lobal **P**ositioning **S**ystem

HA	**H**ighly **A**nnoyed
HALS/DTOP	**H**igh **A**pproach **L**anding **S**ystem / **D**ual **T**hreshold **Op**eration
HMWVL	**H**essisches **M**inisterium für **W**irtschaft, **V**erkehr und **L**andesentwicklung
HSD	**H**ighly **S**leep **D**isturbed
IAF	**I**nitial **A**pproach **F**ix
IATA	**I**nternational **A**ir **T**ransport **A**ssociation
ICAO	**I**nternational **C**ivil **A**viation **O**rganisation
IFR	**I**nstrument **F**light **R**ules
ILS	**I**nstrument **L**anding **S**ystem
Immission	Pollutant Concentration Levels
INM	**I**ntegrated **N**oise **M**odel
kn	**kn**ots
LBA	**L**uftfahrt-**B**undes**a**mt
L_{eq}	Equivalent Permanent Noise Level
LuftVG	**Luftv**erkehrs**g**esetz
LuftVO	**Luftv**erkehrs**o**rdnung
LuftVZO	**Luftv**erkehrs-**Z**ulassungs-**O**rdnung
MLS	**M**icrowave **L**anding **S**ystem
MNR	**M**inimum **N**oise **R**oute
NASA-TLX	**N**ational **A**eronautics and **S**pace **A**dministration **T**ask **L**oad Inde**x**
NAVSTAR	**Nav**igational **S**atellite **T**iming **a**nd **R**anging
NDB	**N**on **D**irectional **B**eacon, ungerichtetes Funkfeuer
NfL	**N**achrichten **f**ür **L**uftfahrer
NIROS	**N**oise **I**mpact **R**eduction and **O**ptimization **S**ystem
NM	**N**autische **M**eile;1 NM = 1,852 km
NN	**N**ormal **N**ull
PANS-OPS	**P**rocedures for **A**ir **N**avigation **S**ervices – Aircraft **Op**eration**s** (ICAO Doc. 8168)
PFV	**P**lan**f**eststellungs**v**erfahren (Planning Approval Procedure)
QICE	**Q**uiet **I**nnovative **C**ommuter
RDF	**R**egionales **D**ialog**f**orum
RNAV	**R**andom **Nav**igation**,** Ar**ea** **Nav**igation
SID	**S**tandard **I**nstrument **D**eparture
STAR	**S**tandard **T**erminal **A**rrival **R**oute
UBA	**U**mwelt**b**undes**a**mt
VGH	**V**erwaltungs**g**erichts**h**of

VwVfG	**V**er**w**altungs**v**er**f**ahrens**g**esetz
ZFI	**Z**üricher **F**luglärm-**I**ndex

CHAPTER 1 Introduction

The Federal Supervisory Authority for Air Navigation Services (BAF) appoints the air routes and procedure – the horizontal and vertical profile of the arrival and departure routes as well as aerodrome circling at airports – by statutory order. The preliminary technical planning of arrival and departure routes is perceived by Deutsche Flugsicherung GmbH (DFS). Besides, the DFS has to follow international directives and regulations of the International Civil Aviation Organization (ICAO) and the German Air Traffic Act (LuftVG) towards the protection of the population against unreasonable aircraft noise; nevertheless, the aspects of flight safety always have precedence [1]. This consideration and definition procedure has been criticised during the last years. Main criticism aspects of the aircraft noise-affected inhabitants are the missing transparency of the procedure, insufficient consideration of noise criteria and insufficient public participation.

With the amendment of the Air Traffic Noise Act as of 7 June 2007 additional environment-related regulations were accepted in the air traffic act [2]. Now as one of the new requirements according to §32 paragraph 3 LuftVG air routes and flight procedures which are of more particularly importance for the affected population concerning aircraft noise are determined in consultation with the Federal Environment Agency. With this a balance should be created between the partly contradicting economic and ecological interests and the protection of the population from aircraft noise.

The development of a proposal for an improved assessment procedure to define air routes and flight procedures is the aim of this study. The main focus of the study is the assessment of the single aspects Capacity, Operational Factors and Environment. Besides, with the procedure developed here a tool should be created which allows carrying out an assessment of individual air routes and flight procedures considering all the respective aspects (environment protection, operations, capacity).

Within the course of this study the actual legal bases of determining air routes and flight procedures in Germany are introduced in Chapter 2 as well as the definition process with the involved stakeholders is illustrated along case studies (airports Frankfurt/Main, Zurich and Bremen). Furthermore, an overview of the sets of rules applied internationally is given.

In the third chapter a choice of international regulations towards the definition of air routes and flight procedures is discussed as well as existing deviations. All introduced modelling processes and selection procedures should bring together the very differing criteria to create an objective balance of interests between all involved parties. Then the operational factors, relevant for safety which takes effect with the choice of corresponding routes, are explained in more detail. In addition environmental aspects along with the definition of air routes and flight procedures are considered. Besides, the planning tool used by the DFS NIROS (*Noise Impact Reduction and Optimization System*) is also introduced.

In chapter four a criteria catalogue is compiled for the assessment of air routes and flight procedures which establish the basis of the later assessment procedure. Basically this study distinguishes operational, capacitive and environment-related criteria. The choice of the criteria should serve the consideration of the different interests between the involved parties and must be clear and reproducible.

Based on the quantification, classification and weighting of each single criterion or the group of criteria is carried out in the Chapter 5 “Assessment procedures”. The precise weighting and quantification of the criteria in the assessment process must be always adapted to the local conditions and is a basis of an objective assessment. The chapter gives an overview how the identified criteria can be standardised. Finally, the practical application is demonstrated along an example.

CHAPTER 2 Status quo- Analysis

2.1 General

The definition of air routes and flight procedures has immediate influence on the noise exposure of the local residents in the airport area. With the modelling process and the selection procedure economic interests of aviation, the need of the general public in mobility and the environmental impact of the air traffic often collide with each other. Hence, a huge number of national and international regulations were determined to consider the different demands and interests. In this chapter these regulations are introduced and explained on the basis of examples. Besides, the stakeholders who are involved with the definition of air routes as well as the present assessment procedure are identified.

For this study the airport Frankfurt/Main was selected as an example, as it is the most important airport of Germany with annually around 500,000 flights. The expansion plans of the airport have already led in the past to strong protests of the population. Main argument of the expansion opponents is the increasing aircraft noise, but also the necessary deforestation of approx. 400 hectares woodland. Hence, already during the preliminary stages of the formal juridical procedures a so-called Mediation[2] was concluded in 2000. The mediation process first applied within the scope of an airport expansion which should give proponents as well as opponents the chance to show their positions in dialogue and to synchronise conclusions. With the following launch of a regional dialogue forum the objective was to achieve that the results of the mediation process are put into practice and the arrangements are kept and followed (see moreover [31]).

[2] *Mediation* (lat. Mediation) is a structured voluntary procedure to the constructive settlement or avoidance of a conflict. The conflict parties want to reach with support of a third impartial person (media gate) a concerted arrangement which corresponds to their needs and interests.

2.2 Legal situation and proceeding to the definition of air routes in Germany

National legislation to establish air routes and procedures are based on international regulations.

2.2.1 International regulations

When planning air routes and flight procedures in particular the regulations of the ICAO are to be followed, which are determined in the PANS-OPS[3]. This is an international applied set of rules about the construction of air routes and procedure protection areas to avoid terrain collisions. These are recommended merely considering the flight safety. Nevertheless, under noise aspects currently no optimisation takes place. The ICAO document 8168-OPS/611, Procedures for air navigation of service – Aircraft Operations, briefly PANS-OPS, was published in 1951 for the first time. Since then the document was reworked and developed regularly. Currently there are two parts:

- *Volume 1* – flight procedures

  This part describes procedures, which have to be kept by pilots. Also, the numerous parameters on which criteria Volume 2 is based are specified.

- *Volume 2* – construction of visual and instruments flight procedures

  This part describes the areas where planning is needed, as well as the demands for the obstacle clearance with the aim to allow safe and regular air traffic under instrument flight rules. It contains the basic directives for States and such organisations that plan and implement flight procedures.

For planning and defining air routes Volume 2 is relevant. It is made up out of six parts and includes numerous appendices. With regard to approach and departure procedures it must be put into practice by the member states of the ICAO within the national law.

2.2.2 National legal bases to the definition of air routes

The juridical basis to the definition of air routes arises from the German Air Transport Act, which refers among others to the ICAO standards. This authorises the Federal Ministry of Transport to remit construction and urban development and in addition, to remit statutory orders for the procedures to be followed in using the German airspace in flight and on the ground (§32 par. 1; sentence 1; no.1 LuftVG).

[3] Procedures for Air Navigation Services – Aircraft Operations (ICAO Doc 8168 OPS/611)

The responsibility for defining flight procedures (including flight routes, altitudes and reporting points) is regulated in §27a of the Air Transport Regulations (LuftVO). Up to now the Federal Aviation Office (LBA) remitted this in the form of statutory orders, what has changed since the law of the establishment of a Federal Supervisory Authority for Air Navigation Services (BAF) coming into force on 4 August 2009.

§27a LuftVO,

(1) *As far as the responsible air traffic control centre gives no air traffic control clearance acc. §26 paragraph 2 sentence 2, the aircraft pilot is obliged during flights within control zones, with approaches and departures from and to airfields with air traffic control service and with flights according to instrument flight rules to obey the prescribed flight procedures.*

(2) ***1. The Federal Supervisory Authority for Air Navigation Services is authorised to determine the flight procedures after paragraph 1 including flight routes, altitudes and reporting points by statutory order.***
2. *To the defence of risks for the safety of air traffic as well as public safety the air traffic control service provider by order may define in particular cases flight procedure by direction; nevertheless, the duration of the definition may not exceed three months.*

In a judgment of the Federal Administrative Court from the 28 June 2000 (file number 11 C 13/99) to the grounds for appeals of airport residents against the definition of arrival and departure routes it is said:

> *„Against the definition of arrival and departure routes from and to airfields according to §27a paragraph 2 sentence 1 LuftVO by statutory order affected airport residents can attain legal protection in the way of the declaratory action. The complaint can succeed only if the interest of a plaintiff in the protection against unreasonable noise pollution has remained arbitrarily disregarded. "*

Hence, comprehensive information of the planning intentions of the DFS takes place in cases of the amendment or introduction of air routes usually in cooperation with the Air Traffic Noise Commission (FLK). However, the FLK has only advisory function and proposes measures for the protection of the population from aircraft noise. The DFS puts these measures into place as far as possible and informs the FLK on deviations if necessary.

2.2.3 Federal Supervisory Authority for Air Navigation Services

The BAF is a federal authority, which was founded in the city Langen after the corresponding law became effective on 18 September 2009. It acts as a German supervisory authority in the area of civil air traffic control services for the purposes of the European regulations to foster the creation of a uniform European airspace. It is a subordinate of the Federal Ministry of Transport, Building and Urban Development.

The BAF ensures that all active air traffic control service providers in Germany fulfil the conditions applied to them. It supervises the international air traffic control centres and besides works closely with the national supervisory authorities of its neighbouring states.

An important function of the BAF is the formal definition of air routes. Thus BAF took over this function from the LBA; the air route planning is perceived furthermore by the DFS.

2.2.4 Law of the protection against aircraft noise

In 2007 the amended law for protection against aircraft noise became effective. This law intends to set the definition of noise protection areas at existing and substantially structurally changed civil and military airfields. The noise protection area of an airfield is divided in magnitude of noise exposure in two protective zones for the day and one protective zone for the night. In the day-protective zone 1 and the night-protective zone structural passive noise protection measures are refunded at the expenses of the airfield operator in existing residential buildings. In addition, within the night - protective zone it is planned that the airfield operator refunds expenditures for the installation of airing facilities in rooms which are used predominantly for sleeping. The definition of noise protection areas is laid down through statutory order of the respective federal state government. Within the scope of the amendment of the air transport noise act a change of §32 LuftVG was also made. Prospectively, air routes and flight procedures, which are affecting the population concerning aircraft noise and are of particular importance, have to be determined in consultation with[4] the Federal Environment Agency (UBA). Thus a balance should be established between the partly contradicting economic and ecological interests.

[4] "In consultation with": Form of the co-operation of an office (e.g., authority) with a legal act whose approval is not required, however, in contrast to „in the agreement“. Indeed, opportunity must be given to this office to the statement and be included this in the decision-making process.

2.2.5 Involved Stakeholders

In the following those stakeholders are described which are involved in the planning and assessment of air routes.

The most important function in the area of the air route planning as well as flight guidance is incumbent upon the DFS. According §27c LuftVG DFS provides air traffic control for a safe, well arranged and fluent processing of air traffic. Besides, the DFS and the responsible aeronautical authorities have to work towards to protect the population against unreasonable aircraft noise (§29b paragraph 2 LuftVG). Nevertheless, the correctness and obligation of the general planning directive applied on this ground of the DFS is disputed. During daytime (06:00 – 23:00 o'clock) in this directive precedence is admitted for fluent air traffic control, i.e. achieving a very high traffic density, before noise prevention interests.

Only during the night hours (23:00 – 06:00 o'clock) a higher importance than the economic aspects is admitted for the noise prevention interests. Besides, flight safety has in general utmost priority [1][46].

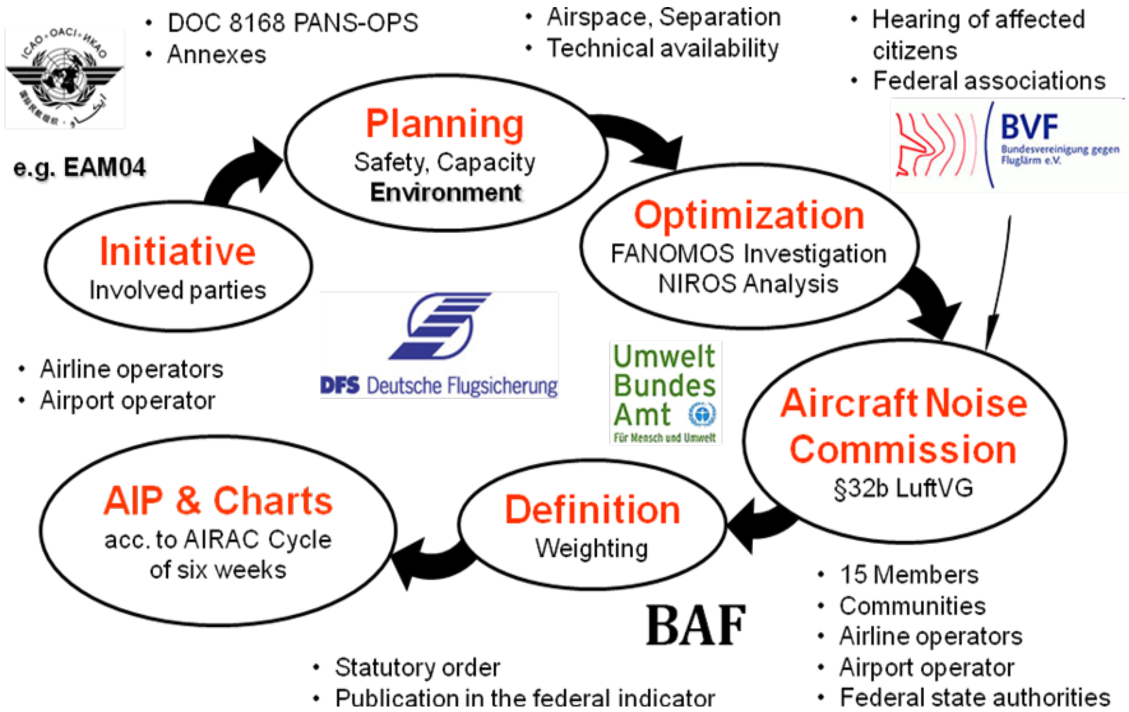

Figure 2-1: Interdependencies during the reassessment and amendment of air routes

The initiative for a change to air routes stems from one or several involved parties (DFS, airline, Air Traffic Noise Commission or a local authority) (Figure 2-1). The initiative can have different reasons. These include flight safety requirements, new flight-operational opportunities (e.g., area navigation procedures) or the specific reduction of existing aircraft noise exposure. Within the scope of this definition process different variants of air routes are planned and also analysed considering the three main criteria; **safety**, **capacity** and **environmental protection**. The planning is based on the procedural criteria according to ICAO Doc 8168 (PANS-OPS) for air route design as well as the results from the software NIROS used by DFS for the noise functional assessment. Then the DFS compiles different options for the next consultation within the local FLK.

The Air Traffic Noise Commissions (FLK) according to the Air Traffic Act have to be established for every commercial airport which is connected to scheduled air traffic and for which a noise protection area has to be established according to the law of the protection against aircraft noise.

§32b LuftVG, Aircraft Noise Commission

(4) *In the commission should be: Representatives of **municipalities** in the area of the airfield affected by the aircraft noise, representatives of the **German National Organization Against Aircraft Noise**, representatives of the **aircraft holders**, representatives of the office responsible for air **traffic control**, representatives of the **airfield operators**, representatives of the higher **federal state authorities** commissioned by the federal state government. Under special circumstances other members can be appointed to the commission if required. No more than 15 members should be appointed. The membership is honorary.*

The function of the FLK is to advise the regulatory authority and the air traffic control service provider about measures for the protection against aircraft noise and against air pollution by aircraft.

After the adaptation by DFS taking into account the consultation results of the FLK the proposals for new air routes are presented to the BAF. Then the BAF establishes the routes for implementation according §32 paragraph 3 LuftVG in consultation with the Federal Environment Agency:

(3) *Statutory orders do not need any approval by the Minister of State if they serve the realisation of directives and recommendations of the international civil aviation organisation (ICAO). The same applies for statutory orders which regulate to the guarantee of safety of the air traffic and the public safety or order to necessary details the realisation of the regulations acc. paragraph 1 and the realisation of training regulations and check requirements for aviation personnel acc. paragraph 1. The Federal Ministry of Transport, Building and Urban Development can transfer the authorisation by statutory order on to the Federal Aviation Office (LBA) to the decree of regulations acc. sentence 2 and of the regulations guaranteeing the safety of air traffic and the public safety or orders to*

necessary details on implementation, checking regulations and operating instructions acc. paragraph 4a ***Regulations acc. sentence 3 which are of particular importance for the protection of the population from aircraft noise will be imposed in consultation with the Federal Environment Agency.***

After the Federal Environment Agency completed the noise functional review of the air route proposals, the evaluation results shall be presented to the BAF. Taking into account, the judgments of the definition of air routes of the **Federal Administrative Court** (see chapter 2.2.2), the BAF carries out a consideration and weighting of the individual interests. Thereby, the BAF has a certain administrative discretion. Finally, the air route change will be issued by statutory order. The **publication of** the air routes takes place in the Bundesanzeiger (official publication organ of the state), the Notices to Airmen (NOTAMs) and in the Aeronautical Information Publication Germany (AIP).

The **German National Organization against Aircraft Noise** (registered society, BvF) is involved above all in the improvement of the protection of the population from aircraft noise and mentions as general aims and requirements [33]:

- „Reduction of the allowed aircraft noise exposure on nuisance limits, not on health limits.
- Reduction of night flights and promulgation of night flight bans.
- The immediate implementation of noise protection measures (e.g., noise preventive windows and air ventilation installations) in flats when exposed to noise in excess of the allowed values, and not only after years. "

The present regulations and practices for amendments and new definitions of air routes in the perspective of BVF are considered as absolutely inadequate from an environmental protection perspective and it has hence compiled a position paper. In this document it describes the rights and obligations to be followed of all those stakeholders who are concerned by amendments and new definitions of air routes. This position paper includes a detailed check list of necessary documents which should be considered. Hence, specifically the BvF in a summary puts up the following demands what has to be followed along with route definitions and utilisation changes [47]:

- "Appropriate determination of the present and the future traffic and the aircraft type distribution.
- Appropriate determination of the impairment through noise immission plans and conflict plans in which transgressions of a threshold value can be identified after certain assessment intervals (in any case and on account of the EU environmental

noise directive). The situation and function of the affected areas, characteristics and continuance of the urbanisation and utilization have to be considered so that areas and facilities needing protection become identifiable. (that to be a responsibility of the respective municipality)

- The protection of the health has precedence before economic considerations
- Up to now considerably exposed inhabitants may be on no account exposed even higher.
- Newly exposed inhabitants may be on no account exposed with more than by day L_{Aeq} = 60 dB (A), in the evening L_{Aeq} = 55 dB (A) and at night L_{Aeq} = 50 dB (A). Newly exposed are entitled to preventive measures.
- A concrete and by extensive and accessible documentation accompanied alternative check
- Affected local authority districts and citizens are to be involved. "

The noise calculation- and -assessment-procedure NIROS (cf. chapter 3.3.2) was criticised by the BvF in this position paper of 2004. Some points are not applicable anymore in the revised NIROS version which is used in the meantime by the DFS (e.g., the only documentation of the route assessment with the help of the single number quality indicator). The BvF demands a proper exposure assessment to be carried out after classification of the affected inhabitants in single 5dB-exposure categories. By this, a calculation of the L_{DEN} index should be carried out with more advanced aircraft noise calculation methods and of concern here, a comparison between the present and the planned air routes (and possible alternatives) should take place. This differentiated analysis allows the examination of the main demand of the BvF to prevent already considerably exposed persons (L_{DEN} >= 55 dB (A) or L_{night} >= 45 dB (A) to be exposed even higher on no account. Above this, in the check list an assessment of the maximum noise level and maximum noise level distribution is demanded [47].

Account is taken within the scope of the approach suggested here that with regard to these demands a detailed documentation of all intermediate results of the noise calculations should take place. While for a final assessment, for example, the day and night assessment in only one descriptor is intertwined, the corresponding calculations are to be documented separately. Furthermore, only those events are included for the consideration of the day hours in the assessment which result at least in a L_{eq16} of 47 dB. The representation of the number of inhabitants exposed can nevertheless make sense for the determination of newly exposed people also below this assessment threshold.

Furthermore, within the scope of the procedure introduced here emphasize is put on the fact that in particular the weighting of the different criteria should take place among themselves within the scope of a clear and understandable dialogue with all involved parties or affected persons. These aspects are taken up again in the corresponding chapters separately.

2.3 Case studies representing the role of stakeholders for the definition or amendment of air routes

The process of the definition of air routes in Germany is not to be seen without criticism as the following case studies indicate. A problem concerning aircraft noise is the still existing imbalance of the involved stakeholders. Due to insufficient transparency, especially the affected local residents and municipalities can often not react to the planning of air routes. Though, formally the opportunity of involvement exists for them, however, this exists mostly only in recommendations without legal obligation.

2.3.1 Anti-noise pact

The participation of stakeholders and affected persons has won in the past more and more in importance. As an example the mediation processes at the airport of Frankfurt can be named concluded in 2000. The specific recommendations of the mediation process are:

- Capacity enlargement by extending the airport (new runway, enlargement of the terminal areas) by concurrent optimisation of the available system, e.g., by HALS/DTOP (High Approach Landing System / Dual Threshold Operation),
- Establishment of an "anti-noise pact",
- Strict night flight ban,
- Continuation of the communication in the mediation process within the so-called Regional Dialogue Forum (RDF).

The RDF was established by the Hessian state government in 2000 and was integrated into the further development of the Frankfurt airport and into the corresponding planning for the Rhine Main region. In the RDF overall 33 members from 27 institutions were represented up to June, 2008 [34]. This should make it easier to start any discussion between all parties involved in the extension of the area around Frankfurt airport.

To adapt to this extensive working program of the RDF, a total of five project teams to different subjects were established. In the project teams cooperating representatives from institutions which, were not represented directly in the RDF, got involved as well. These teams presented coordinated recommendations to open questions by RDF, mainly unanimously. Besides, a project team worked on detailed questions to the implementation of the anti-noise pact. Questions from the anti-noise pact and the RDF dealt among other things with the planning tools and processes as well as with the communication of the DFS during the definition of air routes with minimum noise exposure (minimum Noise Routes).

Among the rest, concrete results of the RDF were [45]:

- Admission of the night flight ban in the application of Fraport AG to the airport plan approval procedure
- Test and operational admission of noise-reducing approach procedures (e.g., Continuous Descent Approach (CDA) cf. 3.5.2, alternative flap setting)
- Transparency for the public (e.g., flight tracks "live" by the DFS)

After the official work of the RDF ended on 17 June 2008, all members agreed that the dialogue must go on. The federal state government already made a cabinet decision on new structures for a "forum airport and region” on 13 June 2008, which should address the three pillars: „Expert panel on active sound proofing“, „convent airport and region“ and "environment house community office". This forum should be guided by a co-ordinating council with three equal chairpersons. This new sophisticated structure is adapted for the future need of dialogue, implementation, and regional transparency and thus follows essential requests of the RDF members.

2.3.2 Departure routes overhead Taunus (TABUM)

In view of forecasted capacity bottlenecks in parts of the German airspace and the concurrent demand of the affected airlines for optimum flight profiles, the DFS resolved this by early design of new airspace structures and investigating the feasibility by means of fast and real time simulations. Tool for the fast time simulations was the Eurocontrol Airspace Model (EAM). The results of the simulations from EAM 04 were introduced as a German contribution to the development of the route model ARN Version 3 (ATS Routes and Associated Navigation Means version 3) and were agreed upon internationally. Hence, among other measures, since 19th of April, 2001 the complete east-west traffic at the airport Frankfurt/Main with northern destinations which was guided up to then overhead the radio beacon TAU is now guided over the new waypoints TABUM and GOGAS. TABUM is approx. 10 km to the east of Bad Camberg, GOGAS is close to Sankt Goarshausen.

The TABUM route is used for northerly departures. Aircraft with normal climb rate follow as far as possible the motor highway in northwest direction and flying over less inhabited area. The aircraft which do not achieve these climb requirements fly in westerly direction towards Mainz, until passing an altitude of 3,500 ft and then turn northwest to overfly Wiesbaden. After a further right turn all aircraft merge over the Hochtaunus as soon as they have reached an altitude of 4,400 ft (approx. 1,330 m).

The representation of the flight expectation areas in Figure 2-2 shows that large parts of the Main Taunus Region (MTK) were loaded with aircraft noise by the new air routes. Obviously this led to considerable protests of the population, particularly as the amendment was carried out without previous hearing of the representatives by affected towns and municipalities:

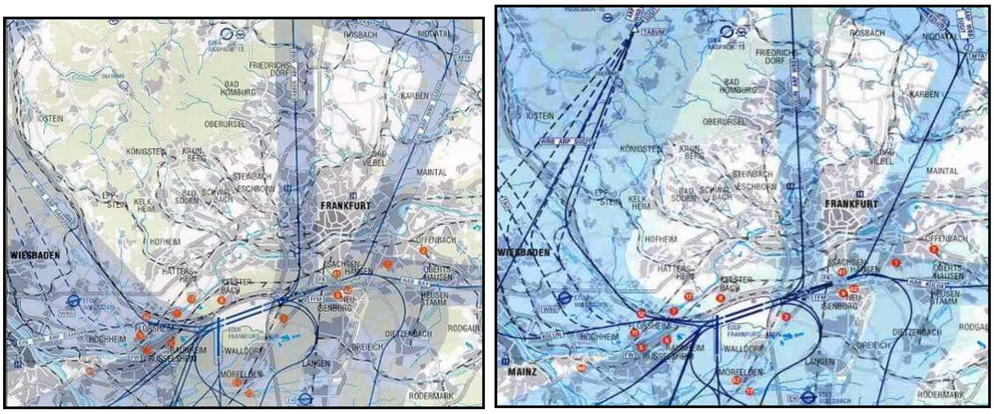

Figure 2-2: Cutting from the flight expectation area Frankfurt/Main in 2000 (on the left) and after the 19th of April, 2001 (on the right) [10]

Below is the extract of a common press release of the Taunus cities Bad Soden, Eppstein, Glashütten, Kelkheim and Schmitten from 8th of March, 2001.

> *[…] All mayors agree on the fact that the information policy of the DFS is unprofessional to the highest degree. No town / municipality were informed about the decision of the air route change. While the MTK towns were officially informed in the country hall on March 01, 2001, the towns of the Hochtaunus County have only been informed on March 08, 2001 by DFS. This has happened only four weeks after (!) the press publication of DFS.*
>
> *Given the history of the expansion discussion where extensive mediation processes took place, the information policy of DFS and the Federal Office of Civil Aeronautics is not understandable. […]*

Therefore, the municipalities affected from the new air routes united and complained to the Hessian higher administrative court (VGH) against this definition of new departure routes in the northwest of the airport Frankfurt/Main.

The urgent application for temporary legal protection was rejected by the VGH in Kassel with decision from 18 April 2001 (file number 2 Q 1064/01). The Hessian VGH explains the ruling with the fact that the plaintiffs who are themselves provider of sovereign competence cannot appeal to the state based on fundamental rights - like the property right - as a defensive law. Only the affected members of the public are entitled to do this.

Then, in the following ruling of the VGH as of 11 February 2003 the plaintiffs have achieved a partial success. There had been complaints against these air routes in the first procedure (file number 2 A 1062/01) of the cities of Bad Soden, Eppstein, Kelkheim and Königstein as well as the municipalities of Glashütten, Schmitten and Niedernhausen and in the second procedure (file number 2 A 1569/01) four private plaintiffs from Kelkheim, Schmitten and Glashütten. The court has found out that the LBA has not sufficiently enough considered the specific topographic relations within the route designation. The noise reduction which appears with increasing altitude is neutralised to a great extent by the substantial increase of the ground, but is qualified at least as considerably. Therefore, the LBA has to check the route guidance taking into account the height above ground level, particularly as it is not to be excluded that a possible small shift of the route leads to an overall noise-reducing alternative. To avoid that as a result of this decision risks originate for the safety of the air traffic or additional exposures for areas which by now are considerably noise exposed, the VGH has admitted to the LBA a transition period of three months in which the plaintiffs have to tolerate the flight procedures in spite of the planning mistake. However, the VGH clarifies that no basic reasons stood in the way for route guidance over currently not exposed Taunus regions. Hence, according to the result of the examination of the procedures criticised by the court it would not be excluded that the LBA settles these or similar air routes anew. The complaints achieved no success, as far as the complaints are directed against approach procedures or those departure procedures which leave the airport first in southern and southwest direction and are led then in a wide right turn to the north-east via TABUM. Anyway, those only relatively seldom used procedures are not subject to be complained after the statements of the VGH according to planning law. The Hessian higher administrative court has not admitted appealing; against this decision appealing is with the Federal Administrative Court.

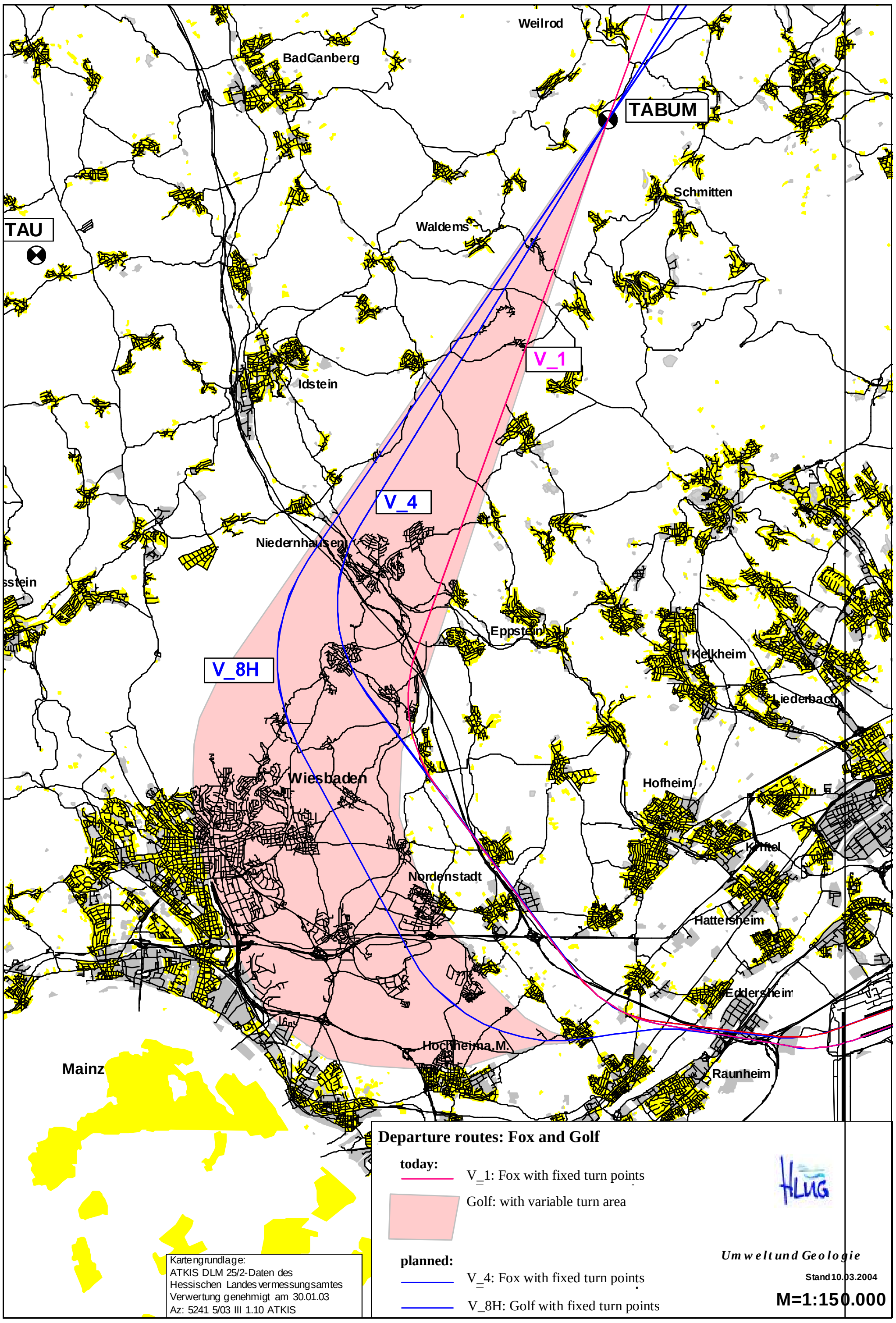

Figure 2-3: TABUM Route comparison Old / new from the 10th of March, 2004 [10]

As a result the LBA has lodged complaint on the 17th of April, 2003 against two judgments of the VGH with the Federal Administrative Court because of the non-admission to appeal:

[...] LBA and DFS do not misjudge the balance of the decisions made by the VGH, which contains widely practicable attempts to the actual and juridical assessment of the definition of flight procedures as from their view. With this objection particularly the statements of the court should be addressed to the aircraft noise levels from which compelling a consideration is to be carried out between operational interests and noise protection interests and to the level of the impairment from which a law breaking can be given. Because of the basic importance of this question, which the legislator has left open up to now a clarification should be made by the Federal Administrative Court. Regardless of this decision, the simulation models of the DFS were adapted to the topography and alternative air routes were checked. [...]

On the 29th of July, 2003 the plaintiffs of the Taunus Region were invited to attend a meeting with the Frankfurt Air Traffic Noise Commission to report their concern. The Air Traffic Noise Commission dealt in detail with the matter and different possible routings were checked. Figure 2-3 shows exemplarily two variants of flight routes.

The Federal Administrative Court (BVerwG) in Leipzig has confirmed the judgement of the VGH on the 24th of June, 2004 and has rejected the complaints. The new air route system has been implemented for the area of Frankfurt; consequently the municipalities strongly affected by aircraft noise in the western area of the airport were relieved. Within the scope of the reorganisation and according to the statements of the VGH, the LBA has made provision for the fact that the area of the Hochtaunus is overflown only by aircraft which have reached a least an altitude of 4,400 ft above Mean Sea Level (MSL). Through this it is made sure in the opinion of the court that no unreasonable aircraft noise burden are caused, because the limiting noise thresholds of a maximum of 50 dB (A) during day and 43 dB (A) at night are not exceeded. Hence, there was no reason for the assumption that the LBA could have overlooked variants of routings within the carried out alternative check when it has not made the terrain conditions in the affected Hochtaunus municipalities to an subject of more precise determinations (file number BVerwG 4 to C 11.03 and 4 C 15.03).

Long-term consequence from this judgment is the aim to keep the aircraft noise exposure below these thresholds. Because it is binding and cannot be arraigned any more, legal certainty came for all involved with this ruling of the Federal Administrative Court.

On 6 December 2004 DFS published the following press release:

[…] The so-called TABUM route is shifted slightly to the west. This is the result of the investigations by the DFS Deutsche Flugsicherung GmbH. The new route was already discussed with the board of directors of the Air Traffic Noise Commission and will be in-

troduced at the beginning of next year. The new departure route used with west wind at the Frankfurt airport proceeds first, as before, to Flörsheim, Wallau, and along the A3 and after to the west passing Schlossborn and Glashütten. After checking all possibilities to meet the requests of the population the following solution was found and in detailed investigations has emerged as the best alternative. Beside this primarily used so-called "TABUM FOX-route", for the relatively small number of heavy aircraft the departure fix shifts slightly to the west (so-called "TABUM GOLF-route"). For the time being, the spreading linked to this routing in the first distance segment continues. The conformist course of the route is the result of a several years' discussion about the aircraft noise exposure in the Taunus region. DFS fully adopts to the solution compiled and with detailed considerations of the low optimisation potential [safety, capacity, environment, Ed.]. With the Air Traffic Noise Commission the different variants had been discussed. At last it appeared that the scope is very low for the discharge from aircraft noise of single areas without generating new impairments […]

It should be noted that meanwhile the air routes were changed in the area of the airport Frankfurt/Main once more and now a fixed turning point is introduced for the departures to the north.

2.3.3 The Rilax judgment of the higher administrative court Baden-Wurttemberg about the re-arrangement of air routes to the airport of Zurich

In the course of a reorganisation of the routings at European level the LBA remitted a statutory order which determines the navigation point RILAX for the approach from the north to the airport of Zurich in May, 2000. This point is above the eastern outskirts of Donaueschingen. At the same time the regulation for this area determines a holding area for the aircraft, which cannot land in Zurich immediately. This statutory order has been challenged by Donaueschingen and Villingen-Schwenningen as well as another eight towns and municipalities. The higher administrative court Baden-Wurttemberg had decided on 22 March 2002 that this statutory order had been issued unlawfully (file number 8 p. 1271/01). As reason it was said that the affected towns and municipalities had not been informed before the decree of the regulation. Besides, the affected towns and municipalities had no opportunity to take stand on the planned regulations. In addition, an investigation of alternatives to the elected routing was omitted.

This judgment shows that up to now no formal participation was planned by towns and municipalities on changes of routings.

The LBA had appealed against the judgment, because objection was granted against the non-admission ruling to the appeal acc. the Federal Administrative Court decision as of 19 September 2002. The admission for the appeal was reasoned by the Federal Administrative Court with the general importance of the case. A decision needs to be made by the Federal Administrative Court on whether affected communities must be informed beforehand about the definition of a holding procedure.

The Federal Administrative Court annulled on 26 November 2003 the appeal on the verdict of the Higher Administrative Court Baden-Wurttemberg and rejected the complaints. It believes that the LBA should not be obliged to listen to the affected municipalities before the issue of a regulation to the definition of flight procedures. Such a right for participation of the municipalities would not be planned in the law and also would not be offered constitutionally. Also the LBA cannot be accused of arbitrary disregard of the noise protection interests of the affected municipalities and local. Following this, the minimum altitude has been raised from originally 7,000 ft to 13,000 ft in view of the noise protection interests of the local residents for the holding procedure.

2.3.4 Reintroduction of the "Wesertal Route" at the airport of Bremen in June, 2007

In June, 2007 the so-called "Wesertal route" was reintroduced after long technical discussions.

In 2006 till mid of 2007, departures from Bremen airport occurred to the east with southern destinations along the so-called "Hemelingen Route". This departure route proceeded via the radio beacon "Hemelingen (HIG)", so that the housing areas at Hemelingen and Osterholz were affected for flights to the south. Because this routing led to numerous noise complaints the reintroduction of the so-called "Wesertal-Route” was discussed. On this routing the departure is not flown to Hemelingen radio beacon, but a turn to the south is already introduced when reaching the river Weser. In 2006 the DFS carried out an assessment of the aircraft noise situation with a NIROS calculation. Nevertheless, this aircraft noise calculation was based on the theoretical ideal flight track and did not consider the lateral deviation of the flights. As a result of this calculation less people would have been concerned with the Wesertal-Route by aircraft noise than with the Hemelingen-Route.

At the same time of the NIROS calculation an engineering firm was contracted by the Bremen Government Office for Building, Environment and Transport with the calculation of the aircraft noise following the EC environmental noise directive. For this calculation, the aircraft noise exposure was determined on the basis of the air traffic at the airport of Bremen in 2005 and was shown in noise maps. Within the scope of these calculations different routings were also investigated (variants "Hemelingen" and "Wesertal"). Also the result of the final report comes up with a slight discharge in noise in northern Hemelingen and Osterholz by the reintroduction of the Wesertal-Route (details see [9]). The essential reasons were:

- Discharge of the areas of Osterholz and Hemelingen which are affected, in addition, by other noise sources (highway, railway, trade / industry).
- A not higher noise exposure of Habenhausen.
- At night; no change arises with the use of the Wesertal-Route.

A press article as of Nov. 30, 2006 addressed the interest of the inhabitants to learn more about the exact effects of this relocation of the departure routing. As a result an event was carried out by Bremen Government Office for Building, Environment and Transport on the environmental noise directive on Dec. 06, 2006 to introduce the calculation results.

After intensive discussion and evaluation of two investigations as well as the special measuring programme Hemelingen/Arsten/Weyhe, the Bremen Air Traffic Noise Commission recommended on Jan. 12, 2007 to DFS to reintroduce the Wesertal-Route with a turning point at 2.8 NM DME (Distance Measuring Equipment) from Bremen DME (BMN).

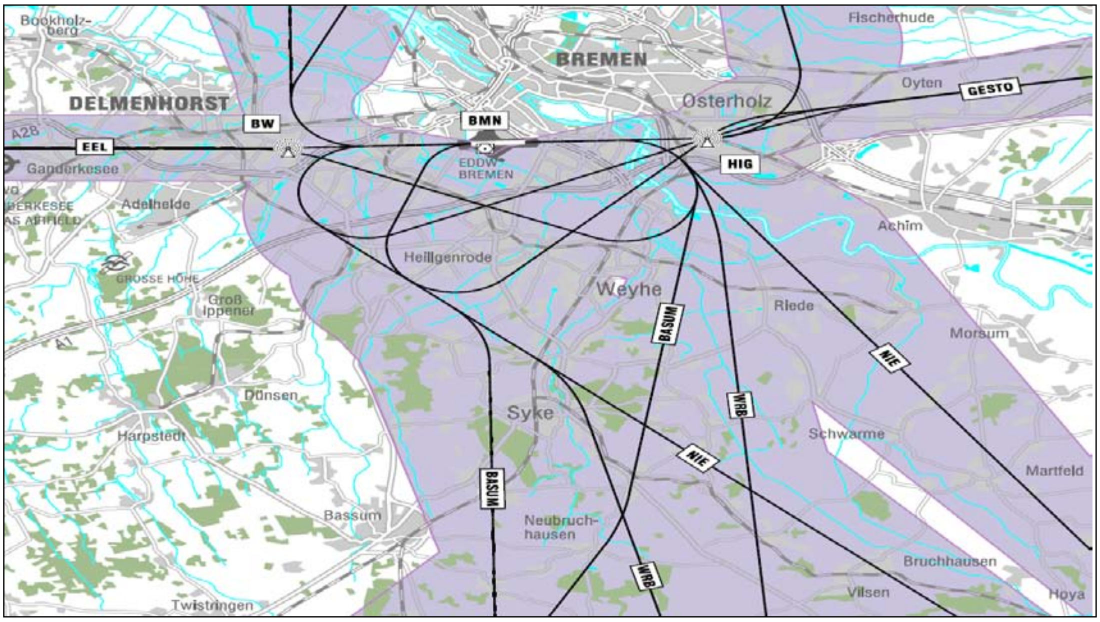

Figure 2-4: Cutting to the actual situation of the minimum Noise Routing with flight expectation areas at the airport of Bremen (source: AIP AD EDDW 5th-8-1th of 22nd of November, 2007)

Then the Wesertal-Route (see air routes BASUM, WRB and NEVER in illustration 2-4) was brought into force on the 7th of June, 2007.

This particular case of the transfer of an air route confirms the strong public interest in clarification and presentation of the technical results. On this occasion, the clear representation of both independent single calculations with though same or similar results, nevertheless, derived from different approaches, plays a big role. Indeed, not all interests could be considered completely and satisfyingly, because the departure route is furthermore a subject of a pending procedure in front of the Committee on Petitions of the Bremen State Parliament [8].

2.3.5 First experiences with §32 LuftVG after the change of participation

Since the amendment of §32 LuftVG, the first experiences were collected in the decision-making process and the cooperation with the involved institutions. For the assessment of the air route proposals the BAF submits to the UBA several documents that were compiled primarily by the DFS. Mainly this contains written and graphic descriptions of the air routes, the classification of the distance allocation on single aircraft patterns and the results of the NIROS calculations. In addition, the statement of the local FLK is presented to the air route proposals to the UBA. Because in the FLK different interest groups are represented and thus already an opinion-forming process has occurred, and the FLK exactly knows about the local situation, the statement of the FLK is of high importance for the UBA. Then, on the basis of these documents, the UBA carries out a noise functional assessment of the air route proposals. The present air route assessments show that the presented documents are a respectable base for the air route review, but still deficits are shown. Thus, the source situation is sometimes not described unambiguously, which is why no exact conclusions on the change of the affected inhabitants can be drawn. Besides, a comprehensive assessment procedure is lacking. This deficiency should be corrected by this study.

CHAPTER 3 Benchmarking

3.1 General

In this chapter an overview about the national and international valid sets of regulations, standards and recommended practices is given, with the definition or amendment of air routes and flight procedures.

Basically every flight procedure is affected to certain inaccuracies like wind effects and navigation failures. Therefore, worldwide valid criteria and standards were determined by the ICAO in the document 8168 (PANS-OPS – *Procedures for Air Navigation Services - Aircraft Operations*) for the implementation of holding-, approach- and departure procedures. The PANS-OPS are internationally applied directives for air navigation services.

The flight-operational procedures applied in practice depend on the actual weather situation, so above all from the wind- and visual conditions. For flight-physical reasons, take-offs or landings should always take place against the wind direction. Accordingly runways are planned and built possibly in the direction of the typically ruling wind direction. In addition, runways must keep to standards to be flown with regard to the curve radii, climb- and descent rates with the approach and departure as well as safety margins to the obstacles which are also determined as directives in the PANS-OPS. For flight-operational reasons arrival and departure routes must optimally connect to air routes in higher altitudes, which within Europe requires an international coordination at the moment, e.g. with Eurocontrol. Last but not least, the air traffic will be carried out safely, environmentally friendly, efficient and customer-oriented, which may possibly lead to further constraints in the routing.

The freedom of choice in planning of new air routes of the DFS, who is the national entrusted organisation by the new Federal Supervisory Authority for Air Navigation Services, is influenced therefore by different factors. In the following chapter approach and departure procedures are described at first in general. This is followed by a presentation of the operational and safety factors and criteria by which an air route is determined, as well as procedures and tools applied for this.

Concluding available regulations in the European and international neighbourhood to the definition of air routes and flight procedures are indicated to finally demonstrate actual developments and trends.

3.2 Approach and departure procedures

The uppermost priority in the definition of approach and departure procedure is operational safety. Therefore, an aircraft must operate within its specific flight-operational limitations which the **flight crew** is responsible for. In addition, a minimum separation dependent on the flight phase is to be kept to other aircrafts which basically the **air traffic controllers** are responsible for. The corresponding regulations were also developed by the ICAO. Particularly in the specific airspace[5] around airports, aircrafts must keep strictly the agreed horizontal standard instrument air routes (SID/STAR)[6]. Exceptions from this rule can only be directed by the responsible air traffic controller.

In addition, minimum separations between aircrafts must be kept close to airports, because a concentration takes place through the merging of the whole traffic. Only a traffic homogenisation enables efficient and safe handling. This is realised, on the one hand, by general speed limits (e.g., maximum 250 kts IAS[7] below Flight Level 100 (approx. 3,000 m)) and on the other hand by the direct allocation of speed by the responsible air traffic controller. On this occasion, it is a matter of fact that different types of aircrafts in dependence of their actual mass have different approach speeds which may not dropped or exceeded because of safety reasons. To reach the approach speed, the configuration of the aircraft is changed in an agreed order. This included the gradual extension of the flaps and slats as well as the landing gear. In the so-called landing configuration the controllability of an aircraft is reduced generally, in addition, the flyable speed range is strongly limited. Basically an aircraft must have stabilised its approach for safety reasons at 1,000 ft (300 m) above ground level (landing configuration and approach speed, only slight deviations of the desired trajectory).

[5] Airspace for the purposes of the aviation are horizontal and vertically clearly separated areas in which definite rules apply for the flight operation (e.g., admitted traffic kinds (visual flight or / and instrument flight), obligations to report (radio), maximum speeds, minimum visual ranges etc.)

[6] *Standard Arrival Chart – Instrument (*STAR); *Standard Departure Chart – Instrument (*SID),

[7] *IAS = Indicated Airspeed*, which is determined barometric.

For safety reasons the approach takes against the actual wind direction, because through this with the same approach speed (relatively to the surrounded air) the speed decreases compared with the ground, and thus the braking distance is shorter. With the standard instrument approaches the pilots follow the exact defaults for the route, then reduce the altitude and speed and set the flaps at the determined points.

The first part of a **standard instrument approach**[8] start´s at the Initial Approach Fix (IAF) and leads over the Initial Approach Segment and the Intermediate Approach Segment to the Final Approach Fix (FAF), the beginning of the final approach. In this part the pilot follows precisely the given route, reduces altitude and speed and selects the position necessary for this of the landing flaps (Figure 3-1). From the Intermediate Approach, the aircraft leaves an altitude of 7,000 ft (2.134 m) and becomes relevant for noise generally. After the FAF the final approach starts under support of the instrument landing system (ILS) which is the worldwide most popular approach procedure.

First the course (track) of the aircraft is aimed by using the signal of the ILS localiser in extension of the centre line of the runway. The Localiser is located at the end of the runway and emits a signal that is displayed in the cockpit and allowing the pilot to get information about the momentary lateral position with regard to the final course. The aircraft is in level flight (e.g., 3,000 ft) until the final descent is initiated with capture of the glideslope (the ILS glide path signal transmitter stands beside the touchdown point of the runway). This leads normally to an angle of 3.0° to the touch down point of the runway. As with the lateral deviation the pilot receives a display about its vertical deviation in regard to the ideal glideslope with the help of the glide path signal. Some airports use higher approach angles (e.g., for topographic reasons Innsbruck with 3.8°). However, the approach angle cannot be increased in any order, because otherwise the airspeed would be often too high for safely landings. Therefore the approach angle is limited according to PANS-OPS to a maximum of 3.5°, for a standard approach procedure.

[8] In the other course a precision approach ILS is described. Other precision approach procedures (e.g. MLS (*Microwave Landing System*) or GBAS (*Ground Based Augmentation System*)) or non-precision approaches proceed in this context similarly.

Take-off procedures start with setting of the slats and flaps. Nevertheless, differently than with the approach, the flaps are not extended fully because this would increase the take-off distance on account of the clearly higher drag. For take-off the calculated thrust can be less than the maximum possible thrust setting. Afterwards the aircraft accelerates, passing the speed V_1 up to the rotation speed V_R and takes off[9]. If a clearly positive climb rate is reached, the gear retracts. Above a height of 500 ft (152 m) different take-off procedures, with special flap and engine thrusts settings are practicable. After Take-Off the aircraft follows the standard departure route (SID)[10], to reach the cruise route or can also get a clearance of the air traffic control to the direct approach on the next waypoint if the traffic situation and safety admit this. Further information can be found in chapter 3.5.3.

By the planning of new air routes a huge number of parameters must be considered. The flight safety relevant factors limit the scope for the planning significant. General flight-operational boundary conditions with the definition of departure routes are, for example, the limitation of the roll angle[11] for curves flown after the take-off on 15° (no curves below 500 ft ground level) as well as the limitation on flyable climb gradients or climb rates.

With this background it becomes clear that the planning of new air routes of minimum noise exposure are settled for departures in the area from a least altitude of 500 ft above ground up to the connection with the higher situated cruise flight routes. The planning for IFR approaches should concentrate upon the segments of the IAF (Initial Approach Fix) down to the FAF (Final Approach Fix).

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[9] V_1 *Critical Engine Failure Recognition Speed* - the speed after whose excess with engine failure the take-off should not be cut off any more; V_R *Rotation Speed* – the speed from which the aircraft is brought by operating the elevator for rotating (lifting off); V_2 *Takeoff Climb speed* – minimum speed with engine failure obstacles by 35 ft can be flew.

[10] SID: Standard Instrument Departure

[11] also bank angle, angle around the aircraft pitch attitude in the body axis co-ordinate system

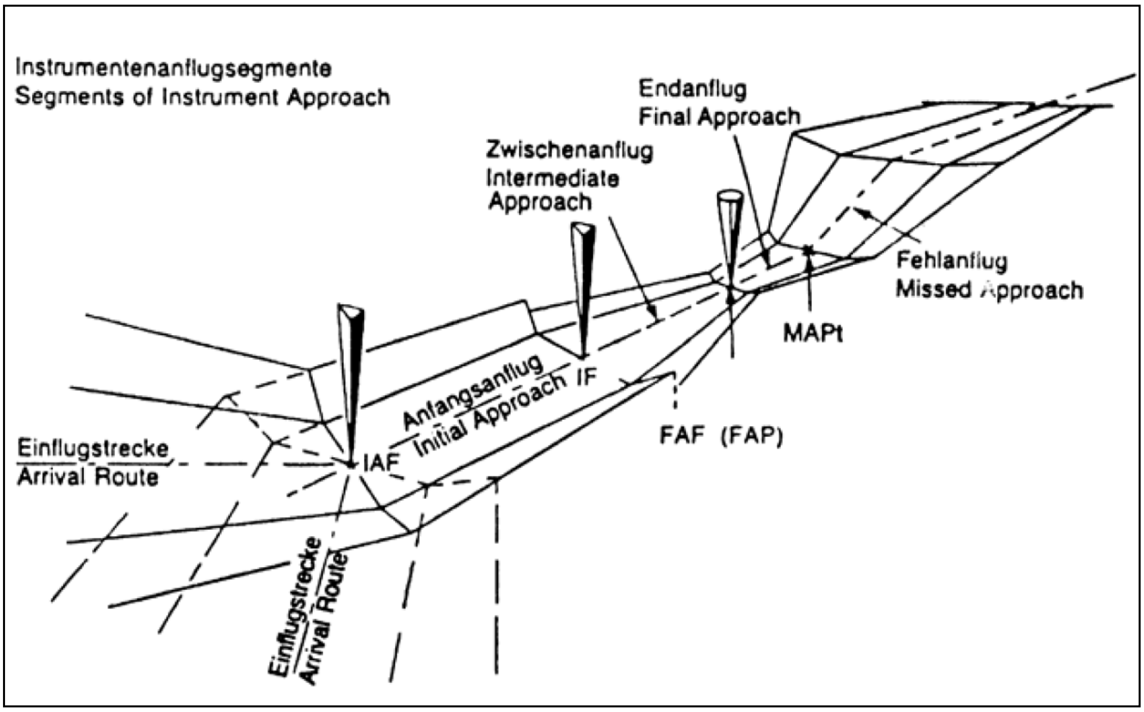


Figure 3-1: Segments of a standard instrument approach [49]

3.3 Overview of the topically used criteria and procedures to the definition of air routes

3.3.1 Operational criteria relevant for safety

By the development and selection of new approach and departure routes, also different criteria are relevant for environment as well as operational matter beside aspects of the flight safety. On-board and groundside factors can be distinguished.

Different engine-power and Take-Off masses of the various aircraft types as well as the climb performances are important. Because of minimum distances to the ground, not all departure routes can be flown with low climb performances. Moreover, curve radii and the exactness of the navigation facilities are to be included, because certain tolerance can be shown by the used systems. Simply designed air routes are basically more precise flyable as complex air routes with for example several curves with which also the workload of the pilots can rise. Limits are set by these conditions to the procedure planner with the construction of the new air routes.

Ground-based factors are mostly relevant for safety. The air traffic control is responsible for the safety margins from horizontally 5 NM (approx. 9.3 km) or vertically 1,000 ft. (approx. 300 m) between different aircrafts. Close to an airport, this is complicated due to the horizontal movements of the approaching and departing aircrafts. Therefore, it is tried to separate the different flows of traffic longitudinal of each other, until the vertical separation is restored, i.e. the approaching aircrafts are below the departing ones. This is to be recognised with the following example of the Frankfurt airport in Figure 3-2 and Figure 3-3. All arriving traffic is directed as much as possible from the north and the east thru the final approach, the departing traffic however is directed south and west to move then by sufficient altitude also in other directions. Departing traffic north is directed below through the arriving traffic from the north (blue: high altitude, green yellow/: low altitude). If this is not possible, segments with the same altitude must become flown what entails an increased noise development as well as higher fuel consumption and thus more CO_2 emissions. Therefore, this should be avoided so far as possible, i.e. approach sector and departure sector should be separated from each other.

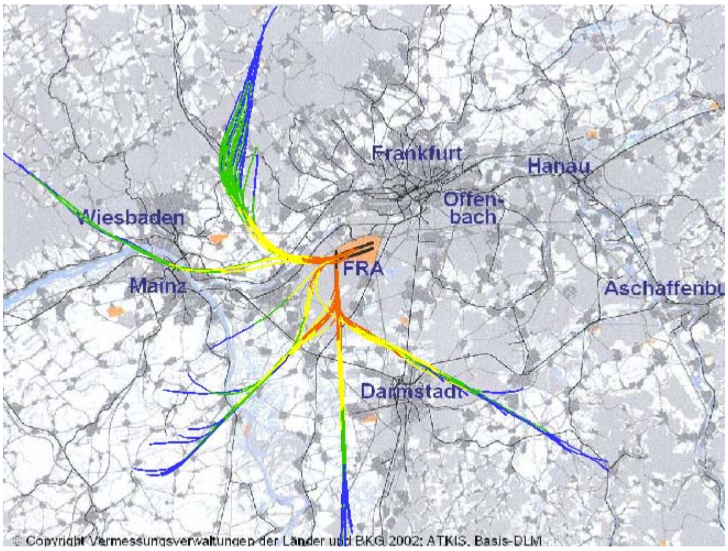


Figure 3-2: Departure sector Frankfurt/Main West-Traffic (RWY 25 l and 25R) [35]

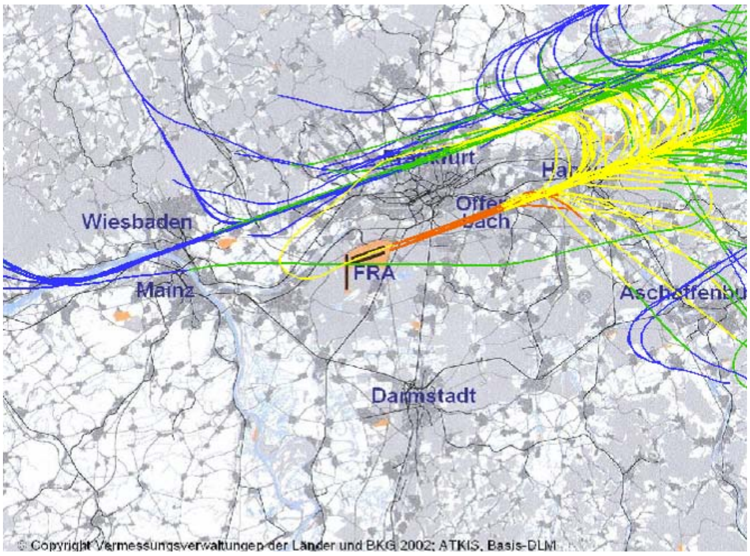


Figure 3-3: Approach sector Frankfurt/Main West-Traffic (25 l and 25R) [35]

In addition, as many as possible different departure routes should be available to increase the capacity of an airport. If departing aircrafts are separated as fast as possible by different departure routes, more departures are possible in the same time; one after the other started aircrafts do not run risk to drop short of their minimum separation. Also by fastest possible spreading of the flight routes, the risk by wake turbulences of ahead flying aircrafts is reduced. Approach routes are extended more and more by the introduction of new navigation systems and offer a better guidance of the traffic. If they ended formerly mostly far before the final approach and were continued then by individual radar guidance of the arrival controller, they now direct the aircraft in so-called “Transitions” shortly before the Final Approach Fix. Nevertheless they offer the controller enough opportunities to merge the aircrafts in a corresponding approach sequence. Accordingly defined waypoints enable to turn in certain distances on the final approach, so that also the prescribed wake turbulence separation is kept. The use of the Transitions led just at high frequented airports to a considerably better and more understandable routeing of the approaching aircrafts, also flying over certain areas by low altitude can be better steered and controlled. Besides, the routes must keep always the corresponding safety margins to ground and obstacles and adapt themselves well in the air route network surrounding them.

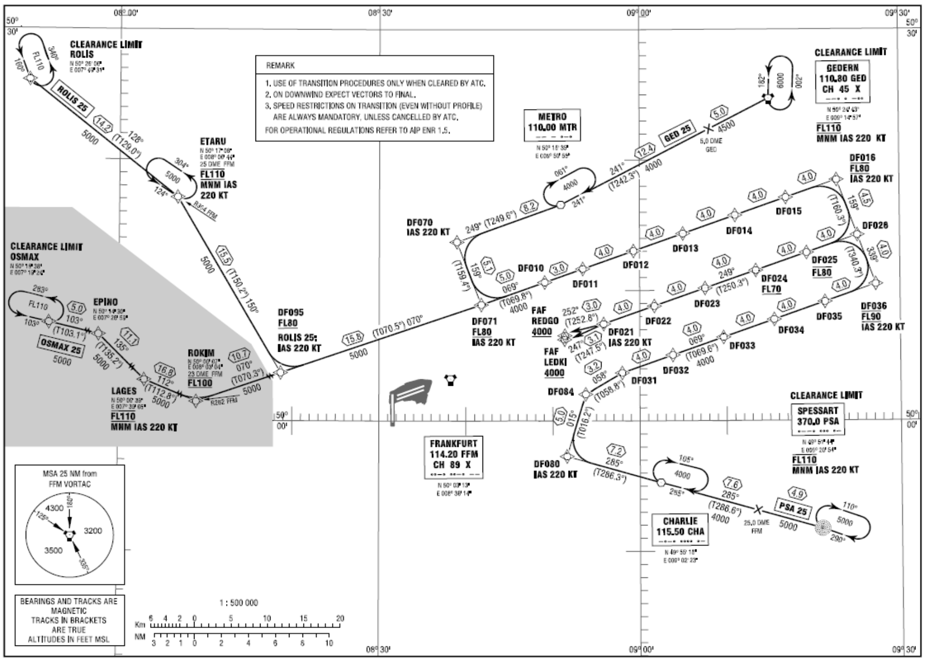


Figure 3-4: *Transition Frankfurt/Main RWY 07 [source: AIP Germany AD2 3-1-4]*

In spite of the huge number of influences to be followed an extensive net of arrival and departure routes is defined by the air traffic control mostly to use the capacities of the airport optimally. The early separation from an altitude of 500 ft reduces the risk of wake turbulences for the following traffic and distributes the noise more steadily. In spite of the technological progress in the area of low noise aircrafts the aircraft noise exposure increase locally partially. That's why the noise and its assessment come to the fore with the definition of air routes.

The DFS operates simulation programmes to check different route alternatives concerning their noise consequences already during the planning process.

3.3.2 Aircraft noise calculation programme NIROS of DFS

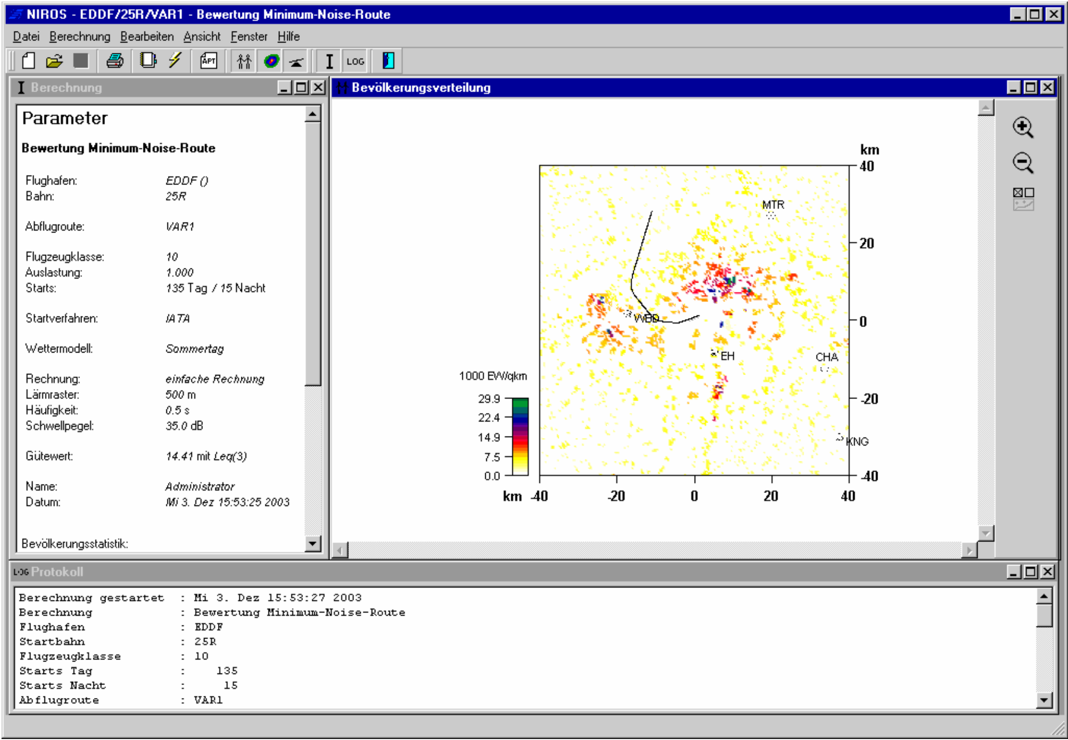


Figure 3-5: User interface "population density" of NIROS [12]

The analysis system used in NIROS (Noise Impact Reduction and Optimisation System) allows the noise functional assessment of standard instrument departure routes. NIROS was developed first by order of DFS in a research project on the subject „computer-supported regulation of routes with minimum noise exposure". The project was carried out at the Technische Universität Darmstadt and was completed in 1998 [4].

From 2002 to 2007 NIROS was improved within the scope of the research association promoted by the Federal Ministry of Transport, Building and Urban Development „Leiser Verkehr" (area: „Quiet commercial aircraft – noise-optimised approach and departure procedures (LAnAb)"). The software package NIROS was ported on a modern operating system level and an adaptation to more flexible procedures to the generation of flight paths was carried out in this improvement. Furthermore the actual document 29 (3rd edition) of the European civil aviation conference ECAC was implemented. This document describes an aircraft noise analysis, which offers the opportunity for the adaptable flight path generation on the basis of a flight-mechanical mass point model. Moreover, data are deposited to the procedure with the international „Aircraft

Noise and Performance Database ANP" for a large number of aircraft types[12]. This list is managed by Eurocontrol in cooperation with the Federal Aviation Administration (FAA).

ECAC Doc 29 represents the actual state of knowledge for a practically oriented calculation of aircraft noise in the area of airports. This procedure was adapted by ICAO at the beginning of 2007 and is published in close future as a specific ICAO document.

For first verification of the implemented algorithms in NIROS, comparative calculations were carried out by DFS and the DLR with provisional implementation of the aircraft noise calculation software *Integrated Noise model (*INM) version 7.0 developed by FAA . The new ECAC Doc 29 procedure will form the basis of this version; hence, an extensive correspondence of the results with NIROS was expected. To the examination for aircraft noise calculations (in each case two trajectories with SEL- and L_{AMAX} values) were carried out and the generated noise contours were compared. These showed relatively good correspondences with all calculations. The appearing differences can be explained by slight deviations with the trajectory generation.

To meet statements on the practical use of NIROS, a validation was carried out as a final working package to the restructuring of NIROS. A comparison was carried out with the measuring values, which came from the aircraft noise measuring system at the airport of Munich. The measured noise level spread distance-adjusted only about few decibels, so that the comparison with certain uncertainties is afflicted. Hence, the validation should be supported in future by the results of other aircraft noise measuring systems. In spite of the necessary simplifications in the parameterisation of the NIROS calculation, the calculated values show a high correlation to the measured values what clear practise nearness speaks. The tool NIROS is used by DFS since 2008 for the noise functional assessment of air route alternatives.

The following options are planned for a future advancement of NIROS:

- Extension to arrivals,
- Implementing of an optimisation algorithm.

In addition, it should be investigated by DFS that the NIROS noise spreads can be brought in correspondence with the flight expectation areas of the system FANOMOS [12].

[12] This data base is available under http://www.aircraftnoisemodel.org

NIROS is taking into account the population structure in the affected area and determines the noise exposure key figure (so-called "quality indicator") for the investigated air route. Besides, the calculated aircraft noise exposure with the population density of the flown surface elements is weighted. An exposure index thereby arises for every surface element. The surface elements have a size of 100 x 100 m in square. By the integration of the exposure indices, an exposure dimension arises for the whole considered area, the quality indicator. Besides, the ISO lines of the single noise level classes as well as the population density distribution and the distribution of the exposure indices are still given. With the help of these results, different flight route alternatives can be compared with each other. A higher quality indicator of an air route means that a higher noise exposure originates from this air route than by the comparative route.

The suitability of NIROS to the noise functional assessment of air routes was seen critical in connection with the following aspects:

- **Quantification of the aircraft noise exposure:** The noise exposure in airport surrounding is expressed in one single number, the quality indicator. Nevertheless, to the assessment of the noise exposure of two alternative flight routes a singular value is often insufficient, because the differences are not evident in single level classes. The question positions itself whether the forming of the basis criterion is generally clear, and whether it is looked by the involved parties as a valid criterion about the route optimisation. This criticism is already considered, while beside the singular value also values of the single level classes are presented.
- **Air traffic and population-related data:** With NIROS the noise exposure with the local population density is weighted and these data are integrated in the investigated area. Besides, the question arises whether the data is precise enough, entire and actual to return the air traffic and the noise exposure in airport surrounding appropriately. This question must be cleared in the respective application case. This applies also for the used data base with the population data.

An application example for the NIROS calculations is the planning process about the definition of the Frankfurt TABUM departure routes. The TABUM routes had started running on the 19th of April, 2001 within the scope of a new European airspace structure as departure routes by the airport Frankfurt/Main. These departure routes ran over the region called Hochtaunus and have led there to new affected persons in view of aircraft noise. Big protest of the population living there had already risen against the departure routes introduction. As a result the DFS reviewed in cooperation with the Frankfurt Air Traffic Noise Commission different route alternatives. Besides, the possible routing was verified first for their flight-operational feasibility as well as safety and conformance with the default of the PANS-OPS. At this the particular topographic conditions of the Hochtaunus played a big role, because only heavy long range aircrafts would have to fly on account of their low climb performance first another curve over Wiesbaden to turn then with sufficient height and safety margin in the direction of north-east to TABUM. Moreover, the new proposals should have the same capacities compared with the existing TABUM route. If a new air route is not flyable for many aircraft types, this would mean it's a restriction of the capacity and show thus no sufficient alternative. Finally a noise assessment was carried out with the help of the NIROS programme. Figure 3-6 shows an overview of possible alternatives which were discussed between the DFS and Air Traffic Noise Commission. As a result of the discussions continuing for several years the TABUM route (variant 1 in Figure 3-6) was selected (which was shifted in 2005 slightly to the west).

Type	Operation	PANS-OPS	Capacity	Noise exposure	Cause of exclusion
1	yes	yes	yes	(NIROS 10.50)	actual state
2	no				More noise exposure to Erbenheim
3	yes	yes	no		too steep climb gradient
4	yes	yes	yes	(NIROS 10.60)	-
5	yes	yes	yes	(NIROS 10.51)	.
6	yes	yes	yes	(NIROS 10.61)	-
7	yes	yes	yes	Single events	actual state
8	yes	yes	yes	Single events	-
9	yes	yes	yes	(NIROS 10.58)	More noise exposure to Breckenheim
10	yes	yes	yes	(NIROS 10.54)	-
11	yes	no			not compatible with enroute system

Figure 3-6: Overview TABUM variants [36]

3.3.3 Construction of flight expectation areas

As already explained, the observance of an air route is influenced by wind and navigation. To support the rules of the PANS-OPS, a flight expectation area (FEG) is constructed by DFS along the air routes. A probability of presence time of 95% (2 Sigma) is taken as a basis, i.e. it is assumed that 95% of all flights are within the flight expectation area. This guarantees instrument flights without collisions. If an aircraft leaves the FEG without urgent reason, a regulatory offence procedure is initiated by LBA.

3.3.4 Flight track recording system FANOMOS

The Flight Track and Aircraft Noise Monitoring System (FANOMOS) operated by DFS is a tool, which allows the representation and analysis of the IFR arrivals and departures (flight trails) in the area of most German commercial airports. It is used for several purposes. Moreover belong the adaptation of objection cases, the control of the flight route observance and if necessary the punishment of aviation law violations as well as the definition of width of corridor for aircraft noise calculations to the determination of noise protection areas after the air traffic noise act.

FANOMOS was developed in 1982 by the Dutch air and space research centre NLR (Nationaal Lucht- en Ruimtevaartlaboratorium) in cooperation with the planning of minimum noise routes for the Amsterdam airport of Schiphol. The major task of this recording system is the examination whether aircrafts keep to the prescribed departure routes. Furthermore the following information should be made available to the system:

- Radar data of the effective flown flight routes (flight trails) and
- Flight plan information, which allows an identification of single flights and the correlation to the air route.

Thus the observation can be carried out as a completely automated, continuous process. As a result of this process flights are identified which deviate in a certain measure from the prescribed standard instrument departure route.

The FANOMOS functions were extended in the course of the years. The current version currently under development also supports the 4D-representation of flight tracks, so that beside the representation of X axis, Y axis and altitude, also the time can be illustrated as animation. Essential parts of the processing of flight tracks by means of FANOMOS are also included in the aircraft noise measuring systems of the airports. These systems have been installed on more than 100 airports in the whole world. If the effective flown routes strongly deviate from the actually published ones, a new definition is advisable if applicable.

The current FANOMOS system at DFS uses as input primary and secondary radar data, which are supplied from an internal network [7].

3.3.5 Direct clearances

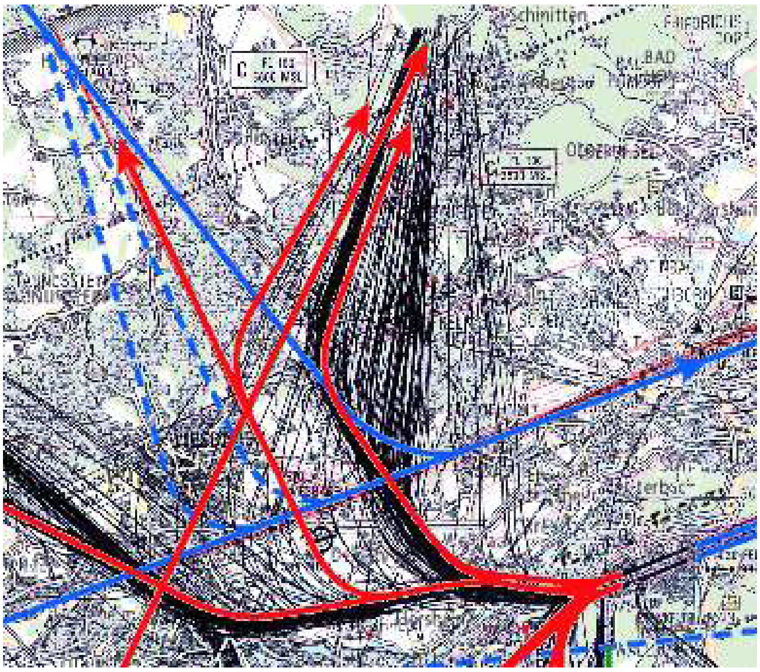


Figure 3-7: Accumulation of direct clearances at Frankfurt/Main (TABUM route) [36]

The Aeronautical Information Publication of Germany (AIP) published instrument flight routes are to be used by the pilots. Nevertheless, it is up to the controller to give a direct clearance to aircrafts to shorten the flight route or to optimise the approach sequence or separation. No consideration by BAF is given for this ad hoc decision of controllers. To hold to a certain extent the noise consequences of the direct clearances, the controller must follow certain minimum altitudes. Thus DFS operating instructions, propeller aircrafts can deviate off the published departure route approx. 3,000 ft above ground level and jet aircrafts from approx. 6,000 ft. Exceptions are possible, for example, at the airport of Leipzig/Halle where aircraft may deviate off the departure route during day only from approx. 9,000 ft and at night only from approx. 11,000 ft above ground level [46].

3.4 Overview about the topically applying European and international regulations to the definition of air routes and flight procedures

3.4.1 General

The definition process of arrival and departure routes in Europe or worldwide is similar to the applied procedure in Germany. Motivated by an initiative the new route is planned in most of the countries by the corresponding air navigation service provider whereby operational and environmental aspects become increasing importance. In addition, special national laws must be considered with regards to the interpretation and noise avoidance. After the planning process the new air route is determined by the respective national authority and is published in the Aeronautical Information Publication. In some countries, groups of the public interest have beside airports and airline companies also influence on the interpretation of new flight routes. This takes place in discussion forums or during roundtable sessions in which also local interest groups can take part.

3.4.2 Comparative analysis at the definition of departure routes

For an overview about the internationally applied procedures for the definition of flight routes a detailed literature and a web search were carried out. In addition, the attempt of an international comparison was started with the help of a short standardised questionnaire. Air traffic control service providers of the European neighbouring states, as well as Canada, Australia and the USA were selected. Aim was the statement, which interest groups (stakeholders) have an influence on the process of development and whether there is a platform to the dialogue together. The extent of the questionnaire was limited to essential points in order to ensure fast response.

A total of 20 air traffic control service providers were contacted from which eleven agreed (bold marked) to take part in questioning:

1. *Aeropuertos Españoles y Navegación Aérea* (Spain / www.aena.es)
2. *Air Navigation Services of the Czech Republic* (www.ans.cz)
3. ***Air Services Australia* (Australia / www.airservicesaustralia.com)**
4. ***Austro Control* (Austria / www.austrocontrol.at)**
5. ***Avinor ANS* (Norway / www.avinor.no)**
6. ***Belgocontrol* (Belgium / www.belgocontrol.be)**
7. *Direction des Services de la Navigation Arienne*
   (France / www.aviation-civile.gouv.fr)
8. **Federal Aviation Administration** (USA / www.faa.gov)
9. *Finavia* (Finland / www.finavia.fi/home)
10. *HungaroControl* (Hungary / www.hungarocontrol.hu)
11. ***Irish Aviation Authority* (Ireland / www.iaa.ie)**
12. *Italian Company for Air Navigation Services* (Italy / www.enav.it)
13. *Luftfartsverket* (Sweden / www.lfv.se)
14. ***Luchtverkeersleiding Nederland* (The Netherlands / www.lvnl.nl)**

15. *National Air Traffic Services* (Great Britain / www.nats.co.uk)

16. ***NAV Canada* (Canada / www.navcanada.ca)**

17. *NAV Portugal* (Portugal / www.nav.pt)

18. **Naviair (Denmark / www.naviair.dk)**

19. ***Polish Air Navigation Services Agency* (Poland / www.pansa.pl)**

20. ***Skyguide* (Switzerland / www.skyguide.ch)**

In the following map the location of the contacted air traffic control service providers within Europe is shown.

Figure 3-8: Air traffic control service providers in the neighbourhood of DFS

The survey results are shown and summarised in Figure 3-9. ATC stands here for *Air Traffic Control* what is often synonymous with the national air traffic control authority. Influencing factors such as operations, geography or safety were already explained in chapter 3.3.1.

	Initiative	Planning	Influencing factors	Statutory provisions noise abatement	Federal Associations	„Round Tables“	Publication
Germany	ATC, Airports, Airlines	ATC	Operations, Technical, Noise Protection	Aircraft Noise Commission (§32b LuftVG)	Airlines, Airports, local authorities	Frankfurt/Main	AIP Germany by ATC
Australia	ATC	ATC	Operations, Geographic, Technical, Noise	Airport specific provisions	not existing	possible (e.g. with military)	AIP Australia by ATC
Belgium	Depart. of Transport, ATC, Airports, Airlines	ATC	Safety, Operations, Noise Protection, Environment Protection	Airport specific provisions	existing	Brussels and four regional airports	AIP Belgium by ATC
Denmark	ATC, Airports	ATC	Operations, Technical, Noise Protection, Safety	Airport specific provisions	existing (Airlines)	not existing	AIP Denmark by CAA
Ireland	ATC, Airports	ATC, Airports	Operations, Geographic, Technical, Noise Protection	no specific provisions	existing (local authorities)	not existing	AIP Ireland by CAA
Canada	ATC, Airlines	ATC	Operations, Noise Protection	TP308, FAA Order 8260.44	existing (local authorities)	existing (ATC Airports, local authority)	Canada Air Pilot CAP by ATC
Netherland	Depart. of Transport, ATC, Airports, Airlines	ATC, (Flight Procedure Designer)	Operations, Technical, Noise Protection	Special provisions for Amsterdam-Schiphol	existing (local authorities, Airlines)	Amsterdam-Schiphol	AIP Netherland by CAA
Norway	ATC, Airline, Airports	ATC, Airline, Airports	Operations, Technical, Noise Protection	Special provisions for Oslo-Gardermoen	not existing	not existing	AIP Norway by CAA
Austria	ATC, Airlines	ATC	Operation, Technical, Noise Protection	Airport specific provisions	existing (local authorities, Airlines)	„Dialogforum Vienna“	AIP Austria by ATC
Suisse	Depart. of Transport, ATC, Airports	IFP planning agency	Operation, Technical, Noise Protection	Airport specific provisions	existing	existing (with ATC, Airports, local authorities)	AIP Suisse by ATC
Poland	ATC, Airports, Airlines	ATC	Operations, Noise Protection, Safety	Noise protection act of Poland	existing (Airports)	not existing	AIP Poland by ATC

Figure 3-9: Results of the survey "international benchmarking"

The initiative for establishing a new departure route and the responsibility in all countries surveyed lies with the respective national air traffic control supplier. In addition, the airport operators and airlines often still have the opportunity to influence and to introduce own suggestions. In the Netherlands this is also entitled to the airport residents. In Australia the authorisation of the initiative lies exclusively with "Air Service Australia", the national air traffic control supplier.

The technical and geographic planning lies exclusively in the hand of the air traffic control suppliers. Besides, in the foreground is PANS-OPS, which is put into practice by all questioned countries notably and, conformist to national needs. Other factors are airspace structure, flyability, safety and available technology on the operational side, as well as aircraft noise decrease and reduction of the CO_2 emissions on the side of the environment protection. The questioning shows very uniform results, aircraft noise protection was called important generally by all countries. This should be achieved by the use of noise-reducing flight procedures, the application of new technologies and the creation of the air route guidance under noise aspects. Nevertheless, the legal bases and regulations differ to each other, partially they are formulated very specifically, but also quite general rules exist. In Ireland only general regulations apply which were determined at European level. Denmark, Norway, Australia and Belgium give special standards to the noise avoidance in their respective AIP. Poland adjusts the maximum permitted aircraft noise exposure in the area of the airports with a special law. Canada and Switzerland confirm the availability of relevant regulations without specifics. The Netherlands prescribe for their great airport of Amsterdam / Schiphol important regulations for the aircraft noise protection (annual noise contingents, "noise footprints" defined by noise measuring points, sanction opportunities among other things).

In Austria there are aircraft noise restrictions and directives especially for the Vienna airport, which are in line with the stakeholders involved. They must be balanced with the "Dialogforum Vienna" which was founded after the „mediation process at airport of Vienna“ in 2005 [31]. "Dialogforum Vienna" offers by the participation of more than 100 municipalities, to Austria environmental advocacies and national aircraft noise citizens' groups more than 20% of the Austrian population the opportunity to take part in the creation of the air traffic all around the airport of Vienna. This is an approach, which is applied partly also in other questioned countries. Thus a dialogue forum was established in Belgium for the airport of Brussels and four other regional airports to discuss important amendments of the air routes. Airlines as well as representatives of military departments take part in the meetings. In the Netherlands a roundtable exists for the airport of Amsterdam-Schiphol with affected local residents, municipalities, administration and the airlines operating there from which, nevertheless, only so-called Home Carrier are integrated into the process. The discussions have the aim to find arrangements about the company of new departure routes. In Switzerland the Federal Office of Civil Aviation (BAZL) has called up such a forum with the airport operators, the civil aviation, the air traffic control, the municipalities and civil representations. Above all at the airport of Zurich is intensely worked on the decrease of the aircraft noise taking into account the affected local residents. Nevertheless, the initiative for the amendment or new definition of a route is left only to air traffic control, the airport operator or the BAZL. In Canada there is the regional-specific Noise Committees, which consist of local interest associations, airport operators and the air traffic control. They have the opportunity to prevent new definitions and to initiate changes of existing departure routes what these cause in partial decisions against operational needs of the air traffic control.

In Poland there are no such forums and facilities at airports, however, a development in this direction is foreseeable. Though Australia and Norway have no special dialogue boards for aircraft noise problems, however, the inclusion of the affected local residents in the area of the departure routes takes place, nevertheless. Denmark and Ireland deny activities of this kind of inclusion of interest associations for the protection from aircraft noise. The final definition of the planned departure route takes place in all questioned countries through the aviation authority; it is published by the air traffic control supplier or the aviation authority in the Aeronautical Information Publication of the respective states.

It is to be recognised that the process of the definition of new departure routes is internationally similar. Meanwhile in many countries public interest plays also a big role and the factors of noise prevention and environment protection are considered increasingly. Pressure groups of the affected airport residents, but also airline companies and airport operators have the opportunity to take part in different ways at the planning and definition of the air routes and have influence on it. Not only operational and economic factors are in the foreground any more, an exchange between all parties is aimed. Consequently first steps have taken place; the initiative for the amendment of an air route is still almost exclusively with the air traffic control, the airport operators or the authorities. For that reason citizens' groups and noise forums often only have the opportunity to react to decisions and problems. Hence, integration should take place in the definition process to do justice to all involved interests. Examples like Switzerland or Austria showing that an institution in the form of a roundtable must have more rights to be an effective tool of the co-determination.

3.4.3 Air route definition procedures in the USA

The U.S. Congress remits in the USA the laws of the air traffic and of the avoidance of aircraft noise. The FAA (Federal Aviation Administration) remits the corresponding rules and carries out the across state planning. The major task of the authority consists in remitting safety regulations and directives (Federal Aviation Regulations - FARs) for the whole air traffic in the USA. The FAA provides air routes (Air Travel Routes) and flight procedures and is generally responsible for flight guidance. All USA ATCs work for FAA as a component of a national airspace system. Though other aviation organisations, including airports and airlines, can direct a petition for a flight procedure to the FAA, but only the FAA can decide what is safe and satisfactory. Only the FAA air traffic control may arrange air routes and flight procedures [14].

Airports are generally a part of a federal or local authority. For example the San Francisco International Airport (SFO) is a department of the city San Francisco. To the decrease of the aircraft noise the office (Aircraft Noise Abatement Office) is decisively involved in the planning and realisation of noise reduction programmes. These noise reduction programmes also contain the definition of noise-reducing air routes (Noise Abatement Flight Tracks) about close settled areas [29].

The airport of San Francisco has established a roundtable (San Francisco airport / Community Round Table) to the argument of aircraft noise problems. This committee was founded in 1981 and consists of 45 representatives of the town and the country San Francisco and San Mateo as well as advisory members, captains and FAA staff. The forum meets monthly and is the propelling strength behind many noise programmes. The roundtable of the SFO has been the first institution of this in the USA and serves, therefore, often as a model for other neighbourhood groups [15].

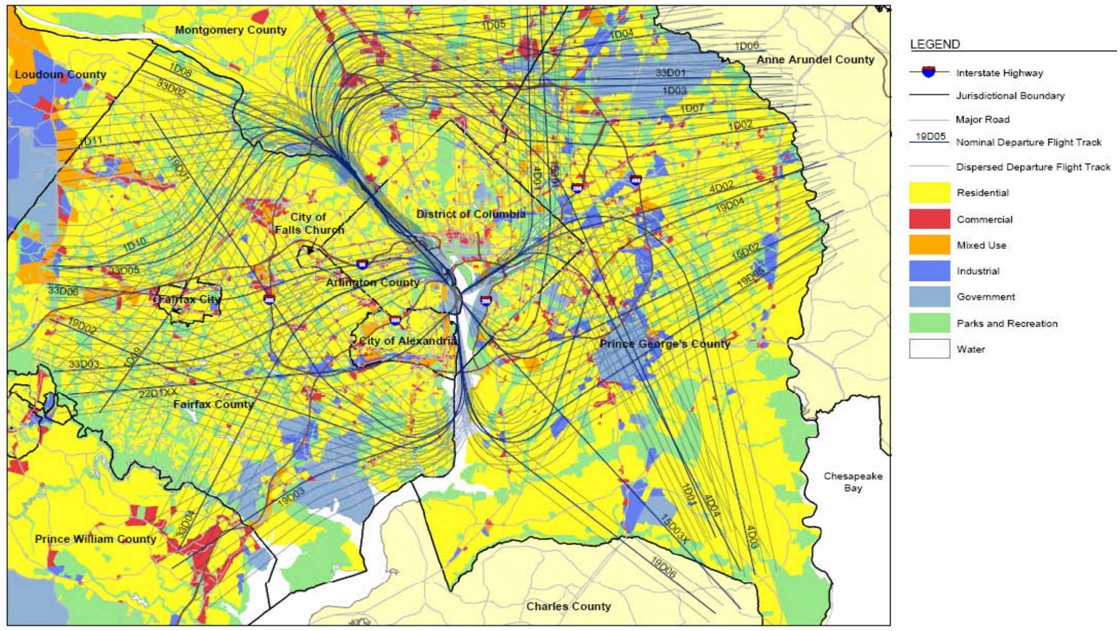


Figure 3-10: Example of arrival and departure routes in the USA

3.4.4 Air route definition procedures in Switzerland

The Swiss air traffic control *Skyguide* is responsible for the elaboration of air routes, while the Federal Office of Civil Aviation (BAZL) gives the approval. In this procedure, the Swiss Federal Office for Environment (BAFU) is also involved. In similar manner the amendment of the company regulation is also an exactly agreed process in which the airport (e.g. Flughafen Zürich AG) is the applicant. With aspects relevant for noise of the company regulation the senior civil servant of the Canton Zurich has as a former owner with its blocking minority a veto power in the administrative council of the Flughafen Zürich AG; all other adjoining cantons, nevertheless, not. Responsible for the approval of the company regulation in this case is also the Federal Office of Civil Aviation.

For important questions regarding aviation, the Swiss Federal Council depends by its decisions and bills in the area of aviation also on the confederate aviation commission as an advisory organ. This constant extra parliamentary commission, which is appointed by the Federal Council, consists of experts of the aviation as well as other interested circles. With the appointment of the members, the Federal Council considers the proposals of the organisations represented in it.

On the 7 July 2004 the national initiative „for realistic airport politics“ was submitted. The initiative wanted to oblige the canton Zurich to work with the Federation towards the fact that the number of the annual take-offs and landings at the airport of Zurich are limited to a number of 250,000 and the consisting night flight restrictions are expanded to nine hours. The senior civil servant recommended an alternative suggestion to the canton advice. This proposal consisted in the fact that a newly introduced approximate value determines the number of very disturbed people by aircraft noise and limits thus. If the number is exceeded the authorities of the canton take measures on time or apply for those with the offices responsible for it, so that the number of very disturbed people by aircraft noise is reduced again on the level of the reference value. The senior civil servant undertook to make an annually report on the noise development and the initiated measures to the aircraft noise decrease to the canton advice and the public.

On the 26 of March 2007 the canton advice rejected the national initiative „for a realistic airport politics“ and agreed to the alternative suggestion, the Zurich aircraft noise index (ZFI). In addition, the canton advice complemented the alternative suggestion from that point of view that the advice from achievement of 320,000 flight movements per year makes decision at the request of the government about that whether the state should work towards a movement restriction. This decision is defeated by the optional referendum. In addition, the canton is obliged to exert itself for a 7-hour night flight restriction.

After the acceptance of the alternative suggestion by the Zurich population on the 25 November 2007 the national economy management of the canton Zurich put the ZFI practice into place. The corresponding amendment of the airport law became effective on the 1st of March 2008.

The first ZFI report was presented on the 26 May 2008 to the public. The years 2005 and 2006 were compared in this report. The increase of people strongly annoyed by aircraft noise by about 8.5% within one year is to be led back on changes with the allocation of different air routes as well as on the population increase in the airport area [11].

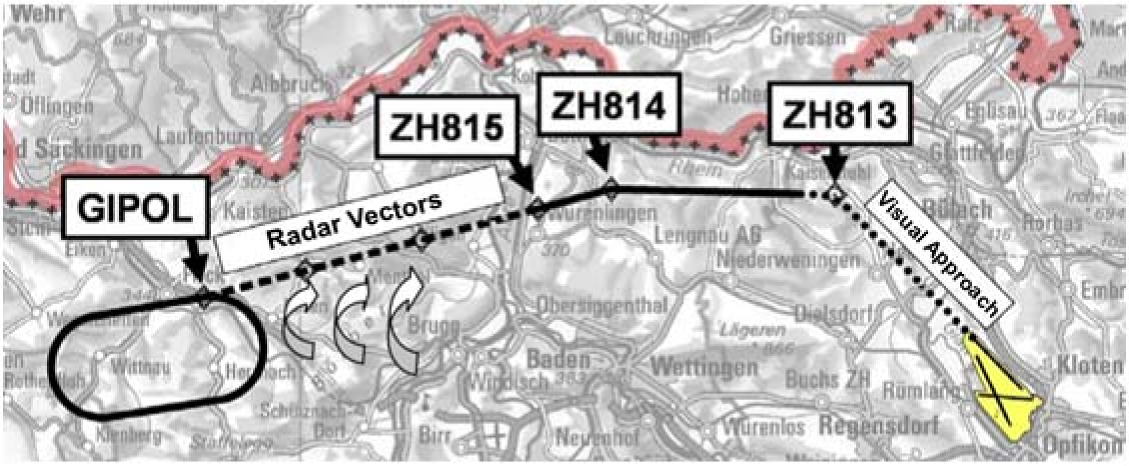


Figure 3-11: Course of the cranked northern approach [18]

The cranked northern approach (briefly GNA, sometimes also NAPP14 or Short 14 mentioned) is a planned alternative approach procedure as a supplement to the existing north approaches on the runways 14 and 16 at the airport of Zurich between 6 and 7 o'clock in the morning (see. Figure 3-11 and Figure 3-12).

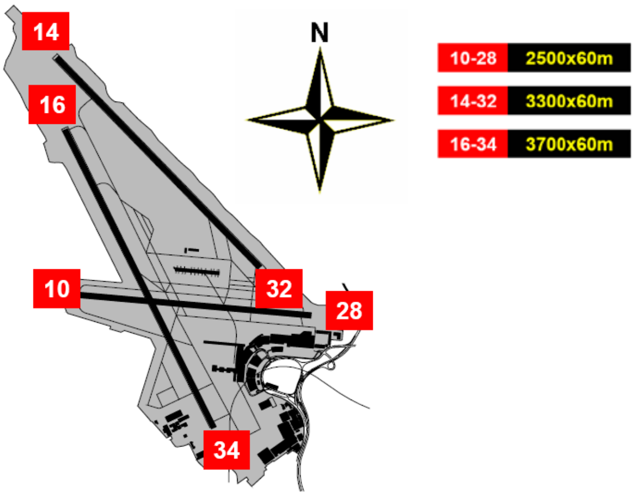


Figure 3-12: Runway system of the Zurich airport [18]

The planned cranked northern approach does not proceed directly from the north over German territory, but arriving from the west and exclusively in the airspace of Switzerland. Two sharp right turns will bring the aircraft on the approach base line of runway 14. Thus the northern approach is "cranked" or the straight approach on runway 14 is shortened (hence, the name is "Short 14").

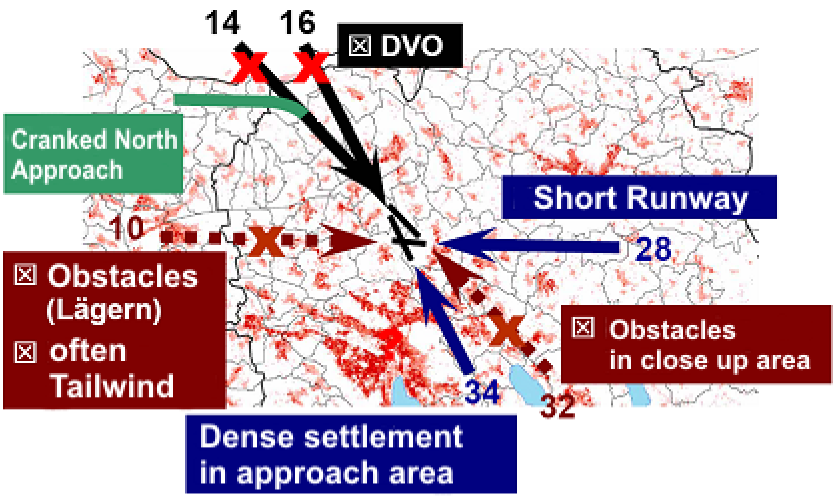


Figure 3-13: Approach routes Zurich (Switzerland) [18]

On 20 July 2005 the test approaches took place for the GNA, which were co-ordinated by the BAZL and *Skyguide*. At the end of March 2008 the Swiss pilot's association of Aeropers refused definitely the cranked northern approach on the airport of Zurich because the flight safety could be affected. Then on 3 July 2008 the BAZL refused the cranked northern approach. The rejection was based on safety concerns, particularly in relation to the VFR flown curve when turning on the runway centreline. According to BAZL this approach procedure is only practicable by means of satellite navigation and is able of approval. The citizens' groups in the south and the east of the airport of Zurich were disappointed about this decision. According to the association “Approach Corridor South – No”, an opportunity has been missed for the discharge of hundred thousands of people. Contently with the decision the canton the eagle's region, which would have particularly been concerned by the air route appeared however [19].

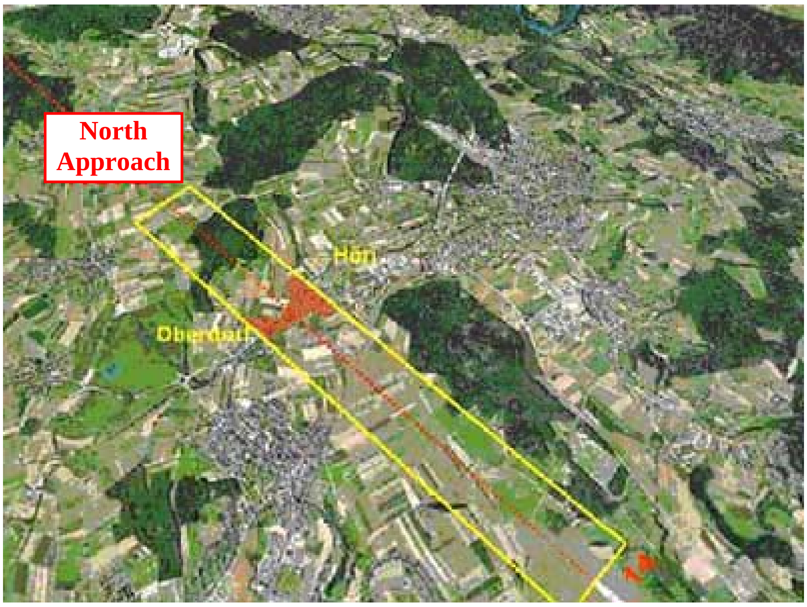


Figure 3-14: Flown settlement areas northern approach [20]

Figure 3-14 and Figure 3-15 show in comparison the north versus to the east approach and south approach flown settlement areas. The yellow border shows an area of 6 km before the runway begins and is 600 m wide. The red hatching illustrates the settlement within this area.

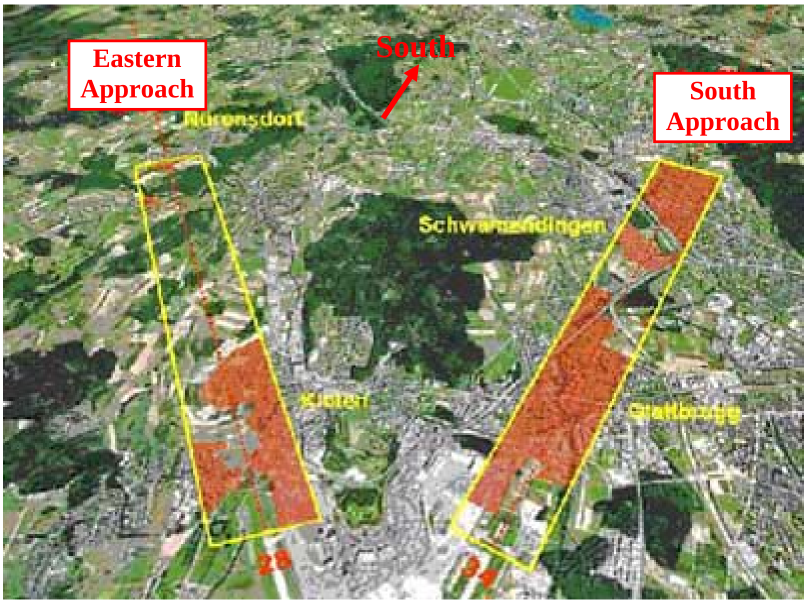


Figure 3-15: *Flown settlement areas east approach and south approach [20]*

The „sectoral plan infrastructure aviation (SIL)“ is the central planning and coordination instrument of the Federation for the infrastructure of the civil aviation. The SIL is, actually, an instrument of the spatial planning. This indicative aim makes it, however, also an important instrument of the aviation politics. Within the scope of the SIL so-called object sheets are compiled for any aviation arrangement in Switzerland. Besides, a particular importance comes up to the development of the facility register for the airport of Zurich as a national key infrastructure. In this presently running procedure the leading Federal Office of Civil Aviation closely works together with the canton Zurich, the Flughafen Zürich AG and the affected neighbouring cantons [21].

Taking the statements of the neighbouring cantons into account and after consultation with the canton Zurich and the airport Zürich AG the Federation has decided that three optimised company variants should become use as a base for the facility register. Thereby the developing scope of the airport as well as all options for talks with Germany about the use of the South German airspace is preserved. It concerns the variants E-optimised and E-DVO on the existing runway system as well as the variant J-optimised on the system with extended runways. The variants contain scope, so that the airport can develop. They are the result of extensive optimisation, concerning the environmental consequences as well as in view of the demands for the safety and the capacity of the airport company. A final approval of the facility register and the cantonal structure plans by the Federal Council is intended 2010 [22].

3.4.5 Air route definition procedures in Great Britain

The CAA is the aviation authority of Great Britain. In the British air traffic act (Civil Aviation Act) the competence of CAA is regulated. The CAA issues air navigation orders and general Regulations and publishes the Civil Aviation Publications (CAPs) [24].

The "Greater London Authority Act 1999 (Section 371) states, that every amendment of air routes or flight procedures which have influence on the noise situation must be discussed with the CAA. As for the air traffic responsible authority (Regulatory Authority) the CAA is responsible for monitoring the technical draughts of air routes. NATS (National Air Traffic Services) is the national air traffic control of the UK and is responsible for the conversion of the amendments of air routes and for the flight guidance. In the last 40 years the air routes of London were amended only minimally. The NPRs (Noise Preferential Routes) of London Heathrow have been changed only slightly, for example, since 1962. NPRs are published in UK "Air Pilot", so that they are known by all pilots. The DfT (Department for Transport) is responsible for the traffic politics and the decree of NPRs. NPRs serves to avoid flying over built up areas as far as possible. These are practically flight corridors of 3 km width in which 95% of all aircrafts. The observance NPRs is controlled with one of the Noise and Track Keeping Monitoring Systems (NTK) [25]. These flight corridors lead from the runways of the airport up to the main air traffic routes and establish the first part of the standard instruments-departure routes (SID). They are published in the "UK Aeronautical Information Package" of the CAA UK and in the "Air Pilot".

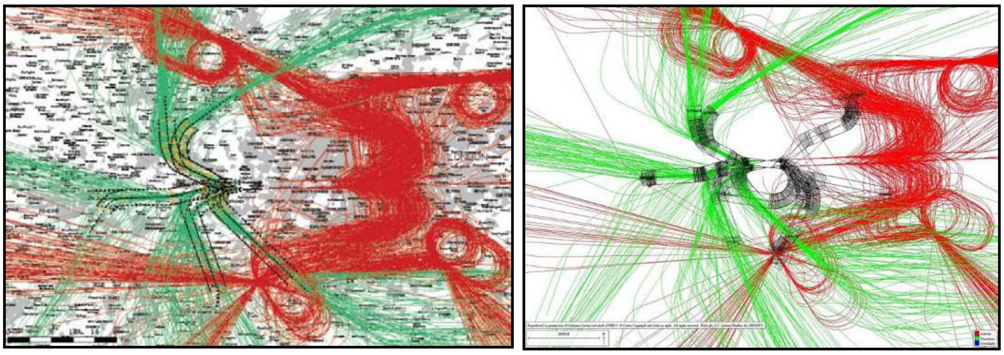


Figure 3-16: Typical NPRs of the airport of Heathrow for 2003 and 2007 [25]

Figure 3-16 shows the NPRs (black dotted line) as well as the departure tracks points in green. The observance of the NPRs is prescribed only up to an altitude by 4,000 ft. Modern aircrafts reach this altitude relatively fast. Then NATS can decide whether it assigns a straighter flight direction to the aircraft. This explains the deviationism of the green departure tracks of the NPRs.

If applications are made for a change in departure routes, they are to be confirmed first by the CAS (Controlled Airspace Section of the Directorate of Airspace Policy). The suggested air route guidance must correspond to the operational demands. Afterwards it will announce the change in the NATS AIS and will hand over the air route change to the British Aeronautical Information Publication. The amendment process is concluded with it [26].

In 2000 the British minister of transport decided that a code of behaviour should be determined. As result representatives of DTLR, NATS, British Airport Authorities (BAA), British Airways and CAA/ERCD provided a Code of Practice. This codex comprised the definition of a noise-reducing approach procedure (CDA, Continiuous Descent Approach), the installation of the air traffic control and the aircraft occupying for the realisation of the CDA, a feedback system of the NTK airport system to the ATC and the Airlines as well as the publication of approach maps.

The Heathrow Airport Consultative Committee (HACC) is a legal institution from representatives of local residents, local authorities, environment protection groups and economic representatives for the airport of London Heathrow. Heathrow area transport forum plays an important role as it is about the land utilisation of the airport. The Noise and Track Keeping Working Group (NTKWG) works on methods of noise reduction. Moreover, the NTKWG supervises the observance of the flight routes within the agreed air routes (NPRs). Annual noise reports are published since 2000/2001. They include, among other information, details of annual flight movements, passenger volume, noise surface contours, number of residents, number of CDAs carried out, night restrictions as well as flight track deviations.

3.5 Present developments and trends

3.5.1 General

In the following section, recent developments and trends regarding noise abatement flight procedures are presented. Thereby two areas can be differentiated. On the one hand, it should be tried to reduce noise emissions directly on the aircraft by changing the flight-operational procedures. On the other hand the range of areas affected by noise emissions should be reduced by modified flight routes. This is achieved by optimizing the vertical climb and descent profiles. Horizontally a widely adaptable route guidance can be put into practice with the help of the area navigation (RNAV) already established. Both can be also combined as for example with the in the following performed CDA approach. In addition, a developing plan of a special low noise aircraft is introduced in chapter 3.5.6.

3.5.2 Noise-reducing flight procedures: Continuous Descent Approach

A CDA (Continuous Descent Approach) is an approach procedure which allows the air traffic controllers to direct the aircrafts from the Initial Approach Fix (or in the ideal case assuming from the cruising level) by radar guidance to a point from which by means of a continuous descent the radio beam of the Instrument Landing System (ILS) used for vertical guidance can be followed.

Mainly due to the modified flight path (see Figure 3-17) and the reduced engine thrust, noise reductions can be achieved below the flight path at a distance from approx. 10 to 25 NM to the touchdown point [52]. As a test this procedure was already applied at several commercial airports within Germany.

At London Heathrow airport a CDA procedure for approaches is used with approx. 80% during the day and during the night-time with approx. 93%. At Amsterdam-Schiphol airport the so-called Advanced CDA procedure is carried out on runway 06. However, during the night about 15 approaches per hour are possible without influence on the capacity.

An advancement of the CDA procedure (Segmented CDA) is currently in the investigation (aviation research program of the Federal Government „quiet air traffic“) and, presumed the most modern flight guidance systems aboard the aircrafts, increases the noise reduction potential further. The use of the CDA offers basically a substantial noise reduction potential, however, it can also come to noise relocation effects to the neighbourhood of the airport. Hence, an optimisation of the procedure on the local situation is necessary which is also to be valued in view of the noise effect. Hence, the assessment procedure introduced here should be able to value not only changes in the routes but also in the flight procedures.

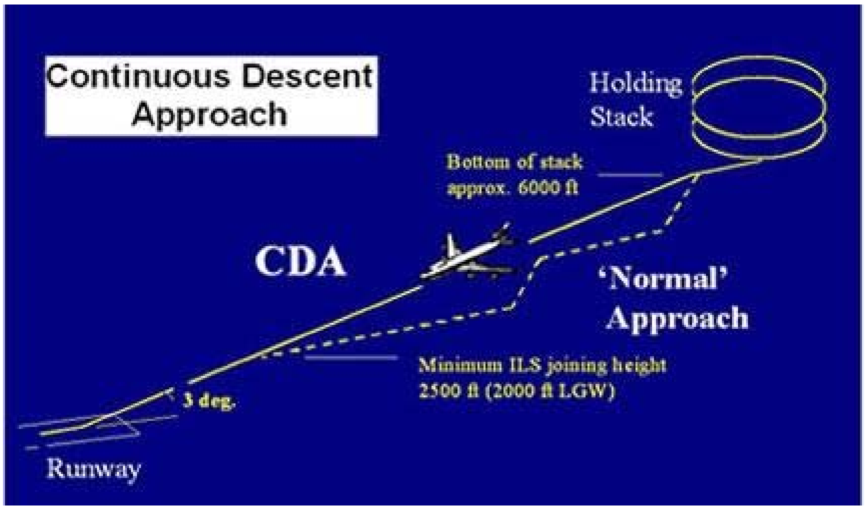


Figure 3-17: Continuous Descent Approach [37]

3.5.3 Noise-reducing flight procedures: Steep Take-Off Procedures

The Steep Take-Off Procedure (ICAO Procedure A) differs from the Quick Take-Off Procedure (= modified ATA procedure or ICAO Procedure B) from an altitude of approx. 1,500 ft. Increase in speed at climb and the retraction of the lift aids takes place with the Steep Take-Off Procedure later at 3,000 ft, with the Quick Take-Off Procedure already at 1,500 ft height above ground. It forms the basis of both procedures the same engine thrust and they differ with the conversion into speed or height. The advantage of Steep Take-Off Procedures is the faster reaching of higher altitudes, so that as a rule a significant noise reduction can be achieved for areas approx. 6 to 12 km from lift off below the departure path.

Currently at Frankfurt/Main airport the so-called modified ATA procedure is recommended for application. It has been demanded repeatedly to introduce the Steep Take-Off Procedure instead, because it is to be classified as poorer in noise [52]. At various international airports the Steep Take-Off Procedure is currently used (e.g., Amsterdam, Zurich, Paris - Charles de Gaulle, Milan - Linate). From the perspective of DFS no difference with the air traffic control processing exists between both departure procedures. In the AIP Germany the Quick Take-Off Procedure is recommended for aircrafts which are admitted after ICAO annex 16, volume I, chapter 3.

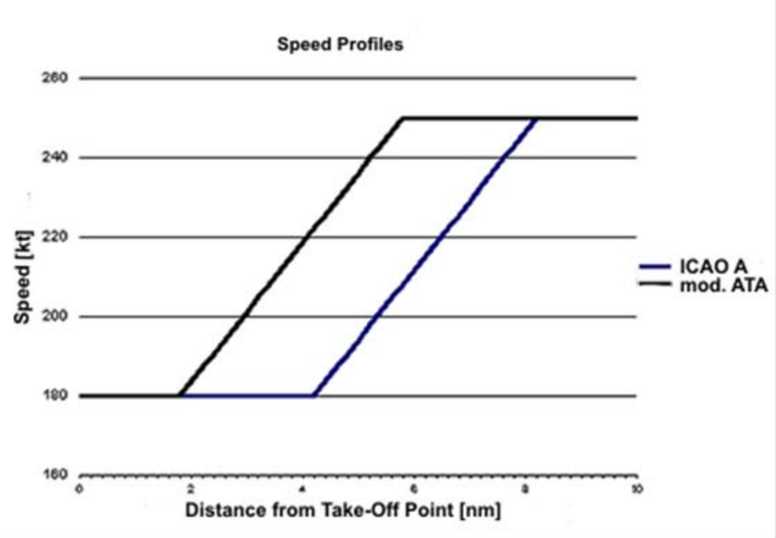


Figure 3-18: Speed profile comparison ICAO A with mod. ATA procedures [source: Fraport AG]

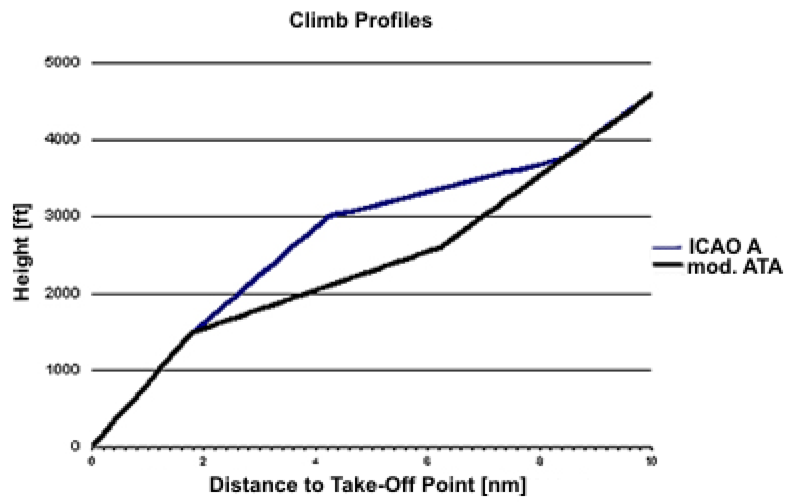


Figure 3-19: Climb profiles - comparison ICAO A with mod. ATA procedures [source: Fraport AG]

3.5.4 Noise-reducing flight procedures: Displaced runway threshold

At Frankfurt/Main airport a relocated landing threshold was tested in the regular air traffic for the first within the scope of the project HALS/DTOP. On account of the too small distance of both parallel runways (25R and 25L) to each other, they cannot be used in the parallel operation. Therefore, parallel approaching aircrafts must be staggered and also separated during final approach in a minimum distance by at least 2.5 NM (4.6 km). Nevertheless, on this occasion a danger exists with combination of certain aircraft categories, by wake turbulences, which is why a considerable enlargement of the separation distances from 4 to 6 NM (7 to 11 km) is necessary. Because this has negative effects on the capacity of the airport, the HALS/DTOP procedure was developed together by Fraport, DFS and Lufthansa. Besides, the landing threshold of the runway 25L was relocated about 1,500 m and therefore a new runway was determined (name of the new runway 26L). This entails that the flight path is shifted up about approx. 80 m vertically, so that no risk exists by wake turbulences and can be achieved on account of the longer propagation ways a small noise reduction effect (Figure 3-20). Besides, it is advantageous that a capacity increase (higher landing frequency) is reached by the better use of the available runways. Against the HALS/DTOP procedure voted above all such pilots who saw an increased safety risk in the shortened runway, because in an emergency case the aircraft would have to be stopped on a shorter runway.

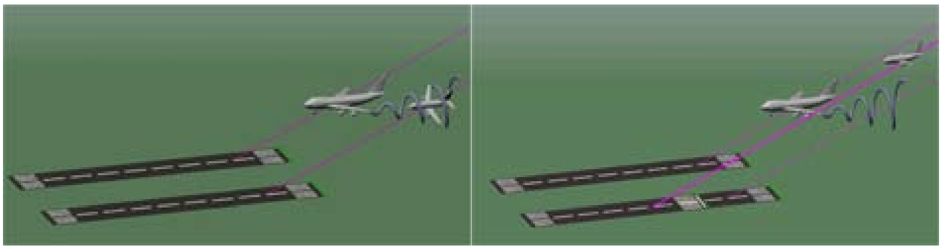


Figure 3-20: Functional principle of the moved runway threshold [source: Fraport AG]

3.5.5 Noise-reducing flight procedures: Alternative flap setting in the approach

At the moment different regulations and recommendations exist at the airlines and aircraft manufacturers for the application of the flap settings during the final approach. There is given among other things according to aircraft types differentiated standards in which order landing flaps and gear should be set. By an additional reduction of the flap setting[13] of around one position (e.g., 25° instead of 30°) and a later extension of the gear a noise reduction can be achieved. Because lift as well as drag is reduced, a lower engine thrust is necessary, so that also lower noise emissions of the engines originate. A noise reduction of approx. 1 to 2 dB is thereby possible with relatively low expenditure in the area between the touchdown point and the last 4 NM (7 km) of the final approach. However, disadvantageously this procedure affects by a slightly increased approach speed and a therefore higher load of the gear structure and brakes.

[13] *Final Flap Setting* during the approach with a height of approx. 1,000 ft (300 m)

3.5.6 Airbus Project QICE

Within the scope of the joint project „high technologies of the new generation“ (HiT) which was funded by the fourth aviation research program for the first time an entire, on new technologies based aircraft with an fitting air traffic concept will be investigated: the so-called Quiet Innovative Commuter (QICE). This QICE aircraft disposes of distinct short take-off and short-landing characteristics (Short Take-Off and Landing, STOL). The noise emissions should be lowered on grounds of the application in close settled areas by new engine integration into the body [48]. As main operational areas of the QICE internal-urban connections as well as point to point shuttle-services are planned. To allow this, new low noise approach and departure procedures are required to the corresponding construction of the aircraft. The aim of the participation of DFS is the predevelopment of the required approach and departure procedures, the integration of these procedures in the existing air transport system as well as the (part) validation in a real time simulation.

The procedures for the QICE aircraft could differ in the following points from up to now usual procedures:

- Continuous extension of the high-lift aids (Auto Flaps / Slats),
- Steep approach (e.g., 6° instead of up to now 3°),
- clearly lower approach speed,
- Multiple curved approaches.

Because the QICE aircraft should operate above all from close to town or even internal-urban airport, the demands in the area of the environmental compatibility are very high. The highest challenge with such a concept is to hold the noise exposure by the air traffic with QICE aircrafts at internal-urban airports in reasonable limitations. Hence, new paths, above all in the concept of the aircraft and the integration of its engine, as well as in the development of noise reduced approach and departure procedures must become treaded for this concept. The experience gained within the scope of this project and the opportunities of the enlarged infrastructure can also incorporate into in the further development of conventional aircrafts and approach and departure procedures [13]. Besides, it is to be considered that just the changed procedures partially cause an absolutely new concept. Approach speed and the flight path angle of the approach cannot be changed with today's aircrafts arbitrarily. In addition, multiple curved approaches are very dependent on weather, so further development progresses concerning this have to be established.

CHAPTER 4 Criteria catalogue

4.1 General

As a basis for the assessment system, a criteria catalogue is developed first which considers the different aspects that play a role during the definition of air routes. On this occasion, three basic areas can be distinguished: the operational criteria which consider a single flight event, capacitive criteria[14] which show a quantitative view[15], as well as environment-related criteria which are related to noise aspects and pollutant emissions.

The preselection of criteria serves, primarily, as a basis for the consideration between the different interests to be carried out later in the process. In order to allow for a well-balanced assessment, the procedure must be unambiguous and reproducible. Besides, the relevant criteria have to be determined already in the beginning of the assessment procedure. This definition should already be a part of the coordination process between the respective involved parties or affected persons.

These criteria are weighted later in the course of the assessment process in order to come to an overall result and, finally, to a recommendation for only one of the investigated air routes.

The selection of the criteria to be considered resembles, in an initial phase, a "Brainstorming" approach that results in a selection of different potential aspects that have to be considered later during the definition or selection of a new air route. If and to what extent the selected criteria will appear in the final assessment, will be concluded during the weighting phase. Basically, the selection of the criteria strongly depends on the local conditions of the considered airport, because in each individual case different aspects can play a role. However, to consider all aspects thoroughly, cost-intensive investigations would be necessary, whose benefit sometimes does not justify the expenditure. Thus, a balanced approach is mandatory.

For example, an assessment of single flight based operational criteria would require investigations that involve flight experiments or at least experiments in the flight simulator. This aspect takes effect in particular with the assessment of the pilot's load with certain procedures. In these

[14] The aspects which influence the maximum number of flight movements per time unit

[15] Calculation determination of the capacity or amounts per time unity, throughput determination

circumstances, where such aspects have a major impact, the assessment should be based on already available investigations. However, in some cases the selection of relevant criteria is already limited by data availability.

Another example are extensive airspace simulations that deem necessary for a comprehensive consideration of all interaction between single routes in an overall system for a capacity assessment. These simulations are often in a disproportion to the expected benefit. However, if capacity aspects are the focal point during the definition or change of air routes, this approach can become necessary.

Finally, in the field of the environment-related criteria, noise aspects are always crucial to the definition of air routes. Therefore, a model-based calculation of noise exposure is recommended for any definition or change of air routes.

4.2 Operational criteria

Operational criteria include all aspects which concern a single flight event. They provide information on differences between air routes looking at a single flight event. In this context, human factors aspects play an important role. For example, with the introduction of new approach procedures, additional work load for the pilots should be avoided. Hence, operational criteria are to be considered based on a single flight event for both approach and departure procedures.

Other operational criteria, which would have to be considered within the scope of an assessment of air routes, are the flyability, the pilot and controller work load or the passenger's comfort.

Another group of criteria that has to be considered when looking at a single flight is related to safety aspects. However, the non-observance of relevant safety regulations can be considered as exclusion criterion.

In the following chapter, flyability, pilot and controller work load as well as passenger's comfort will be discussed in more detail. This shall illustrate the practical application of these criteria within the overall assessment.

Flyability

The area of Flyability is a basic criterion for the assessment of air routes. Like flight safety, flyability must be given for each of the considered routes. Nevertheless, a gradation can make sense, because flyability can differ significantly for different aircraft types. In particular with respect to area navigation (RNAV) capabilities, a differentiation within the field of flyability makes sense, because not all aircrafts are equipped with the necessary navigation instruments. While

RNAV-routes are more flexible, as they are not dependent on ground based radio beacons, aircraft not equipped with the necessary instrument may not use these routes.

Furthermore, it depends on flight performance of a single aircraft type, whether specific flight profiles can be followed, so that also for vertical profiles a gradation of the criterion flyability may apply.

Although in general the flyability of a route should be granted by adherence to the requirements laid down in PANS-OPS, further investigations in this area might be advisable in certain cases.

Pilot’s workload and controller work load

The pilot and controller work load is the second criterion which is included in the operational aspects. Certain routes require increased attention and more interaction from the pilots and controllers with the systems and other involved parties. Hence, it should be valued, to what extent the investigated air routes differ in terms of work load for the pilots and the controllers.

Besides, it has to be distinguished on the one hand between the actual work load, e.g. the number of tasks involved and their complexity, and on the other hand the mental stress resulting from it. While the work load can be described by the necessary tasks to fulfil, the assessment of the resulting stress level with the pilots and/or controllers requires the interaction of the latter. Therefore, as mentioned before, the effort for an assessment of the pilot and controller work load based on an experimental setting should always be held against the specific local conditions and requirements

For numerous aspects, extensive investigations have already been carried out, on which an assessments can be based. This applies particularly for new approach and departure procedures, for which the pilot's work load has been investigated during flight experiments and simulator trials.

In comparing two or more air routes, separation requirements between two consecutive aircraft may differ between the routes, thus resulting in a different assessment concerning controller work load and, therefore, the routes themselves.

As a general rule, lower work load for a route or a flight procedure will lead to a better valuation of that specific route. As with the flyability so also applies for the pilot and controller load that in the ideal case can be assumed from the fact that the suggested routes do not differ concerning their assessment or only a little of each other, because aspects of the general flyability and the load are already considered with the definition of the air routes. Nevertheless, for example by the introduction of new flight procedures, the demands for the pilots or the controllers should change significantly, this is to be considered in a whole consideration with.

Passenger comfort

In contrast to the Pilot's/controller workload and the flyability, which have a strong relation to safety aspects, the Passenger comfort refers only to the perception by the passengers. Ruling for the passengers comfort are e. g. the charge state changes during the take-off and landing. Frequent braking and accelerating are generally perceived as unpleasant by the passengers, why flight procedures with fewer charge state changes will value better.

4.3 Capacity aspects

While the assessment of the operational criteria is based on a single flight, the capacity aspects show the quantitative examination. On this occasion the use of the air route is in focus.

In general the airspace capacity on certain routes is determined by the fact, how many aircrafts can pass in a defined period the considered route. The so-called separation, the distance between two aircrafts following on each other, is decisively for the capacity. It depends on numerous factors, e. g. the size of the advance-flying and the following aircraft, the meteorological conditions and the technical equipment of the aircrafts and the airport or the air traffic control. In dependence of the aircraft size combination of the ahead-flying and following aircraft, the legislator defines minimum distances which always have to be respected. If the following aircraft flies faster than the ahead-flying aircraft, the distances will increase partly significantly. In this case higher distances have to be kept accordingly, caused by the legislator‘s given separation minimum distances which have to be respected during the approach. The same will basically apply on departures, if two aircrafts use same route.

The speeds which are used in the different arrival and departure procedures can differ partly strongly from each other. Caused by this, capacity losses can be the result.

But also the lateral route guidance can have negative effects to the capacity which a separate assessment requires. In particular dependences between the different routes lead to capacity losses. E. g. route intersections as an extreme case can generate negative capacitive effects which have to be excluded and play a role by the assessment of each procedure. On this occasion, the interaction between arrivals and departure routes have to contemplate, too.

Because of the strong dependences of the flight routes a consideration of the overall system is normally preferable, because an isolated contemplation of a single air route cannot grasp the described effects. Therefore the interactions in the whole system have to be considered by the capacitive assessment of single air routes. For a valid assessment of capacity aspects an airspace simulation is mostly necessary. Nevertheless small air routes amendments lead to changes in the other aspects, but to small capacity changes, why a consideration are not basically necessary. Restrictions, e. g. noise contingents or similar restrictions have to incorporate in the capacity assessment to observance all aspects.

In summary it can be assumed for an overall consideration from the fact that a route variant or a flight procedure gets a better assessment, the higher the capacity of the system with the corresponding route is. In case of arising capacitive restrictions for a investigated route variant are detected, the resulting reduction of the flight movements within the noise and pollutant calculations on this route will have to be compensated by a path on other routes. It takes the displacement of flight movements to make sure that the total load is in each case comparable to other routes. Furthermore capacitive restrictions do not automatically lead to a reduction of the environmental impact by the assessment.

4.4 Environmental criteria to the definition of air routes and flight procedures

4.4.1 General

An important aspect by the assessment of air routes and flight procedures are the environmental criteria. Basically it is distinguished by noise aspects and the consideration of pollutants and greenhouse gases. Nevertheless, the most important decision criterion by the assessment procedure and is the noise, because the aircraft noise load is generally in the airport neighbourhood from more importance than the pollutant load of the air. Therefore, the main object of the following examinations is the assessment of the noise aspects.

4.4.2 Aircraft noise

Concerning the aircraft noise, different calculation methods and approaches exist for the effect assessment of new-definition or change of air routes and flight procedures. Nevertheless, the basic approach is nearly similar by all of them.

At first a noise calculation will arrange for the investigation area which includes the considered air route(s). The basis of these calculation is the available the air traffic on the air route(s). As a result of the calculation the noise level contours of the same noise load, so-called isophons, are received.

In a second step, the determined noise contours are overlaid with the population numbers which live in each case within these isophons. Therefore, it can be estimated how many people are exposed to a defined noise load.

At third the questions have to investigate how many of the people who are exposed by the aircraft noise load fell affected and what health interferences are to be expected by defined threshold values/limits of aircraft noise and how the aircraft noise affects or could affect on other aspects of the life.

In allusion of this basic approach different so-called noise-indices has been defined which are passing by the assessment of aircraft noise. The Zurich or the Frankfurt Aircraft Noise Index which are explained in Chapter 5 in more detail are exemplarily mentioned in these study. These indices establish the basis for the suggested approach.

4.4.3 Pollutant emissions

Only low differences of pollutants and greenhouse gases output arise by the investigation of different departure procedures caused by the already high engine performance in the take-off phase with the corresponding high kerosene consumption. For this reason no closer consideration takes in the study here. Nevertheless, if local conditions or the legislation are changing or if the route variants differ strongly concerning their length, a consideration or investigation will become necessary. In this case costly emission calculations are necessary to be able to make valid conclusions about the different pollutant charges of the air routes or procedures.

CHAPTER 5 Assessment procedures

5.1 General

The exact quantification of the single criteria and their description is the base of an objective assessment of air routes and flight procedures. The assessment procedure which is introduced in following chapter is carried out with a model which cuts into five phases. The procedure begins with the definition of the necessary criteria which should be included by the assessment. Caused by accounting of a quantitative representation opportunity the problem is the accurate und exact definition of the criteria before the assessment. On this occasion some criteria are easy to quantify because they are already given in a scaled form. These include for example the number of the flight movements per hour or the number of the affected people from the aircraft noise in the investigation area. However, there are criteria which have to be first transferred in a scaled form, e. g. the pilot's and controller workload or the passenger comfort.

The next phase encloses first the quantitative allocation of the criteria which are included in the investigation. Chapter 5.2 explains this step in more detail.

As soon as all criteria are given in a numerically detectable form, they are transferred in the third phase in a standardized scale from 0 to 10. Furthermore some factors have an inverse proportionality which has to consider in the standardization process. An inverse proportionality is given for example by the consideration of the affected people from the aircraft noise. The more people are affected, the lower the index on the scale. A non-linear context can also exist by the definition of the transfer function. This has to take into account in these cases, e. g. a small number of exposed people with a higher load leads to a strong decrease of the indexes, while other criteria concede certain tolerances.

After the quantitative representation is given for all criteria from 0 to 10, the next step is the classification of each criterion into the three main categories Operational, Capacity and Environment and the weighting within these categories. This indicates in the area Environment, e. g. to weigh the subjects Aircraft noise and Pollutant emissions among themselves.

Finally the three categories are weighted among themselves to reach to a overall index. Figure 5-1 shows and sums up the whole definition and quantification procedure of the criteria up to the weighting.

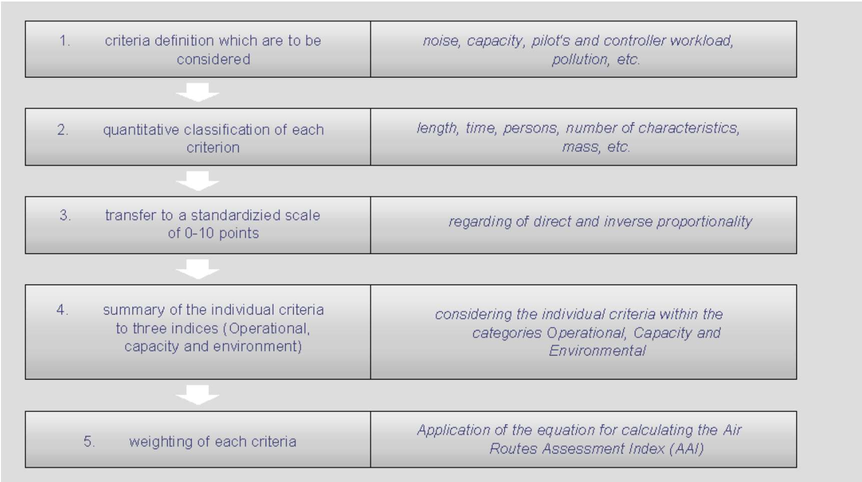


Figure 5-1: Overview of the procedure to the assessment of air routes and flight procedures

5.2 Quantitative classification and standardisation of the criteria

5.2.1 General

A quantitative representation is necessary for the assessment of the criteria. Only in this way it is possible to set up a comparability of different variants and to consider all aspects appropriately. Besides, there are criteria which are already given as measurable values and others which have to be quantified at first with the help of scales.

Furthermore the quantification has to be divided whether the values permits an absolute representation or whether a relative comparison of the investigated variants is possible among themselves. This differentiation is important to define reasonable upper and lower assessment limits for the standardisation of the criteria.

Besides, there are basically two different ways for the assignment in the standardised scale. The aim is in each case to transfer the assessment in a scale of from 0 to 10 points. To illustrate the extreme values (0 or 10 points), at first a corresponding reference which satisfy to these points has to be defined. The definition can take place in two different ways. On the one hand it is possible that the highest score is reached when e. g. in the noise load not a single one (10 points) or everybody (0 points) of the airport residents is/are affected by the aircraft noise. The advantage of this perception is that an absolute statement about the noise load is possible and the possibility of comparison between variants is given. Nevertheless, the small differentiation of the routes which has to be considered among themselves is disadvantageous within this variant presents because on this occasion the results lie mostly close together. This case is shown as a blue sketched line in both following pictures.

The other possible perspective assumes that the determined route receives the maximum score (10 points) which shows the lowest noise load, while the route with the highest load gets accordingly 0 points. This perception permits a very high differentiation of the routes among themselves. But because the routes are only compared among themselves an absolute statement is not possible.

In addition, a route which is absolutely seen positive can be assessed with this approach under noise aspects and in comparison to the other routes with 0 points. This case is shown in Figure 5-2 as a red sketched line.

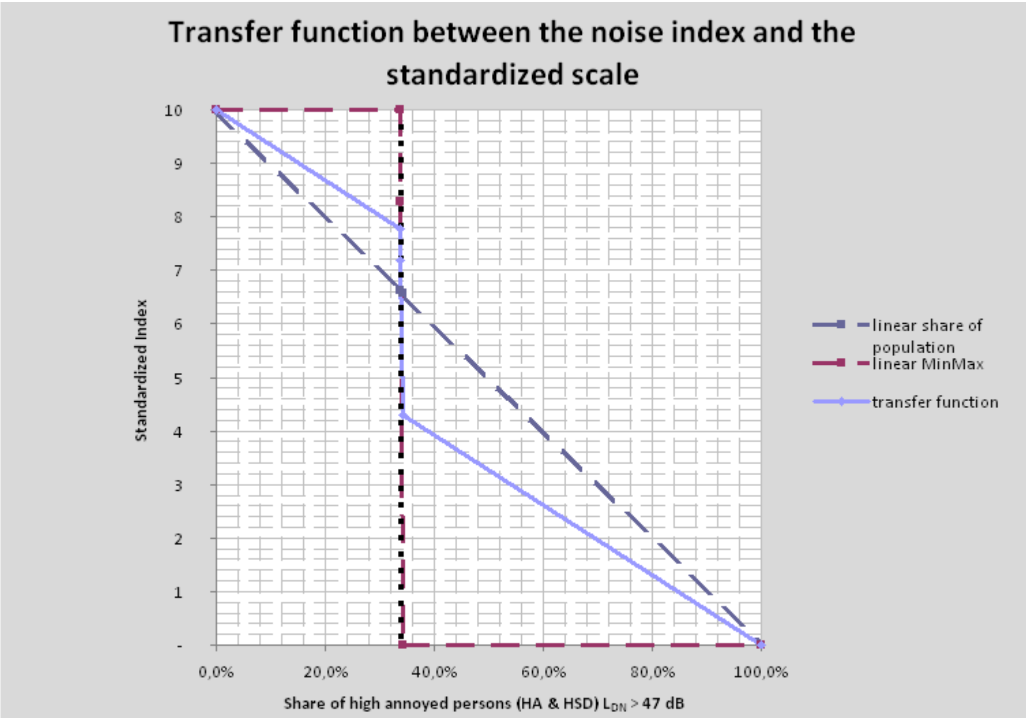


Figure 5-2: Transfer function between the noise index and the standardised scale

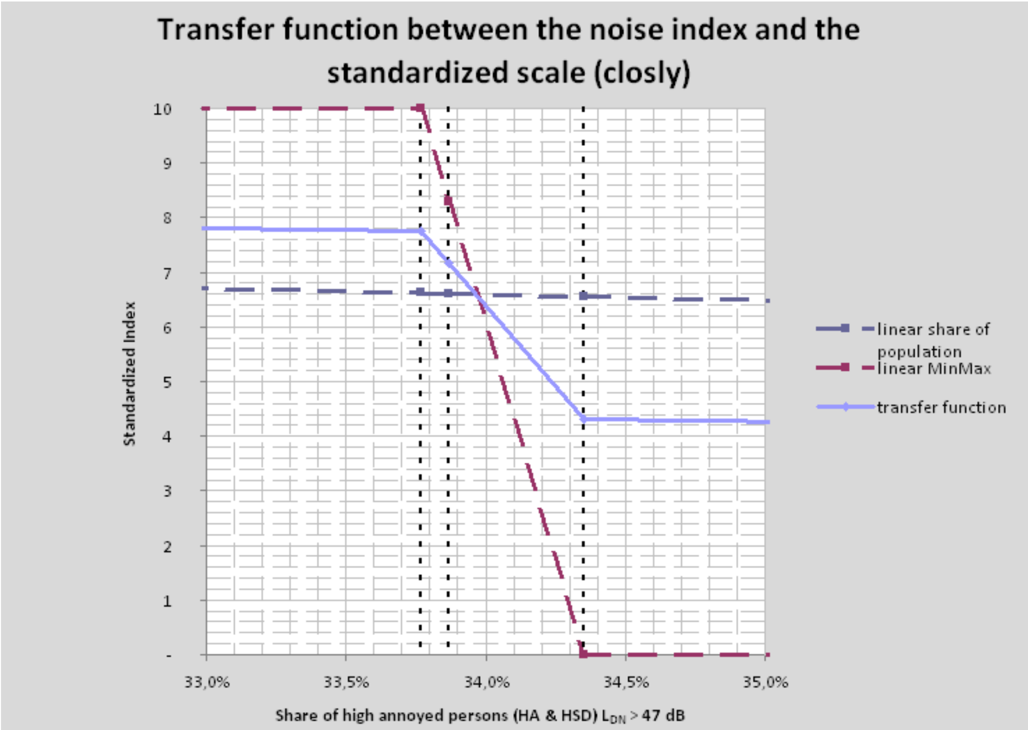


Figure 5-3: *Transfer function between the noise index and the standardised scale (near)*

Both approaches have advantages as well as disadvantages why a combination of both procedures is obvious. This happens at first with the help of the calculation results in which the limitations of the routes are determined, therefore the variant with the lowest and highest load are searched at first.

To be able to carry out a better differentiation between the values the minimum value is exalted and the maximum value is reduced. The increasing of the minimum value occurs with the proportional value which is a result of the calculations and describes the exposed population. In the considered example (cf. Chapter 6) the calculated value of the noise related best route (TAB NEU) is increased by 6.62 points around the population portion of 33.77% which are exposed in the area. The maximum value of the route TAB N which amounts in case of the linear consideration to 6.56 points with a population portion of 34.35% is decreased around the portion of 34.35% why it has now the value of 4.32 points.

Now it is interpolated linearly between the determined limits, why the other route variants get interim values which permit a comparison among themselves. This case is shown in Figure 5-2 and Figure 5-3 as a continuous blue line.

The problem with this approach, which is described on top, lies into the identification of sensible absolute maximum and minimum values which allow a statement how well or bad a variant is.

These maximum and minimum values have partly a theoretical character, because they can be never reached. The statements, basing on these values, are regardless to the fineness of the other investigated route variants. After this only in connection the absolute and the relative perception can be combined like in the described principle to determine what the differences are exactly.

Referred on the investigation area it can be held on for the shown example of the noise pollution that the highest possible number of exposed persons defines the lower limitation and the lowest number of exposed people the upper limitation.

5.2.2 Operational criteria

In chapter 4.2 the operational criteria flyability, pilot's workload and controller workload as well as passenger comfort were complied. These criteria bases on single flight considerations for arrival and departure and are quantified differently.

Flyability

At first, for a quantitative assessment of the flyability, it is investigated, whether the PANS-OPS are observed. This default has to be fulfilled by the construction of the route variants. If it is not the case, no points will award, e. g. the route is excluded because of the non-flyability.

If the PANS-OPS condition rules are fulfilled, a consideration of the usability for different operating aircraft types at the airport will be advisable. For the reason it will lead to a deduction if the route is only usable for a limited number of flights/aircraft types because of flight performance or special navigation equipment standards. E. g., an arrival with a glide path angle from more than standard 3.0° (e.g., London city with 5.5°) is not flyable for all aircraft types. The comparative air routes and flight procedures have not to show necessarily similar vertical profiles why the flyability for special aircraft types is not given likewise on a route. In view of the flyability the non-observance of the PANS-OPS can see as a lower criteria limitation and will lead to 0 points in the assessment. If all aircraft types which operate at the airport can use the investigated route under all conditions, it will be seen as upper limitation and will lead to 10 points.

If a deduction on the basis of restrictions by the flyability is necessary, the usability of a route concerning the capacity will have to investigate because effects on the capacity are possible.

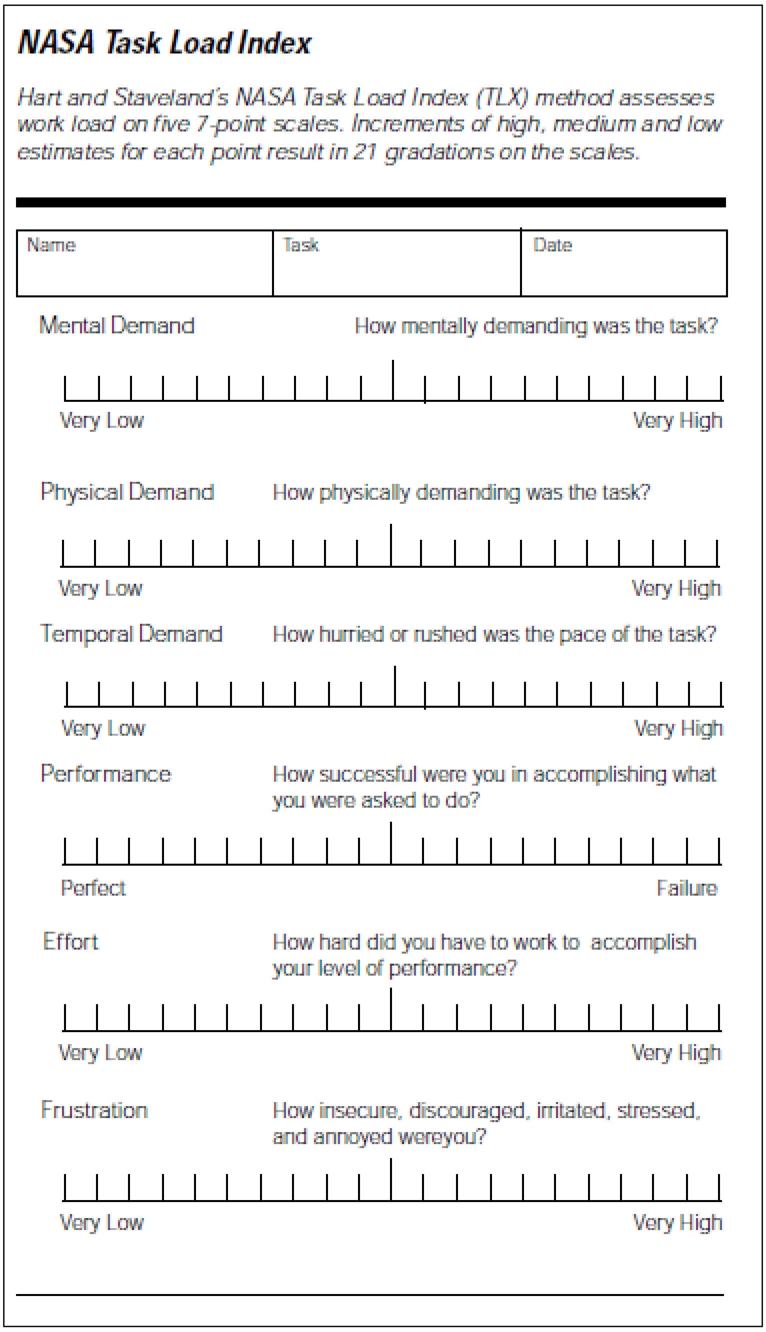
Pilot's and controller workload

The assessment of the pilot's and controller workload can take place on two different ways. On the one hand the complexity and frequency of the necessary actions can be determined with the help of the exact description of the tasks. Conclusions about the load of the pilots or controller can be admitted by this way.

On the other hand, Task Load Index (TLX) which was developed by the NASA (*Nationwide Aeronautic and Space administration*) can help to determine the pilot's and controller workload. The NASA-TLX is a multidimensional scale which has to be indicated by ratings of test persons (pilot / controller) on different subscales. Finally these sub-values can be integrated to a total value, the NASA-TLX. The final score of the NASA-TLX is based on weighted ratings of the following subscales:

- mental demand,
- physical demand,
- temporal demand,
- function fulfilment,
- effort and
- frustration.

Three of these dimensions refer exclusively the made demands (mental, physical, temporal demand) to the experimental subject, while the remaining ones grasp the interaction with the task. The following Figure 5-4 shows an example of a questionnaire.



NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Figure 5-4: Questionnaires to the workload (NASA TLX) [39]

In addition another list of questions is presented once to weight the single categories. Each single category (e.g.: mental demands) is assigned a rank in the direct comparison after whose personal importance (the rank reaches a value between 0 (insignificant) and 5 (very important)) and leads to a numerical value between 0 and 20. After the value is multiplied by the belonging rank, the six categories per questionnaire are added up. The result is the workload value of every questionnaire [39] which lies between 0 (no workload) and 600 (very high workload).

Referring to the score is transferred in the standardised scale of the from 0 to 10. A value of 600 points in NASA-TLX leads to zero to points by the assessment, because the as low as possible workload is the aim of the air routes and flight procedures assessment. Zero points in NASA-TLX leads accordingly to full ten points of the assessment scale. It is linearly interpolated between these values.

It should mention that the controller and pilot's workload does not change necessarily by the application of low noise flight procedures. Furthermore a rising workload of the involved persons should show rather an exclusion-criterion than a not-use-criterion, because the safety sinks often by a rising workload. For this reason, low noise flight procedures are often in use by small traffic loads (cf. the Munich airport CDA procedure which is used mostly at night).

Passenger comfort

The passenger comfort, which is the last of the single flight based criteria which are introduced in the chapter, can occur, e. g., through an assessment of the number of the charge state changes on the respective route[16]. On this occasion, a suitable transfer function have to be found between the number of the charge state changes, which are linked with the number of route segments, and the standardised scale. In general it is to be noted that a higher number of segments leads to a lower assessment.

Normally, if air routes or flight procedures primarily discern themselves horizontally, the passenger comfort shall be given in any case. Hence, this aspect takes effect rather when different arrival or departure procedure should be assessed. These criteria which can contribute to a possible interference of the passenger comfort are to be determined in particular case. In general the aspect of the passenger comfort plays a subordinated role because of the very subjective perception within the scope of the whole assessment. If procedures which give priority to this aspect should be developed in future, investigations which including passengers will be advisable to permit valid statements similarly as it was applied with the exposure-effect relationships in the noise area. To simplify the exemplary assessment, it is to be expected that the passenger comfort can be disregarded or can be valued with 10 points by "normal" route assessments.

5.2.3 Capacity aspects

After the classification of the three operational criteria which are based on single flights in the standardised scale of from 0 to 10, the capacity aspects are to be determined. Because of the dependences of the determined air route/flight procedure with the whole system of the remaining arrival and departure routes a simulation is unavoidable as already in the preceding chapter

[16] Acceleration phases, Deceleration phases, curve flights

described. A lot of commercial systems are available for this task, e. g. Simmod [43] or TAAM (*Total Airspace & Airport Modeller*) [44]. Simmod has the advantage that the data basis is identical to the aircraft noise analysis data of the *Integrated Noise Model (*INM) and the pollutant emissions data of the *Emissions and Dispersion Modelling System* (EDMS) which has been also developed by FAA.

Simmod is a generic simulation model which can be simulated the traffic flow at any airport. Simmod focuses and straightens on the simulation of air-sided airport processes why it is very well adapted for the detailed process modelling of an airport. Also the data, e. g. flight performance data or a rolling guidance optimisation, are already deposited in the model and allow a high detailed level. Simmod is a standard model which is mostly applied by FAA to the regulation of capacities. A capacity calculation, which proves the number of the flight movements in a certain period, usually one hour, by a given (accepted) delay, is possible with the help of this model. The hourly capacity can be determined for any variant within the scope of several scenarios which differ in view of the different air routes or flight procedures which are to be investigated. This capacity equates to the whole capacity of all air routes of an airport.

The number of the flight movements per hour which was determined can be also transferred in the scale by from 0 to 10 points. Again the capacity values which 10 points or 0 points are awarded have to identify like by the determination/assessment of the operational aspects. A capacity of 0 possible flight movements as the theoretical lower limit it is obvious to attach. This case is only theoretical, nevertheless the consideration still opens the opportunity to deviate absolute statements for different route variants. In contrast to this, the variant which can exhaust the technical capacity in regarding of the runway system establishes the opposite pole and can be used for the identification of the lower und upper limitation.

The technical capacity is a size which refers to the maximum, theoretically accessible number of flight movements of a runway system in a defined time interval. The technical capacity is often also called "border capacity" or "saturation capacity". This definition assumes optimum operating conditions and a stationary inquiry, i.e. there is a steady flow of arriving and departing aircrafts. In case of this consideration the standard waiting periods in practice are not attended, i.e. aircrafts can always start and land without delay. These conditions are not to be guaranteed in the practical company permanently. For this reason in practice the number of the flight movements will be tied with delays, in particular if a high extent of runway utilisation should be achieved.

5.2.4 Environmental criteria

5.2.4.1 Pollutant emissions

At first for the quantitative representation of the pollutant emissions as well as the CO_2-output with the help of a suitable model a calculation of the emissions is necessary. For this, e. g. EDMS of the FAA is suited, because the aircraft noise calculation program INM uses the same data basis. The help of a distribution calculation which build up the assessment basis the emissions are determined.

To compare different air routes among themselves, all variants have to be included in the calculation in case of the pollutant emissions consideration to be able to confront able to determine the overall load and to be able to confront the results with the limit values. To guarantee a sensible comparison, the total number of the flight movements on the different air routes have to be the same for the emission calculations, because otherwise no scenario comparability would be given among themselves any more.

The result of the calculations can be shown as the pollutant amount or with the help of the kerosene consumption. It is to be assumed for the standardisation that the maximum score of 10 points is deciding the theoretical value of zero-emissions which cannot be reached though, but allows an absolute classification. The lower limitation of the assessment (also theoretically) presents itself more complex because arbitrary high emissions are conceivable. Basically it is noted that in view of CO_2 primarily the emissions are dependent on the number of flight movements and less of the position/look of the arrival and departure routes. For this reason a pure quantitative view supplies no sensible differentiation of the air routes among themselves.

Moreover the only alternative is a comprehensive emission calculation, which provides information about the areas, and therefore how many people, are put out potentially to pollutants, analogy with the noise determination. The effective limitations which are held in the 22. BImSchV can be pulled up as the assessment base and as the lower limitation of the zero points. If these limit values are exceeded at certain places, this variant will be refused and will value with zero points.

5.2.4.2 Aircraft noise

The determination of the aircraft noise load of the population in the neighbourhood of an airport can be calculated, beside other methods, with the help of the noise analysis of the ECAC Doc 29 (3rd edition) and, e. g. under use of the software INM (*Integrated Noise Model*). This analysis permits a relatively differentiated consideration to alternative air routes and flight procedures. Suitable assessment dimensions of the noise load are the “equivalent permanent sound level” L_{eq} and/or the number and height of the “maximum levels” L_{max}. Important differences between these sizes still exist in the number of the considered periods as well as whose addition with a minus point for the increased disturbance effect in this period. The L_{DN}-calculation differs between day and night hours while the L_{DEN}-determination takes the evening or the morning hours into account and adds them with different minus points (e.g., 5 dB for the evening and 10 dB for the night). Also the consideration of ground noise, reflections or shielding effects within the calculation leads to differences in the determination regulations. Because of this reason the different, commercially available noise calculation programmes offer mostly a huge number of the noise identification dimensions.

In particular discussion need and research need are existed in the assessment of the noise-psychological aspects which includes the noise-effect-research. This is not least caused by continuously new knowledge which is won about the contexts between noise effect and the medical and social results. These results incorporate into in the corresponding procedures. Nevertheless, basic consensus consists in the need of a separate assessment of the day and night hours because in particular the protection of the population from noise during the night comes up an high importance. Under the consideration of the actual knowledge wake-up-reactions caused by aircraft noise is a suitable means for the noise assessment during the night. Nevertheless today it is contestable how the results for the day and night can be tied together in a overall assessment. However this linking makes sense for the final overall assessment even though it presents a simplification of the different interpretation opportunities. In view of the traceability it is to ensure that both indices are listed individually to be evaluated separately.

The Zurich Aircraft Noise Index ZFI as well as the similarly formed Frankfurt Aircraft Noise Index FFI apply as the farthest developed procedures to the assessment of noise effects currently.

Following the ZFI is introduced closer and the suggested assessment procedure which bases on the ZFI is explained. On this occasion the changes which were made at the ZFI and lead to the used, in this study, index are entered.

Zurich aircraft noise index and its variation

The ZFI is a singular size which consists of the number of persons which are strongly annoyed by aircraft noise during the awake state on the day (*Highly Annoyed - HA*) and the number of people which are very disturbed by aircraft noise in the sleep during the night (*Highly Sleep Disturbed - HSD*). The HA-component is determined by using a dose-effect relationship after Henk M.E. Miedema; the HSD-component is determined about the number of the additional wake up reactions which are induced by aircraft noise (AWR).

The Zurich aircraft noise index is defined as follows:

$$ZFI = HA + HSD$$

The value of the HA component (*Highly Annoyed Day*) corresponds to the number of strongly annoyed people which are exposed by aircraft noise of a permanent sound level of Leq_{16}> 47 dB(A) during the awake state on the day. The underlying dose-effect relationship (cf. Figure 5-6) was proper determined for a day-night-level L_{DN} which the night hours are usually stronger weighted with a minus point of 10 dB. Nevertheless, the ZFI uses, aberrantly from this, the L_{eq16} because of the night flight restrictions/ban in Zurich the deviations are small and therefore insignificant. The L_{eq16} is calculated for the day of from 06 to 22 o'clock in which both day edge hours (from 06 to 07 o'clock and from 21 to 22 o'clock) are charged with a minus pinot of 5 dB.

The HSD component (*Highly Sleep Disturbed*) corresponds to the number of very disturbed people in sleep which are exposed by aircraft noise of a permanent sound level of Leq_8> 37 dB (A) during the night. The HSD-index is calculated only for the night (from 22 to 06 o'clock). The following picture summarises the approach schematically.

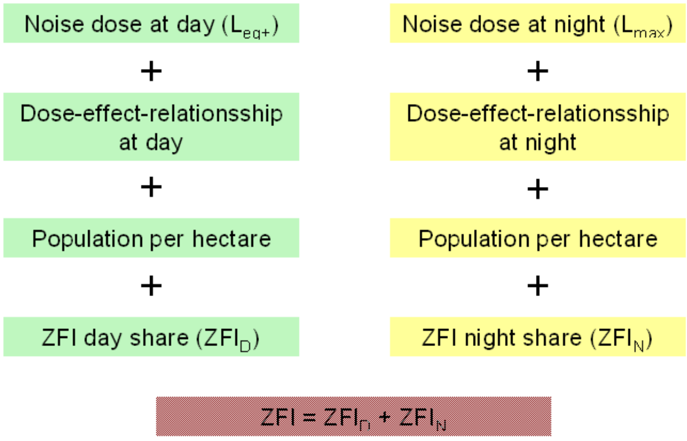


Figure 5-5: Overview to the determination of the ZFI (The Zurich aircraft noise index, in 2006)

Therefore the basis for the noise load calculation during the day is the 16h-average-level and for the night the determination bases on the number and the height of the A-valued-maximum-level. At first aircraft noise contours are calculated for these noise dimensions. Then on the base of a population distribution (population data) the number of the inhabitants is determined within these contours.

Afterwards the respective shares of the population which are interfered strongly on the day (HA) or are disturbed strongly in sleep at night (HSD) are determined then with the help of the dose-effect relationships. The corresponding interrelations are based on scientific investigations which apply at first only for Zurich airport. These relations are shown for the day in Figure 5-6 and for the night in Figure 5-7.

On the one hand this combination of two basically different components is absolutely controversial because different dimension bases are at the bottom of the calculations and permits actually no addition. On this occasion people who are affected by a permanent sound level during the day are mixed with people who feel strongly disturbed in the sleep at night. In addition a multiple counting of the night affected persons is possible caused by the summation of these people why the results, the determined person figures, are difficult to interpret.

On the other hand for an overall view it makes sense to reach a decisive quality indicator which allows to give up a recommendation for a procedure or route. For this reason a mixture of the components „affected persons on the day“ and „wake up reactions at night“ is accepted as an established procedure and has been applied in this study for an overall view. The clear representation of the intermediate results guarantees that information about the result origin is preserved. That's why the present study should adhere to the addition of both noise components.

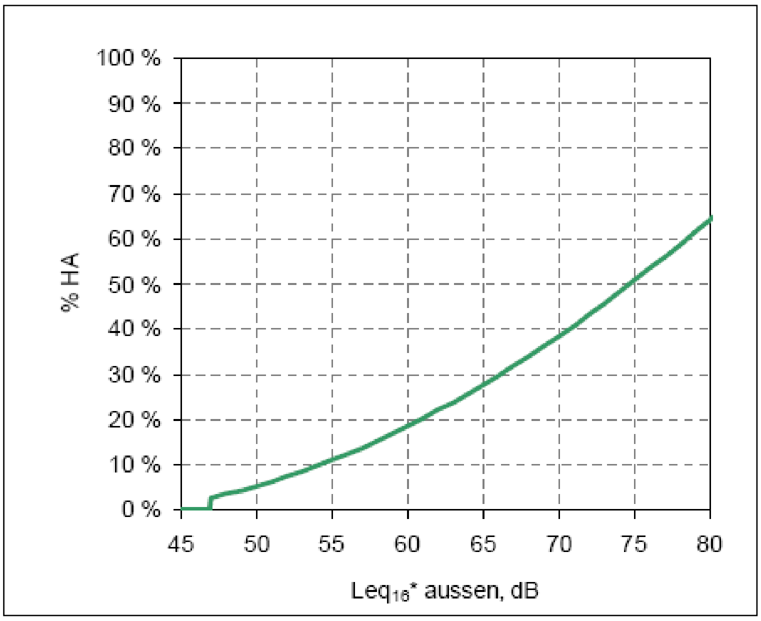


Figure 5-6: *Dose-effect relationship to the regulation of the percentage for strong nuisance %HA*

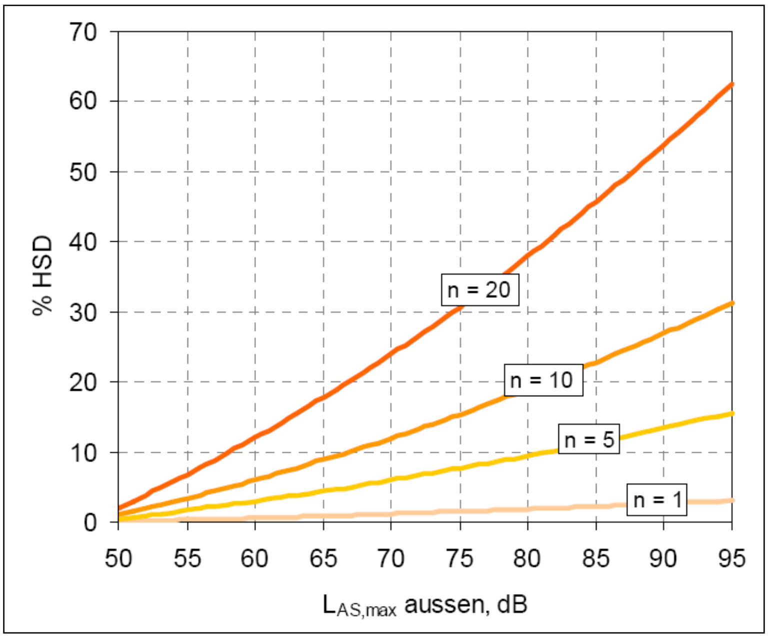


Figure 5-7: *Dose-effect relationship to the regulation %HSD for one, five, ten and twenty overflights*

In the following the single steps of the determination of the aircraft noise index which used in this study are explained in more detail. Deviating from the ZFI the starting point for the HA-component-determination is the calculation of the equivalent permanent sound level. This is determined for a 24h-day with a separate assessment of the „legal night“ (from 8 to 22 o'clock) and of the morning hour (from 6 to 7 o'clock). After the following equation the permanent sound level takes place in the calculation:

$$L_{DN} = 10 \cdot \lg\left(\frac{15}{24} \cdot 10^{0.1 \cdot L_{day}} + \frac{9}{24} \cdot 10^{0.1 \cdot (L_{night} + 10)}\right)$$

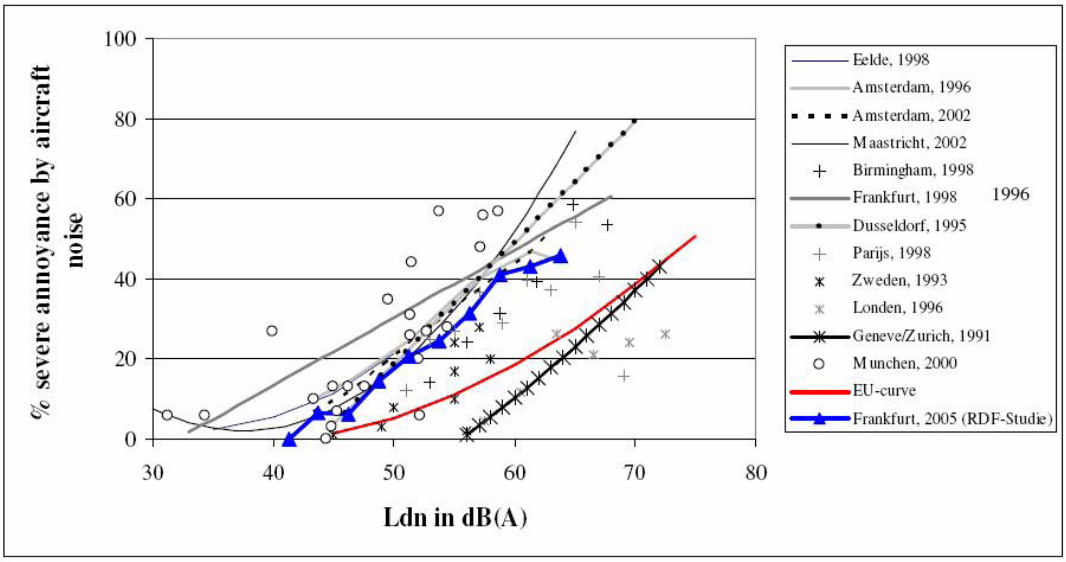
At this are	L_{DN}	Day Night levels
	L_{day}	A-valued 15h-average level during the day (from 07 to 22 o'clock)
	L_{night}	A-valued 9h-average level during the nighttimes (from 22 to 07 o'clock)

To be able to apply the dose-effect relationship on the basis of the L_{DN} a differentiation of the single time slices is not carried for a additional consideration of the day and night edge hours. Differing from this it can make sense to add the evening hours or day edge hours which are both especially noise-sensitive times with a minus point of 5 dB, i.e. to underlie the L_{DEN} as a base for the calculation. However, additional investigations would be necessary which confirms the transferability of the dose-effect interrelations which refer to L_{DN}-values. This is one of the mentioned deviations to the Zurich aircraft noise index (of the suggested approach).

In another step the share of the exposed persons for each grid point which build the feed size 100m x 100m is determined. Here the dose-effect interrelation, which is shown in Figure 5-6 (L_{eq16} and %HA) and actually describes the relation between day night level L_{DN} and %HA, comes to the use. According with comparative calculations the L_{eq16}-%HA-relation corresponds on average practically with the L_{DN} (cf. calculation regulations Zurich aircraft noise index), but the dose-effect-interrelation can be already locally very different why a procedure deviation to the Zurich Aircraft Noise Index is possible or even advisable/necessary. The different curves which are shown in Figure 5-8 describe the relation from %HA and L_{DN}. Caused by the later shown case study of the Frankfurt/Main airport the corresponding curve for 2005 is selected. After [41] this relation can be approximated by a linear equation:

$$\%HA = 2{,}18 \cdot L_{DN}[dB] - 91$$

Caused by the very different noise felling on the regional level a new dose-effect-relation which considers particular the corresponding night flight regulations in these regions has to put up for each new investigation of the air routes or flight procedures.



Quelle: van Kempen, und van Kamp (2005, S. 25, Fig 3b; ergänzt um Daten der RDF-Studie).
Die aus dem Original stammende niederländische Schreibweise der in der Legende aufgeführten Orte wurde hier beigehalten.

Figure 5-8: Dose-effect relationships between L_{DN} and %HA for different airports [42]

By using the function above, the number of strongly annoyed persons by aircraft noise is received for each investigated grid cell. The total number of the strongly annoyed people in the investigation area arises finally by integration (summation of the grids). According to the ZFI people who are exposed to a Leq_{16} by more than 47 dB are only considered.

The maximum levels L_{ASmax} have to be determined at first with a noise calculation programme to attend the night hours between 22 and 6 o'clock. Then with the help of the context, shown in Figure 5-7, between the number and height of the maximum noise levels and the part of persons which are strongly disturbed by sleeping, the part of the strongly-distributed person can be determined for each grid cell. Again the total number of the sleeping-disturbed persons is calculated by the summation of all grid cells. The equation which forms the basis of the Figure 5-7 is:

$$\%HSD_i = GsS \cdot AWR_i = 26 \cdot AWR_i \qquad \text{für } Leq_{8,i} \geq 37dB$$

$$\%HSD_i = 0 \qquad \text{für } Leq_{8,i} < 37dB$$

The factor GsS is a weighting factor for strong sleeping-disturbances. It says that one additional wake-up-reaction corresponds with 26% of HSD.

The second factor in the equation, AWRi, names the number of the additional wake-up-reactions which is established by the following equation:

$$AWR_i = \sum_j AWR_{ij} = \sum_j n_j \cdot \int H_{ij}\left(L_{AS,\max} + D\right) \cdot P_{AWR,ij}\left(L_{AS,\max} + D\right) dL_{AS,\max}$$

AWR_i	Anzahl durch den Fluglärm induzierte zusätzliche Aufwachreaktionen am Hektarpunkt i.
j	Index für den Flugzeugtyp.
n_j	Anzahl Bewegungen des Flugzeugtyps j.
H_{ij}	Häufigkeitsverteilung der Maximalpegel des Flugzeugtyps j am Hektarpunkt i.
$L_{AS,max,ij}$	A-bewerteter Maximalpegel des Flugzeugtyps j am Hektarpunkt i.
D	Einfügungsdämpfung für den Übergang vom Aussen- zum Innenpegel. Für gekipptes Fenster rund -15 dB
$P_{AWR,ij}$	Wahrscheinlichkeit einer zusätzlichen Aufwachreaktion durch ein Fluggeräusch des Flugzeugtyps j am Immissionsort i

The probability of an additional wake-up-reaction caused by aircraft noise events is determined by the following equation:

$$P_{AWR,ij}(L_{AS,\max} + D) = 1.894 \cdot 10^{-5} \cdot \left(L_{AS,\max,ij} + D\right)^2 + 4.008 \cdot 10^{-4} \cdot \left(L_{AS,\max,ij} + D\right) - 3.3243 \cdot 10^{-2}$$

To answer e. g. the question how much will be the part of the total population which is concerned by (aircraft noise-induced, additional) wake-up-reactions AWR if a maximum sound level (outside) of 65 dB level appears five times per night in the investigation area (%HSD), the Figure 5-7 is consulted. The result is that approx 10% of the population are concerned. In this connection the attenuation (in generally the acceptance of -15dB is standard by a tilted window) of the outside sound level to the inner sound level has to be noted.

The programme INM is used within the scope of the presented investigation for calculation of the noise-physical dimensions. This worldwide used programme bases on the calculation algorithm of ECAC Doc 29 (3rd edition) and is suited for the assessment of alternative air routes and flight procedures. It allows the input of special flight profiles for single aircraft types or aircraft classes. Any arrival and departure procedures/routes can be modelled in INM what Figure 5-9 exemplarily shows.

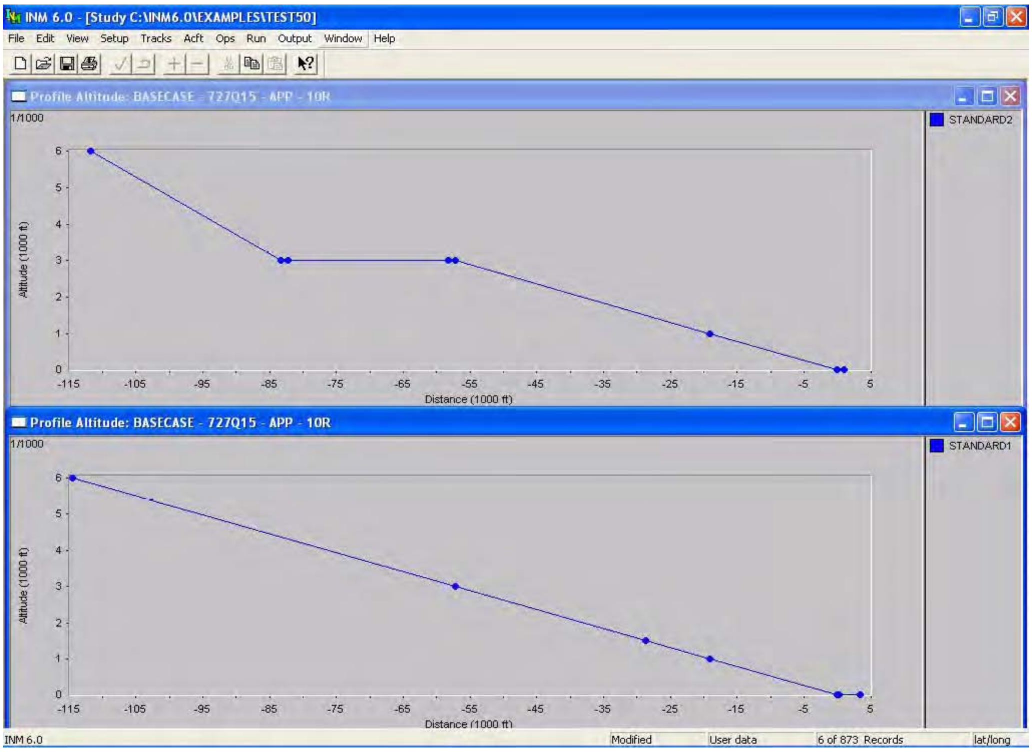


Figure 5-9: *Exemplary representation of two approach profiles in INM 7.0*

Then the aircraft noise contours which are determined with INM for different noise identification numbers, the equivalent permanent sound level for the day and the maximum noise level for the night, can overlay with the population number in the corresponding grids. Afterwards the respective part of the strongly exposed or the strongly in-sleeping-disturbed persons are identified with the help of the dose-effect-relationships which is described above.

Finally, as the result the number from the aircraft noise of the strongly annoyed or in-sleeping-disturbed people within the noise contour is received for each of the investigated routes (variants). In the next step by the addition of these absolute figures of the affected persons (HA during the day and HSD at night) the performance of an air route or flight procedure can be shown in the context of all air routes and flight procedures with the help of the standardised scale (0 to 10). Besides, the variant with the lowest exposure receives the higher score. The theoretical case that all resident in the investigation area are concerned serves as the lower limitation, while the also theoretical case that nobody is exposed by aircraft noise describes the upper limitation. Even if both limitations are never reached, nevertheless this approach will allow an absolute statement about the noise aspects performance of the investigated route. In this connection it is to be marked that the investigation area limitation shows another difficulty. Here it is recommended to select the spatial delimitation that all routes and procedures which can be potentially investigated lie within this investigation area.

It is decisively that the noise calculations are carried out in all cases for the complete airport (and all routes) and not only for the routes (or alternative routes) which will be investigated. To make an absolute statement about the noise load of the population the flight movements which use other routes than the investigated air route have to be included and are the background of this demand. A valid statement can only be made to the noise exposure load by the (logarithmic) addition of the noise which results from all movements. Even thought the relative difference between the investigated routes will be smaller by using this approach than by a direct comparison. This difference can be still shown afterwards with the absolute number of exposed people within the single contours.

5.3 Summary of the single criteria

To receive a single quality indicator for a investigated routes in the three areas Operational, capacity and environment, the single criteria which are ascertained before are summarised within the different categories. Possible trade-offs can be shown later with this delimitation more clearly and be valued finally within a complete consideration.

The overall assessment takes place even with the help of a standardised index. For each of three categories the index can adopt values between zero points (for unfavourable operational conditions, high environmental impact and small capacity) and 10 points (for the accordingly best conditions). By the introduction of such an index a comparison of different airports is possible among themselves, too, as long as the assessment takes place after the same procedure (standardised / absolute assessment, the same criteria, etc.).

5.4 Weighting of the criteria

Finally the weighting of three categories Operational, Capacity and Environment occurs among themselves as a essential point and leads at the end to an "Air Route Assessment Index" (AAI). The quantifier is to be formed variable to consider specific local conditions in the assessment process.

The basic idea of the weighting is the representation of three assessment categories in a three-dimensional space like Figure 5-10 shows. A cuboid whose volume is a quality measure of the investigated procedure originates from multiplication of three factors with each other. If one dimension is determined with zero points (exclusion criterion), this air route or this flight procedure will fail at the assessment, because the volume would be zero. The shown case assumes first that all three categories enter to the same degree into the assessment, i.e. no weighting of an aspect has still taken place.

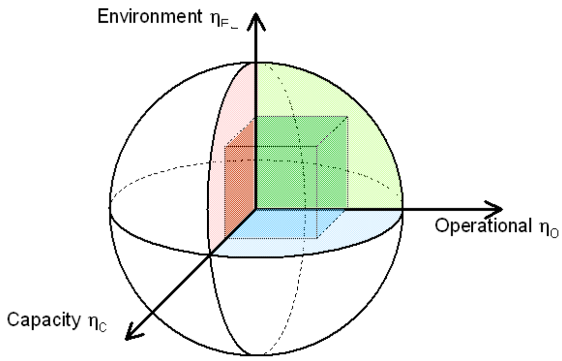


Figure 5-10: Representation of the weighting factors

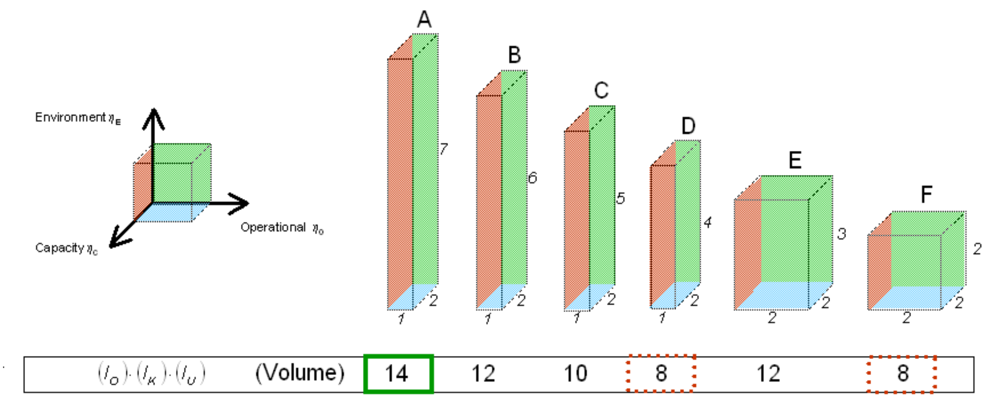


Figure 5-11: Exemplary weighting of the criteria

To consider local conditions by the assessment (e.g., especially noise-sensitive areas or considerable capacity problems of the airport), a weighting of the factors among themselves is necessary. Specifications by the development of the AAI were the transparency of the approach as well as the constant elasticity of substitution. The elasticity of substitution indicates how much the input dimensions can be substituted mutual with constant final result in the AAI, i.e. the relative amendment of a single index/criterion around x% can be compensated by a relative amendment of another single index around y%. E.g., the increase of the index I_n around x % leads to an increase of the FBI around η_n *x* %. First if all single indices are increased by 1%, the FBI will also increase by 1%. The equation which fulfils these conditions is the following:

$$AAI = (I_O)^{(\eta_O)} \cdot (I_C)^{(\eta_C)} \cdot (I_E)^{(\eta_E)} \qquad \text{with } (\eta_O)+(\eta_C)+(\eta_E)=1$$

Therefore, first the three categories are multiplied with each other in terms of a cuboid volume determination. In addition to carry out a corresponding weighting, a weighting "factor" which go into the assessment as an exponent is assigned to each of three categories. The sum of the three (weighting) exponents always has to be “1” to fulfil the requirement for the constant elasticity of substitution. If an exponent rises, at least one other exponent will be reduced to a lower value.

Finally, this approach provides an assessment index whose height delivers information about the quality of the respective air route or flight procedure. The procedure with the highest FBI is recommended for implementation.

CHAPTER 6 Exemplary use

6.1 General

The approach of the assessment procedures which was developed in this study for air routes and flight procedures is to be illustrated in the following chapters with the help of a practical example. For the example of use an extensive data set is available and used for an air route discussion of a Frankfurt/Main airport extension. Nevertheless, the results, are shown here, are not comparable with the official determinations caused by the adopted simplifications, the main concern of the calculations is the demonstration of the assessment procedure. The routes which are adducted for the comparison has been selected to show the procedure very clearly. Overall the three different departure routes TAB N, TAB G1 as well as TAB NEU (see Figure 6-1) which lie in the direction of north over TABUM are compared with each other.

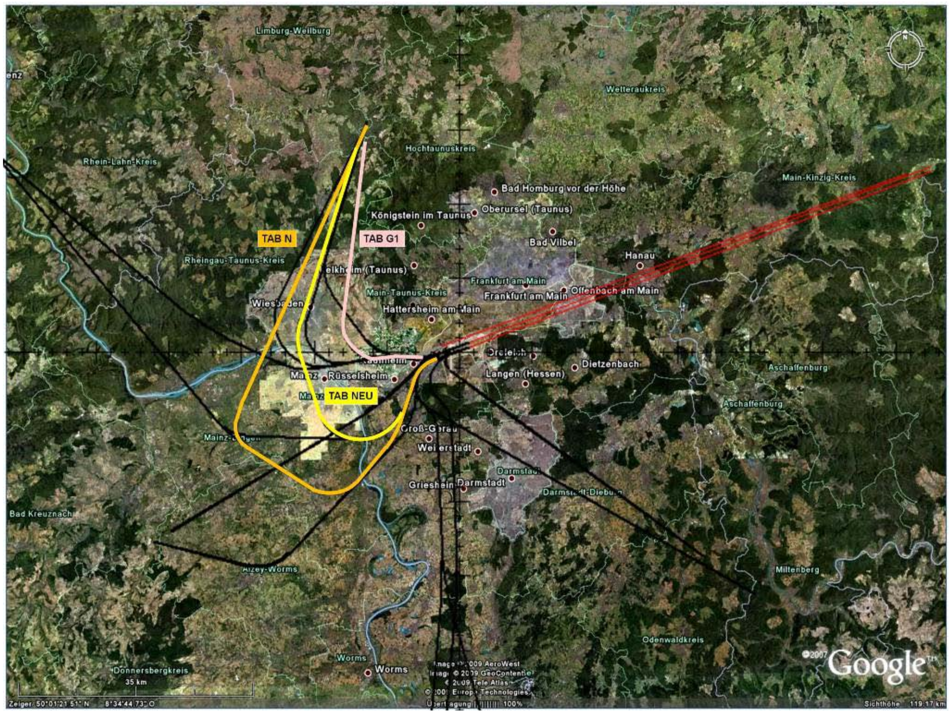


Figure 6-1: Representation of the exemplarily investigated route variants

6.2 Application of the criteria catalogue

6.2.1 General references

Chapter 4 describes that the framework of the assessment criteria can be adapted in each case to consider the local conditions why the criteria inclusion which is introduced in this study is only exemplary. The criteria catalogue can be reduced or added for a concrete application case.

In the example a locally adapted framework of criteria which describes the situation at the Frankfurt/Main airport is used. The exact definition of the criteria and whose later weighting have to arise from a comprehensive coordination process in which air traffic control, airport, airlines, municipalities and associations work together. The specification of the criteria catalogue is decisive to consider all interests of the involved parties as far as possible. In addition the flyability, the pilot's and controller workload as well as the passenger comfort were selected on the side of the operational criteria. In this study no differentiation into sub criteria takes place concerning the capacity. The environmental component differentiates between the pollution and the aircraft noise emissions (main focus in the investigation).

Because of the construction of the considered air route according to PANS-OPS, the flight safety does not take into as an exclusion criterion.

6.2.2 Operational criteria

Flyability

The flyability is subordinated for all route variants which are investigated here, because the statutory planning documents say that all routes correspond to the PANS-OPS-requirements as possible variants.

Within the scope of the assessment for the TABUM routes the DFS conducts investigations of the alternative procedures. These analyzes show that route variants which lie even more to the east as TAB G1 or the fox-trot-variants of the TABUM-routes (are also investigated by the DFS) are not compatible to the Frankfurt/Main air route system or possess a too high climb gradient. These variations will fail to the assessment or receive a lower score.

However, no differences exist concerning the flyability for three air routes considered here why all procedures receive the full number of 10 points (see Table 6-1).

Route	Description	Points [0-10]
TAB G1	No restrictions regarding fly-ability	10
TAB NEU	No restrictions regarding fly-ability	10
TAB N	No restrictions regarding fly-ability	10

Table 6-1: Assessment example flyability

Pilot's and controller workload

Concerning the pilot's workload it is to be supposed strong simplistically that the air route complexity is represented by the number of the curves. All three routes possess four changes of direction to the waypoint TABUM what would lead to an identical assessment. In addition the sequence of the actions is considered for a more differentiated assessment. Two of the investigated routes (TAB. N and TAB. G1) are shown as an extract from AIP Germany in Figure 6-3. The respective routes description is shown in Figure 6-2. But there are up to now no published maps for the investigated TAB NEU route.

MARUN 1N	**MARUN ONE NOVEMBER** On RWY track to 4.5 DME FFM or 800, whichever is later; LT (MAX IAS 220 KT until established on track 184°), on track 184° to intercept R223 FFM; on R223 FFM to 14.0 DME FFM; RT, on R302 RID to 16.0 DME RID; RT, on track 023° to TABUM; LT, on track 018° to LIKSI; LT, on track 016° via LORPA to MARUN (△). **GPS/FMS RNAV:** [A800+] - DF134 (25R)[L] / DF135 (25L)[L] - DF162 (25R)[K220-] / DF165 (25L)[K220-] - DF166[R] - DF164[R] - DF161[R] - TABUM[L] - LIKSI[L] - LORPA - MARUN.			After 16.0 DME RID BRNAV equipment necessary.
MARUN 1G	**MARUN ONE GOLF** On RWY track to 5.0 DME FFM or 800, whichever is later; RT MT 276° (RWY 25L: MT 279°) on R259 FFM to 3500; RT to TAU, but not before reaching R259 FFM; when passing 4400; RT to TABUM; on track 018° to LIKSI; LT, on track 016° via LORPA to MARUN (△).		Langen Radar 120.150*	After 4400 BRNAV equipment necessary.

Figure 6-2: Description of the SIDs for Frankfurt in AIP Germany

As shown in the air route description, the variants TAB.N and TAB.G1 may be used only by the aircrafts which dispose of an Area Navigation equipment/system (RNAV). Besides, both are formed similar complicated why they are assessed equivalent considering these aspects. Differences exist at most in the time component, because in comparison the necessary control inputs happen in a denser sequence by using the G-variant (TAB.G1) as by using the N-variant (TAB.N). Besides, the RNAV-ability is much later necessary in the N-variant than in the G-variant what is an indicator for the higher complexity of the g variant, too. Corresponding to the location of the route TAB.NEU (between the routes TAB.N, TAB.G) the complexity and the pilot's workload are assessed in the similar way.

Regarding the controller workload, no difference senses between three air routes. However, it has to be mentioned that DFS found by the assessment of the TABUM routes an expected confusion danger of one suggested variant why this variant was excluded.

Concerning the pilot's workload the preceding considerations show that the air routes differ slightly wherefore different scores were awarded (see Table 6-2). Because of the absence of relative values, which are the result from a workload and stress assessment (e.g. NASA-TLX), regarding to a possible assessment only assumptions are made in this example.

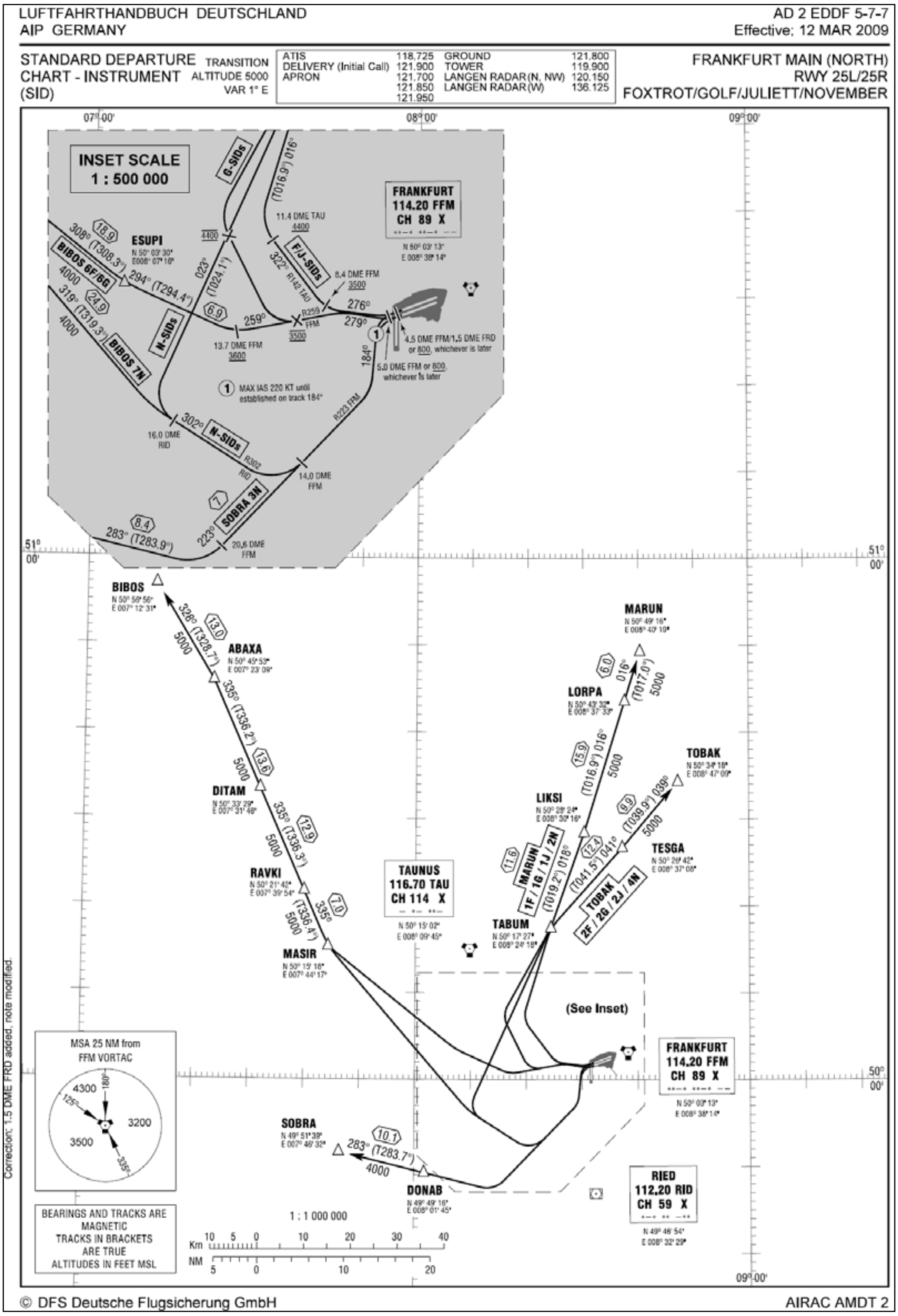


Figure 6-3: Extract from AIP Germany of the departure routes of Frankfurt (SID)

Route	Description	Score [0-10]
TAB G1	On account of the quick sequence of the necessary control inputs point deduction with the pilot's workload	6
TAB NEU	Average pilot's workload	7
TAB N	In the direct comparison of the variants the most favourable route but whose complexity leads, however, to a point deduction	8

Table 6-2: Assessment example pilot's workload and controller workload

Passenger comfort

The passenger comfort of the respective departure routes cannot be distinguished understandable because this area takes rather effect by the differentiation of vertical profiles. That is why all three routes are valued in this example with 10 points.

Route	Description	Score [0-10]
TAB G1	No recognizable restrictions in passenger comfort	10
TAB NEU	No recognizable restrictions in passenger comfort	10
TAB N	No recognizable restrictions in passenger comfort	10

Table 6-3: Assessment example passenger comfort

6.2.3 Capacity

Chapter 4 describes that a complex/costly calculation of the complete route system capacity is inevitably to assess the capacity aspect and to make a valid statement. E. g. it takes place through a simulation. Because of the scope of the present investigation no simulation can be performed, nevertheless in this study a qualitative evaluation is to be carried out.

With regard to the investigation of the TABUM routes by DFS it is to be marked that one of the suggested variants retired because of a too high climb gradient some aircraft types could not use them why capacity losses were feared.

Nevertheless, there are no restrictions of the investigated variants regarding the flyability and the linked flight-performance-related capacity losses. The only condition is the RNAV-ability wherefore no one of three routes is usable unconditionally. Hence, in view of the capacity aspect no differentiation of the routes is recognizable among themselves, but anyway a point deduction is necessary for this criterion.

Route	Description	Score [0-10]
TAB G1	Small restrictions due to necessary RNAV ability	8
TAB NEU	Small restrictions due to necessary RNAV ability	8
TAB N	Small restrictions due to necessary RNAV ability	8

Table 6-4: Assessment example capacity

6.2.4 Environment

6.2.4.1 Pollutant emissions/ immissions

An emission calculation which retires within the scope of the present investigation caused by cost reasons is necessary to make an exact statement about the pollutant emissions and the CO_2emissions by the air traffic on the considered route. Besides no differentiation is to be expected concerning the pollutant emissions which depends on charge state changes because the vertical profiles of the flight courses are very similar.

Simplifying in this example a differentiation of the routes is to take place among themselves with the help of the route length, because the variants differ significantly in this point. E. g. the length of the route TAB.G1 amounts to approx. 37 km, the route TAB NEU is approx. 74 km long and the route TAB. N is approx. 55 km long. Therefore a differentiation opportunity which is reflected in the following table arises for the kerosene consumption and the linked CO_2 emissions. The limit values, zero emissions for 10 points and the excess of legal limit values for 0 points, are not reached.

Route	Description	Score [0-10]
TAB G1	Length approx. 37 km	8
TAB NEU	Length approx. 55 km	7
TAB N	Length approx. 74 km	6

Table 6-5: Assessment example emissions

With the understanding that short distances should be covered for the minimisation of the pollutant emissions and the kerosene consumption, the variant TAB.G1 already shows an optimum. At this route it is flown shortly after lift-off/departure in the direction of the waypoint TABUM in which the three route alternatives meet again. However, detours are accepted for the routes TAB NEU and TAB.N.

6.2.4.2 Calculation of the aircraft noise immissions

In the assessment of air routes and flight procedures the main focus is on the detailed consideration of the aircraft noise effects. At first the noise-technical dimensions which play a role in the later assessment procedure are calculated in this study with the help of the noise calculation programme INM. The L_{DN} is calculated for the day to determine the HA-component of the Noise-Index, as well as the L_{Amax} is for the night to determine the HSD-component.

The aircraft noise calculations were conducted on the base of the air traffic forecast of 2020 at the Frankfurt/Main airport. Besides, the planned 4-runway system was assumed. Three investigated route variants were exemplarily selected because the following calculations provide the illustration of the route assessment procedure.

The aircraft noise calculations were enforced by including the topography of the relevant airport area. In return the data of the *National Geophysical Data Centre,* subordinated to the *US-American Department of Commerce,* which were freely available in a resolution of 1,000m x 1,000 m were updated. It was interpolated linearly for the model between the sampling points. A higher resolution which is commercially available makes sense, if an actual application is necessary. The topography, built into INM, is shown in Figure 6-4.

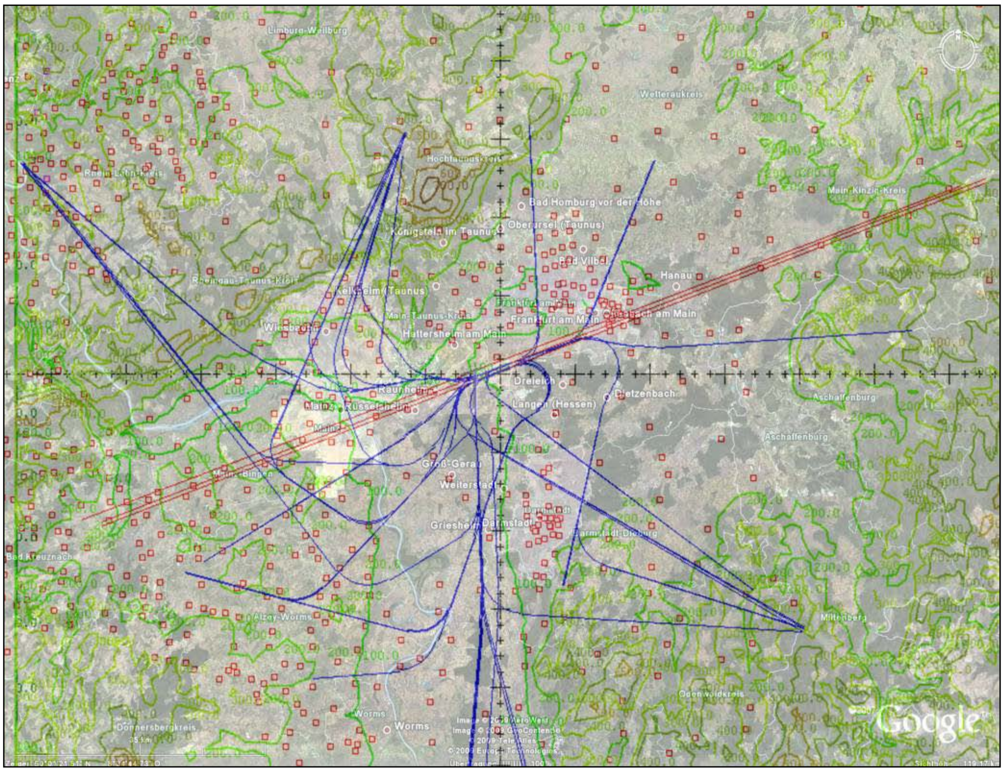


Figure 6-4: In the model deposited topography and population distribution

For the population figures which were entered for this study on the basis of the information of the statistical regional authorities as well as the municipality register of the Federal Statistical Office of Germany at local level it is applying the same. Here a more precise resolution can be acquired commercially, too. A resolution at district level was evaluated on the base by information of the municipalities accordingly for urban agglomerations that a differentiation opportunity of the numbers of exposed people has arisen for the investigated routes. The population figures are given in INM as so-called *Population Points* with which population figures are assigned certain geographical co-ordinates. The population points which are given in the model are also shown in Figure 6-4.

The aircraft noise calculations were carried out on this data base. The load (flight movements) which is deposited in the planning flight plan of the route TAB NEU was moved in each case to the both alternative routes for the differentiation of the variants among themselves, while the others which were not in the investigation focus were also calculated with the same load in all three scenarios to achieve the complete noise load. Therefore it is assured that the differences of the numbers of exposed people are to be led back really on the applied load of three investigated routes and not on their horizontal or vertical profile which perhaps covers a bigger surface.

6.2.4.3 Calculation of the HA component

The L_{eq16} which considers at 16-h-day is used for the calculation of the HA component of the ZFI. In addition, the day edge hours are added with a penalty of 5 dB to give particular weight to these especially sensitive times in the ZFI. However, in general the HA-component calculation, base on dose-effect relationship, takes place with the help of the L_{DN}. Hence within the scope of the practical application for the Frankfurt example it was also used the L_{DN} as base which was calculated with the help of the INM.

The results of the calculations are shown in Figure 6-5 to Figure 6-7. The differences of the variants are seen clearly in the northwest area of the airport.

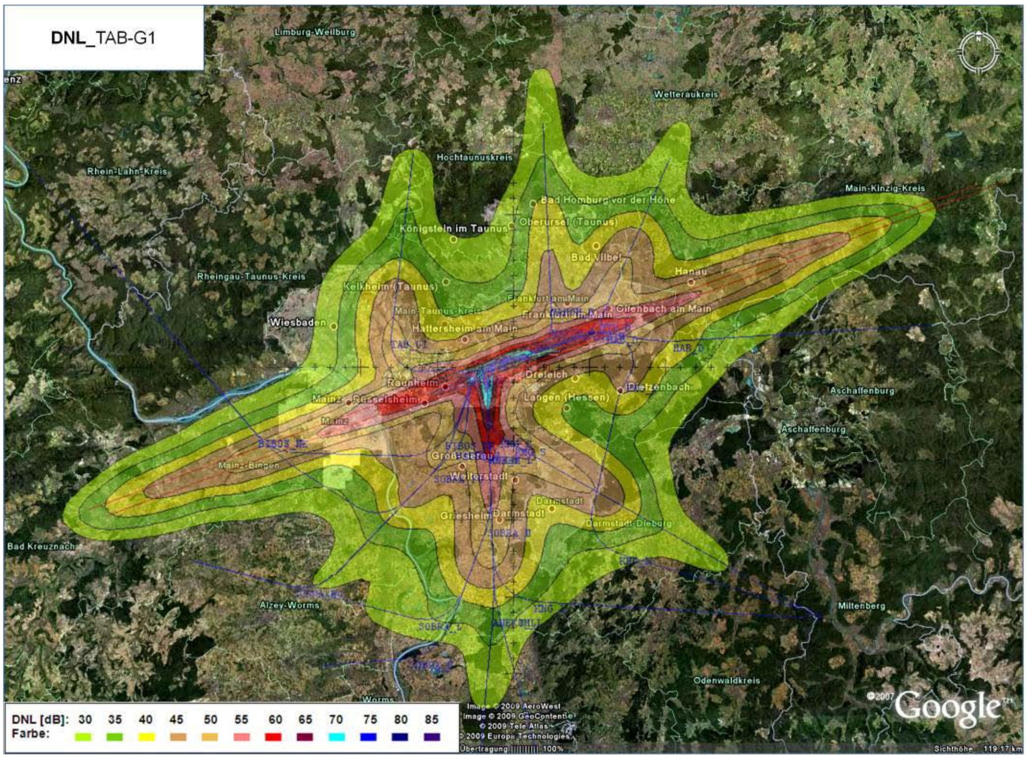


Figure 6-5: L_{DN} contours for the route variant TAB. G1

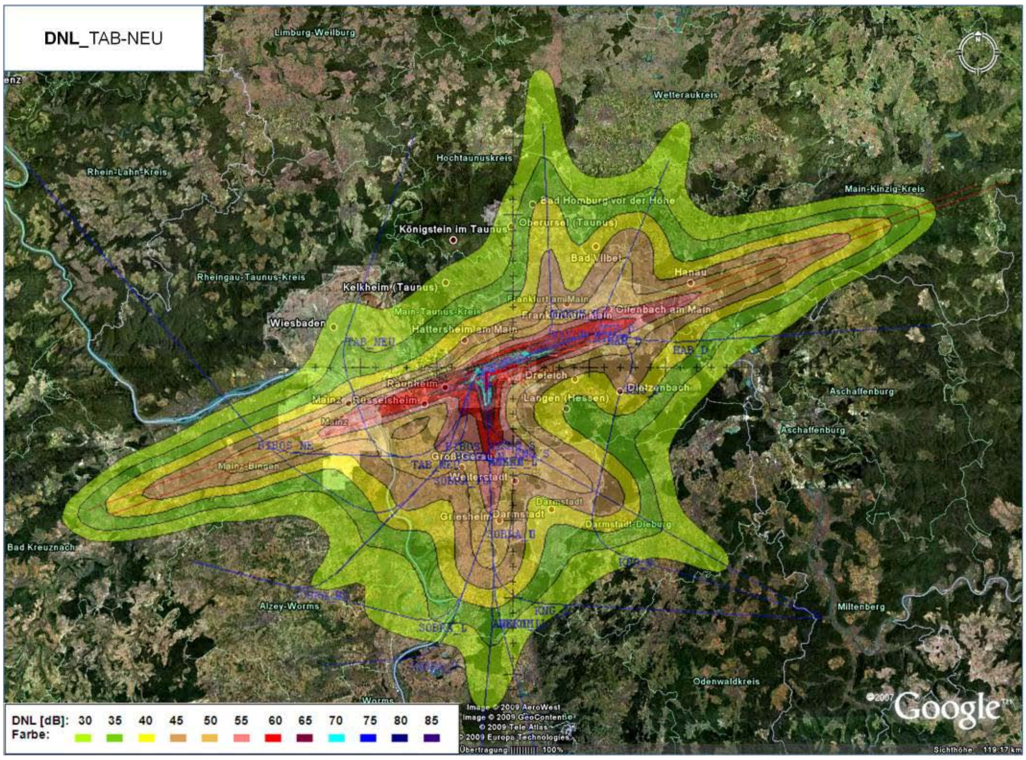


Figure 6-6: L_{DN} Contours for the route variant TAB NEU

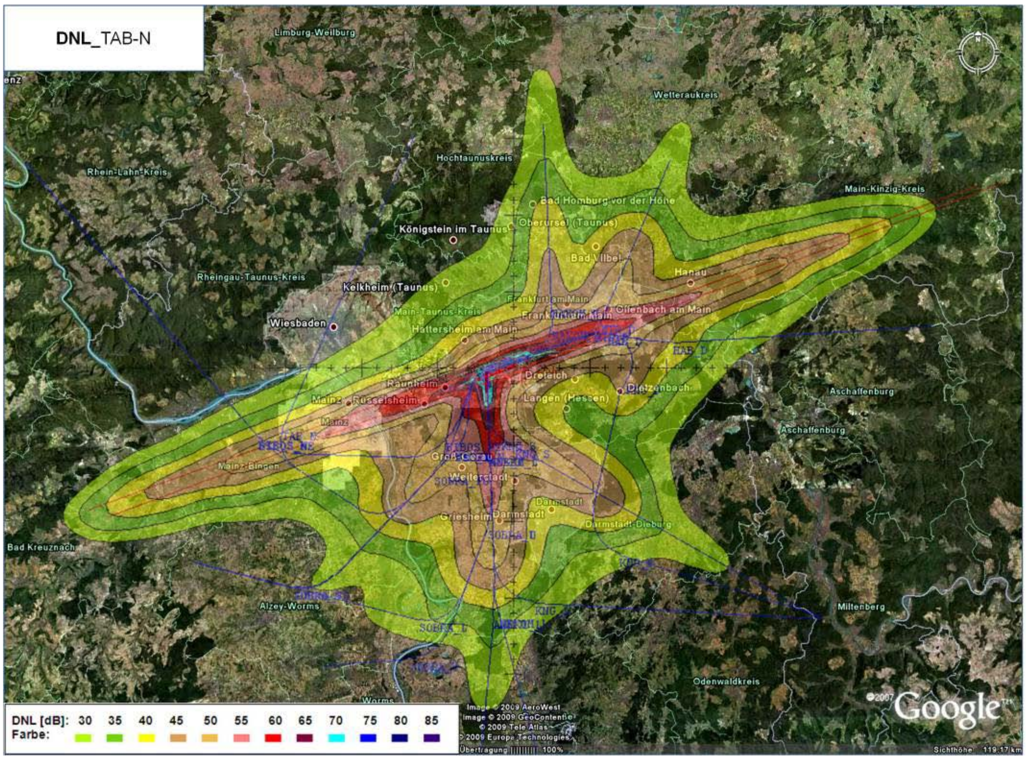


Figure 6-7: L_{DN} Contours for the route variant TAB. N

Afterwards to determine the numbers of exposed persons within the contours the ascertained noise contours were overlaid with the population figures which are deposited in the model as the *Population Points* (see Figure 6-4). The result, shown in Table 6-6, was proved by the analysis. In addition, the surface data of the aircraft noise contours are shown here.

L_{DN} (dB)	TAB G1 - Use		TAB NEU - Use		TAB N - Use	
	POPULATION	SQ.KM	POPULATION	SQ.KM	POPULATION	SQ.KM
<30.0	625.700	894	635.940	854	566.800	820
30.0-35.0	530.940	632	540.710	599	501.950	590
35.0-40.0	726.970	564	648.350	518	669.160	520
40.0-45.0	427.244	498	423.440	435	394.819	455
45.0-50.0	458.015	316	420.461	318	425.277	310
50.0-55.0	106.523	132	131.821	133	150.546	131
55.0-60.0	102.328	65	102.328	67	102.328	68
60.0-65.0	20.320	28	20.320	28	20.320	28
65.0-70.0	0	10	0	10	0	10
70.0-75.0	0	6	0	6	0	6
75.0-80.0	0	2	0	2	0	2
80.0-85.0	0	1	0	1	0	1

Table 6-6: Result table L_{DN} [dB]

The number of the strongly affected persons was determined on the base of the population figures within the noise contours in the connection with the help of the dose-effect relationship, introduced in Chapter 5:

$$\%HA = 2{,}18 \cdot L_{DN}[dB] - 91$$

With the help of the preceding equation first it was determined the numbers of exposed persons for each of the calculated aircraft noise contours which then were added up. So the figures of the strongly affected persons which are shown exemplarily in the following table by 5 dB steps arise for three routes. However, the calculations were accomplished with an exactness of 1-dB steps to cope with the abort criterion from >47dB of the HA-component. Overall it has to be marked that the exactness of the results is strongly dependent on the exactness of the population figures why in view of the numbers of exposed people isophons with a higher resolution are not achieved a higher exactness.

Route	HA-Component [EW]
TAB G1	194.591
TAB NEU	194.872
TAB N	199.119

Table 6-7: Assessment HA component

The relevant figures in Table 6-7 show that the route TAB.G1 is slightly better than TAB NEU by an assessment of the strongly affected persons during the day. The gap to route TAB.N is accordingly a little bit bigger. However, a comparison of the absolute figures in Table 6-6 indicates clearly that the biggest differences between the routes can be found in the range below 45 dB (L_{DN}). This band does not incorporate into the assessment, because by the definition of the transfer function noise levels above 47 dB are only embraced.

Anyway this differentiated representation of noise levels below the assessment threshold allows a comprehensive assessment of the number of new exposed people. This fact is demanded over and over again in numerous discussions.

6.2.4.4 Calculation of the HSD component

Base for the determination of the wake up reactions at night first is the determination of the L_{Amax}. The results of these calculations are shown in Figure 6-8 to Figure 6-10.

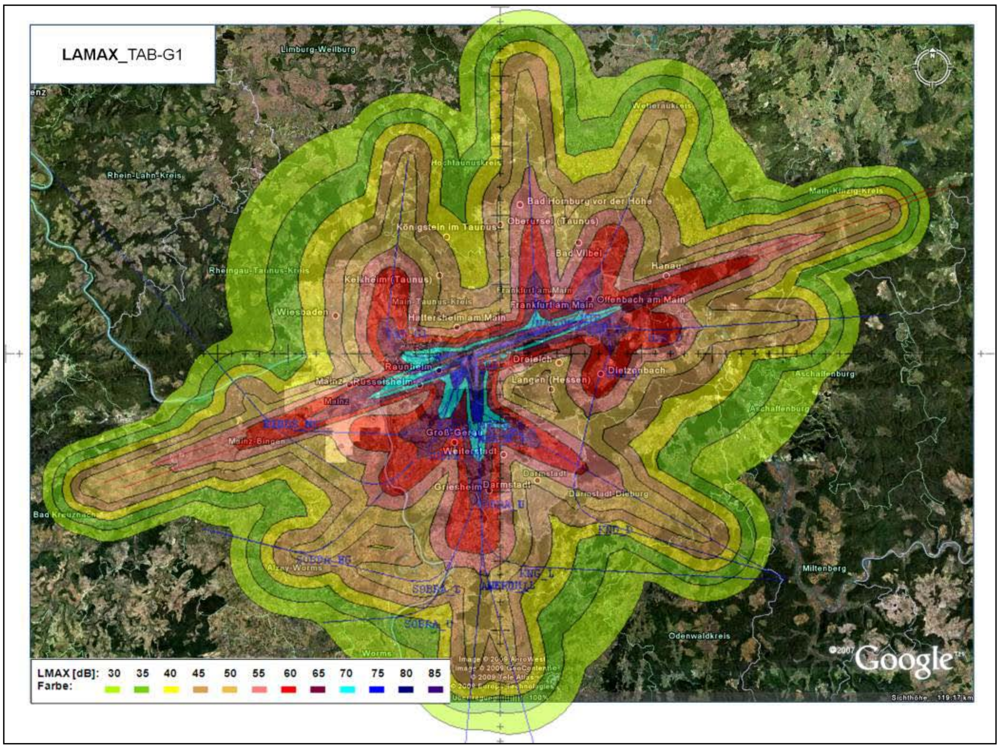


Figure 6-8: L_{Amax} *contours for the route variant TAB. G1*

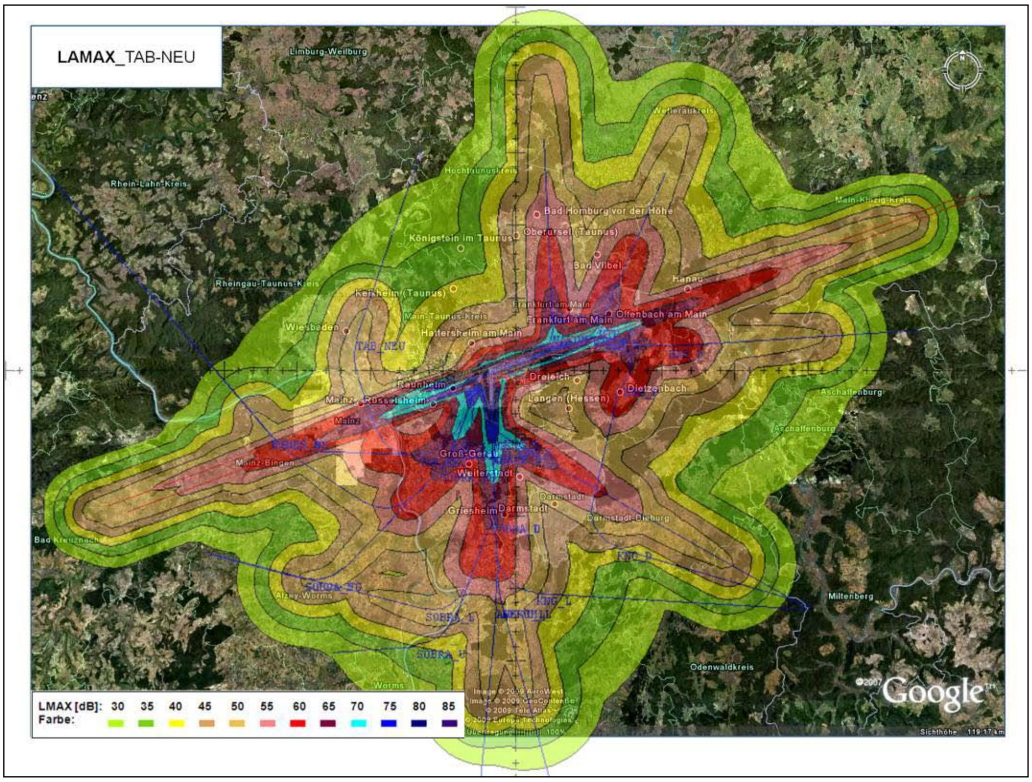


Figure 6-9: L_{Ama} *contours for the route variant TAB NEU*

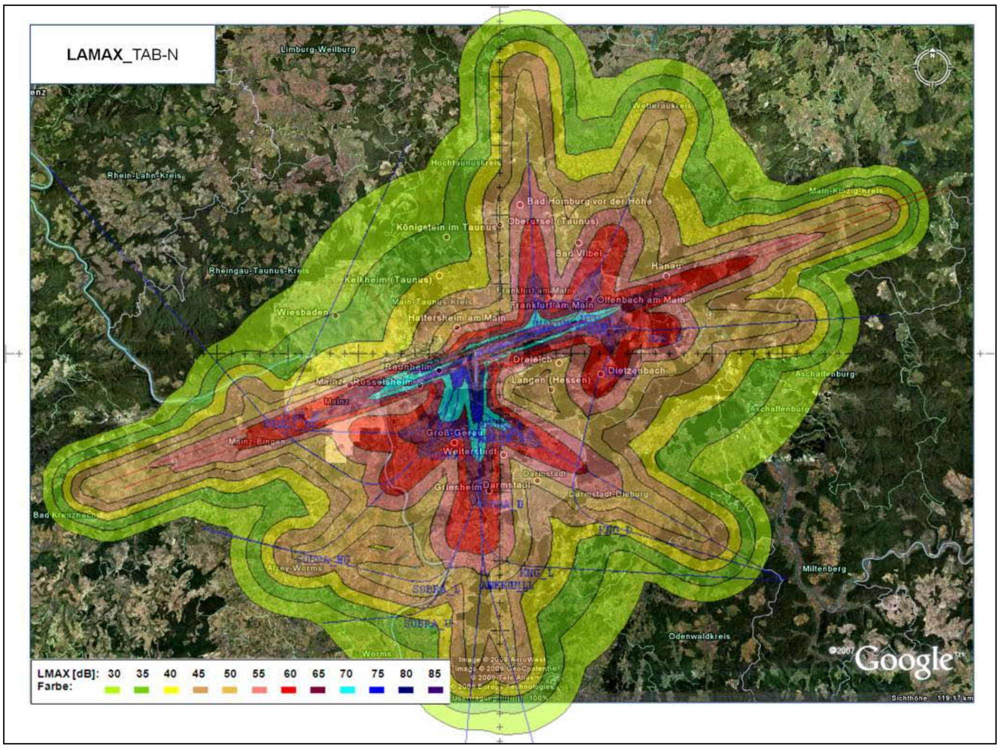


Figure 6-10: *L_{Amax} contours for the route variant TAB. N*

The values which are shown in Table 6-8 are the summarised tabular form of the population figures within the L_{Amax}-contours in which the corresponding level appears arise at least one time. 5-dB-level classes are designated in the table, while the number of the respective maximum levels in 1-dB-level classes is evaluated for the HSD-determination. Moreover, the surface data of the respective contours are also registered.

Now the equation to the determination of the HSD component which was described in Chapter 5 is applied to the shown values.

L_{Amax} (dB)	TAB G1 - Use		TAB NEU - Use		TAB N - Use	
	POPULATION	SQ.KM	POPULATION	SQ.KM	POPULATION	SQ.KM
30.0	340.410	1.086	331.400	1.065	453.270	1.117
35.0	273.070	938	285.060	893	354.550	928
40.0	555.280	845	463.280	801	438.100	780
45.0	505.800	904	599.290	842	469.180	800
50.0	828.180	984	749.840	923	713.770	886
55.0	523.208	555	495.538	501	504.357	504
60.0	559.047	486	553.834	442	545.015	437
65.0	222.989	208	217.982	187	217.982	185
70.0	129.536	85	129.536	75	129.536	79
75.0	218	32	218	30	218	31
80.0	20.102	15	20.102	15	20.102	15
85.0	0	16	0	16	0	16

Table 6-8: Result table L_{Amax} [dB]

The HSD-component depends not only on the L_{Amax}, but also on the number of the overflights which cause the corresponding maximum level. Outside sound levels of more than 50 dB are only relevant by underlying the contexts of the dose-effect relationship for the night between maximum level and the wake-up-reactions. Within the scope of the study the following numbers of inhabitants, feel disturbed at night strongly in the sleep and shown in Table 6-9 were arisen by the simplistic application of the transfer function for a flight movement of the maximum level in the night time.

Route	HSD-Component [EW]
TAB G1	38.154
TAB NEU	37.188
TAB N	36.955

Table 6-9: Assessment HSD component

6.2.4.5 Determination of the aircraft noise index

With application of the equation for the ZFI and concurrent determination of both components for the day and night the assessment results by a simple addition of both partial indices. This addition proves the values shown in Table 6-10 as well as their possible transference in the standardised scale.

Route	Description	Score [1-10]
TAB G1	HA + HSD = 232.745 (corresponds to a part in the total population (>47 dB) from 33.87%)	7
TAB NEU	HA + HSD = 232.060 (corresponds to a part in the total population (> 47 dB) from 33.77%)	8
TAB N	HA + HSD = 236.074 (corresponds to a part in the total population (> 47 dB) from 34.35%)	4

Table 6-10: Assessment example noise

The route TAB NEU has the fewest affected person number when the route TAB.G1 shows only a slight difference of affected persons. The TAB.N-route has the slightest HSD-component, but it comes off badly in view of the complete consideration because this route has more than 4,000 exposed persons more. The route TAB NEU will be recommended under noise aspects if no subdivision of the flight movements on different routes in dependence of the time of day- and nighttimes is possible.

Then the limitations between 0 and 10 points will be presented themselves that no exposed person addicts 10 points and 100% exposed people (of the inhabitants) arises 0 points. The difficulty with this approach consists accordingly in separating the investigation area. Within the scope of the present investigation the solution proposal is assumed from the fact that the basic set (100% of the population is determined in the investigation area) affects by the number of people which are put out to a L_{DN} by more than 47 dB. 47 dB shows the abort criterion for the determination of the HA component. It would correspond in this case to 687.186 people.

6.3 Application of the assessment procedure

A complete assessment is carried out finally on the basis of the determined partial evaluations. At this point a clear approach which is conformist on local conditions is necessary. The summarised results of the partial evaluations are shown in the following table

Single criterion	TAB G1	TAB NEU	TAB N
Operational			
Flyability	10	10	10
Pilot's and controller workload	6	7	8
Passenger comfort	10	10	10
Capacity			
Capacity	8	8	8
Environment			
Pollutant emissions	8	7	6
Noise	7	8	4

Table 6-11: Summary of the single criteria

At first it is the matter to find from these single criteria an assessment criterion within the respective categories Operational, Capacity and Environment. For this, assumptions about the weighting which consider local conditions accordingly have to be hit in each case. The weighting within the categories enforces with the help of the following table which bases on an appraisal of the relevance by the authors of the present study. Because of this, the weighting is not transferable easily on other application cases, because the result determination should also be a result of a coordination process between the different involved parties.

Single criterion	Weighting factor [%]
Operational	
Flyability	80
Pilot's and controller workload	15
Passenger comfort	5
Capacity	
Capacity	100
Environment	
Pollutant emissions	10
Noise	90

Table 6-12: Used weighting factors within three criterion categories

The following shown values addicts for these route variants on the basis of the weighting within the three categories Operational, Capacity and Environment:

Criterion	TAB G1	TAB NEU	TAB N
Operational (I_O)	9,40	9,55	9,70
Capacity (I_K)	8,00	8,00	8,00
Environment (I_U)	7,30	8,00	4,20

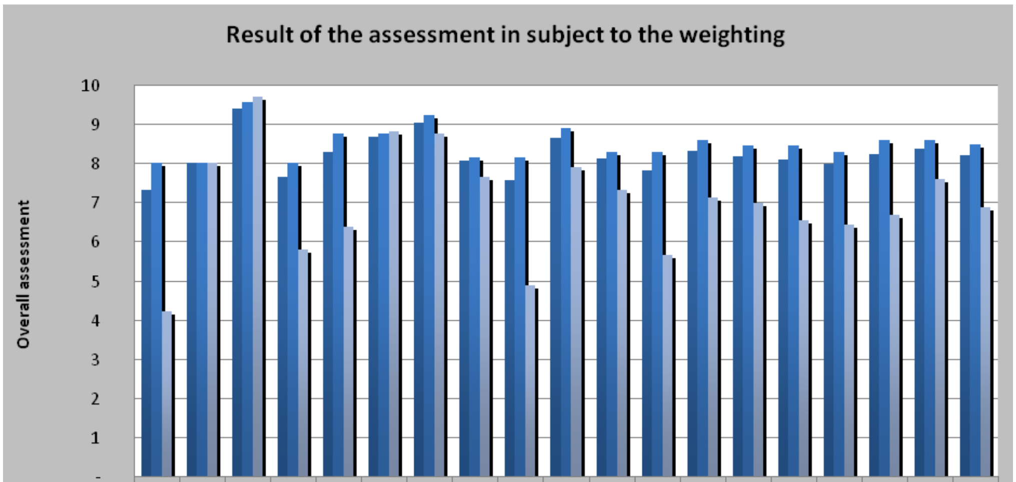
Table 6-13: Assessment examples of the criterion categories

The assessments, shown in Table 6-13, assume into the determination of the Air Route Assessment Index (AAI). Caused by that, the product from the respective sub-ranges is established. In addition, the categories are weighted among themselves with the help of the exponents as the equation of the AAI points:

$$AAI = (I_O)^{(\eta_O)} \cdot (I_C)^{(\eta_C)} \cdot (I_E)^{(\eta_E)} \qquad \text{with } (\eta_O)+(\eta_C)+(\eta_E)=1$$

The respective exponents which are selected for the weighting of three categories among themselves are also the object of the coordination process of the involved parties. In any case, it is advisable to addict a sensitivity analysis to understand better the influence of different weightings on the final assessment result. In general it is advisable to show clearly all partial steps in the calculation, too. This measure is to make known the direct effects which result from amendments in the data base or in the weighting.

Such an analysis is shown exemplarily in Figure 6-11. Every group of bars represents another distribution of the weightings between operational aspects, capacity and environmental concerns. Every colour corresponds to one of the investigated routes. It has to be recognised that the weighting plays only one minor part in the selected example, because at the route TAB NEU receives the most points. Only in case of an extreme weighting (e.g., exclusive consideration of operational criteria) an other routes gets the highest score. This trend says that the route TAB NEU corresponds best in all aspects with the demands, even with different weightings. For these reasons an implementation recommendation is pronounced for this route in the illustrated example.



η	1,0	-	-	0,5	0,5	-	0,1	0,1	0,8	0,2	0,2	0,6	0,3	0,3	0,4	0,4	0,4	0,2	0,3
υ	-	1,0	-	0,5	-	0,5	0,1	0,8	0,1	0,2	0,6	0,2	0,3	0,4	0,3	0,4	0,2	0,4	0,3
η	-	-	1,0	-	0,5	0,5	0,8	0,1	0,1	0,6	0,2	0,2	0,4	0,3	0,3	0,2	0,4	0,4	0,3
TAB G1	7,30	8,00	9,40	7,64	8,28	8,67	9,02	8,06	7,56	8,65	8,11	7,82	8,30	8,17	8,09	7,97	8,23	8,38	8,19
TAB NEU	8,00	8,00	9,55	8,00	8,74	8,74	9,22	8,14	8,14	8,90	8,29	8,29	8,59	8,44	8,44	8,29	8,59	8,59	8,49
TAB N	4,20	8,00	9,70	5,80	6,38	8,81	8,75	7,65	4,87	7,89	7,31	5,65	7,12	6,99	6,55	6,43	6,68	7,60	6,88

Figure 6-11: Result of the assessment in dependence of the weighting

CHAPTER 7 Summary

For the improvement of the aircraft noise situation it was determined in 2007 by an amendment §32 of the air traffic act that the Federal Environment Agency is to be involved with the definition by air routes and flight procedures. Presently the assessment of proposals for the amendment of air routes rests primarily on operational criteria relevant for safety. Low transparency of the assessment procedure and insufficient consideration of the noise prevention was criticised during the last years by the aircraft noise affected persons. Within the scope of this study a proposal should be worked out for an improved assessment procedure which takes into account for these criticism points.

First it is entered in the study on the legal bases and the present procedure to the definition by air routes and flight procedures. Besides, the involved stakeholders are as introduced as case studies to make clear the actual activities and judgments. Approach and departure procedure and their potential to the decrease of aircraft noise are explained and an insight into the actual assessment criteria and assessment procedures is given. A comparative analysis of internationally approved assessment procedures provides to the determination of *Best of all Practice-examples*. Besides, actual trends and developments are included in the study.

Main focus of this study is the determination of a criteria catalogue which unites the different capacitive environment-related and operational aspects. In the developed 5-phase model for the assessment of air routes an unequivocal definition of the criteria is met. The quantitative classification and standardisation of the aspects is vital to guarantee an objective assessment. The assessment method based on the Zurich aircraft noise index. Finally the practical application is explained with the help of an example.

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