

Final report

Public

SOURDINE

PL97-3043

Project

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1. Introduction

1.1. Purpose

The Commission of the European Communities (CEC), through the contracts placed to date under the ECARDA initiative within the 4th Framework Programme, has launched a number of tasks dedicated to the definition and development of many of the building blocks of a European Air Traffic Management System (EATMS). The additional set of tasks released on 16 December 1997 included tasks to prepare future transport RTD activities. In particular, task 12.5 was to "develop and assess noise abatement procedures in air transport to determine their contribution to reducing environment impact".

Within the context of task 12.5, the Sourdine project was conceived as the first step in an overall noise abatement procedure definition and validation process, which was to be pursued in the 5th Framework Programme.

The Sourdine project (Study of **Optimisation procedURes for Decreasing the Impact of NoisE** around airports, French word for *mute*) aims at defining new procedures leading to the reduction of noise in the airport vicinity and the requirements for supporting tools.

This document is the project's final report, which encompasses three main parts:

- an administrative view of the project which comprises an executive summary (see §2), a context description (see §3), details on the approach used (see §4), the dissemination actions performed (see §5.6) and a contact list (see §7);
- a technical summary of the previously edited interim reports (see §5.1 through to §5.4);
- a cost-benefit analysis (see §5.5).

The report concludes on future plans (see §6).

1.2. Intended audience

This document is open to all public.

1.3. Associated documentation

1.3.1. Internal documentation

<i>SOURDINE</i>	<i>CEC contract and its annexes (Technical Annex and General conditions), December 98</i>
<i>SOURDINE/ISR-W6-MGT-001</i>	<i>Project handbook, Stéphane Paul, December 98</i>
<i>SOURDINE/ISR-W6-MGT-002</i>	<i>Document identification and presentation guidelines, Stéphane Paul, December 98</i>
<i>SOURDINE/ISR-W6-MGT-003</i>	<i>Project management manual, Stéphane Paul, December 98</i>
<i>SOURDINE/ISR-W6-MGT-004</i>	<i>Project summary, December 98</i>

- SOURDINE/AENA-DOC-D1-001 Environment Requirements and Operational Constraints, Marife Anton Cruz et al., February 99 - new release in February 2000*
- SOURDINE/ASP-DOC-D2-001 Study of key elements acting on noise impact of aircraft in operation, Bernard Coignus et al., June 99*
- SOURDINE/NLR-DOC-D3-001 Establishment of Noise Abatement Solutions, Robert J. de Muijnck et al., May 2000*
- SOURDINE/ISR-DOC-D4-011 Requirements for tools, Jean-Yves Vocisano et al., May 2000*

1.3.2. External documentation

- [DLR] Cost/Benefit studies within the framework of Airport and Airspace Capacity investigations, Dipl. Ing. Thorsten Flache, October 1999.*
- [EATCHIP 1] EATCHIP (European ATC Harmonization and Integration Programme) – Guidelines for the economic appraisal of the EATCHIP projects – The effective use of Cost/Benefit studies, Edition 1.2 - August 1996.*
- [EATCHIP 2] EATCHIP Overall Cost/Benefit Scoping Study, Version 1.3 – November 1998.*
- [EATCHIP 3] EATCHIP Policy Support Bureau, Cost Database (Studies), Edition 1.0 - August 1998.*
- [EATCHIP 4] EATCHIP ATM Strategy for 2000+, Eurocontrol.*
- [ENHANCE] ENHANCE – European Harmonised Aircraft Noise Contour Modelling Environment - Project Charter, Eurocontrol, IG01 Edition 0.1 Effective Date 21-APR-99.*
- [NASA] Modelling Research under NASA/AATT – Final Report, Existing and Required Modelling Capabilities for evaluating ATM Systems and Concepts, A. Odoni et al., March 1997.*

1.4. Acronyms

AATT	Advanced Air Traffic Technologies initiative
A-CDA	Advanced CDA
ACI	Airports Council International
ACMS	Aircraft Condition Monitoring System
AEA	Association of European Airlines
AENA	Aeropuertos Españoles y Navegacion Aerea
AMAN	Arrival Manager
APAS	Accompanying, Promotion And Support (measures)
A-SMGCS	Advanced Surface Movement Guidance and Control
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATF	Aeronautics Task Force
ATM	Air Traffic Management
CAA	Civil Aviation Authority
CAEP	Committee for Aviation Environmental Protection
CBA	Cost Benefit Analysis
CDA	Continuous Descent Approach
CEC	Commission of the European Communities

CNS	Communication, Navigation and Surveillance
DANSIM	Danish Airport Noise Simulation Model
DERA	Defence Evaluation & Research Agency
DG	Directorate General
DME	Distance Measurement Equipment
EATCHIP	European ATC Harmonization and Integration Programme
EATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference (or Community)
ECARDA	European Coherent Approach to RTD in Air Traffic management
EPNL	Effective Perceived Noise Level
FAA	Federal Aviation Administration
FANPAC	Fan Noise Prediction and Control
FMS	Flight Management System
ft	foot, feet
FWP	FrameWork Programme
GNSS	Global Navigation Satellite System
HBR	High Bypass Ratio
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
INECO	Ingeniería y Economía del Transporte
INM	Integrated Noise Model
JAA	Joint Aviation Authorities
kt, kts	knot, knots
LBPR	Low Bypass Ratio
LLZ	LocaLiZer
MLS	Microwave Landing System
NAP	Noise Abatement Procedure
NASA	National Aeronautics and Space Administration
NLCP	Noise Level Computation Program
NLR	National Aerospace Laboratory
NPD	Noise-Power-Distance
PAPI	Precision Approach Path Indicator
P-RNAV	Precise RNAV
RLD	RijksLuchtvaartDienst
RNAV	Area Navigation
RNP	Required Navigation Performance
RTD	Research and Technological Development
SEL	Sound Exposure Level
SICTA	Sistemi Innovativi per il Controllo del Traffico Aereo
SOURDINE	Study of Optimisation procedURes for Decreasing the Impact of NoisE around airports
TEFA	The Environmentally Friendly Aircraft
TTA	Target Time of Arrival
TWR	ToWeR

2. Executive summary

This summary has a public level of dissemination and can be published.

Do note that a small glossy was also published. A copy can be obtained at DERA (Richard Pinker) or CEC (Christopher North).

The Sourdine project (Study of Optimisation procedURes for Decreasing the Impact of NoisE around airports) aims at defining new procedures leading to the reduction of noise in the airport vicinity and the requirements for supporting tools.

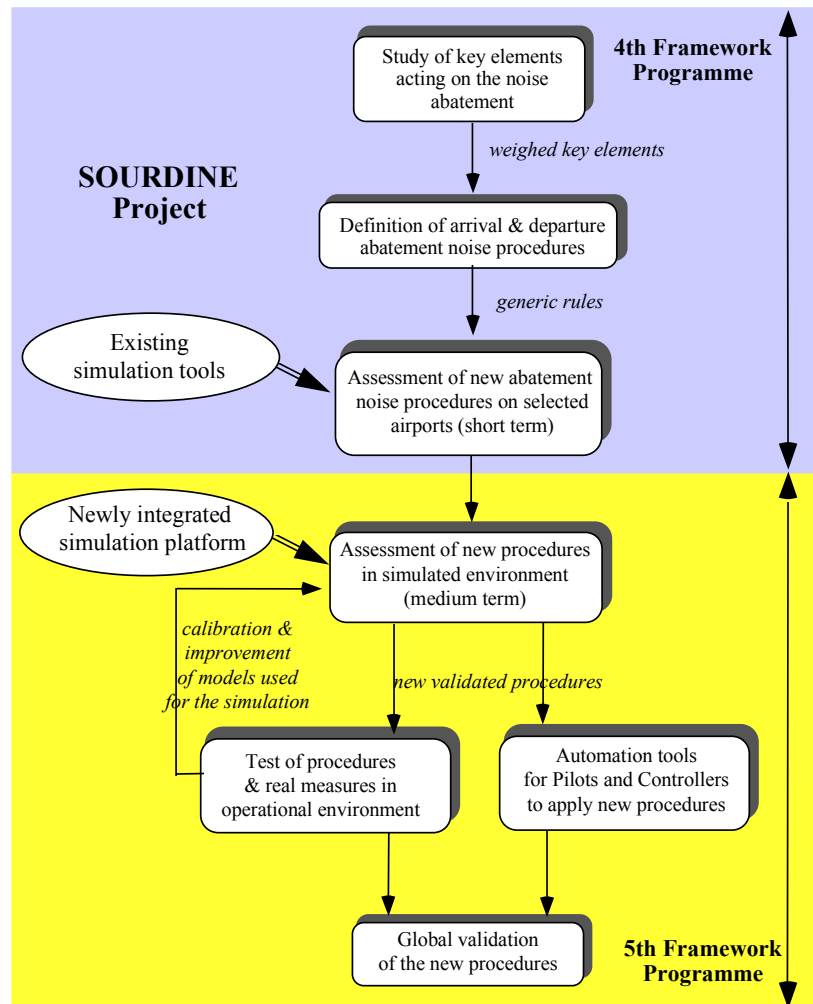
Setting the scene

Since the entry into service of the jet transport aircraft at the end of 1950's, the increased number of flights in and out of airports and the increased density of the urbanisation have given rise to much greater intrusion of aircraft noise on community life and hence to noise exposure. Community noise is today cited as a major problem to be solved by the aircraft transport industry if its current growth is to be pursued.

Approach

The Sourdine project is the first step towards the definition, validation and use of noise abatement procedures, emphasising on new arrival and departure procedures (see figure). It has the following objectives:

- Study alternatives to reduce noise levels around airports, by:
 - elaborating generic rules for updating the existing approach and take-off procedures for short-term improvement applicable to most of the existing aircraft,
 - investigating new procedures taking benefit from new airborne and ground technologies;
- Apply those rules to define new procedures for three selected airports (Schiphol, Madrid and Napoli), considering the feasibility of such procedures, and provide qualitative effects in noise reduction;
- Identify the simulation tools aiming at carrying out the operational validation of the procedures within the scope of the 5th FWP.



Noise abatement procedure methodology

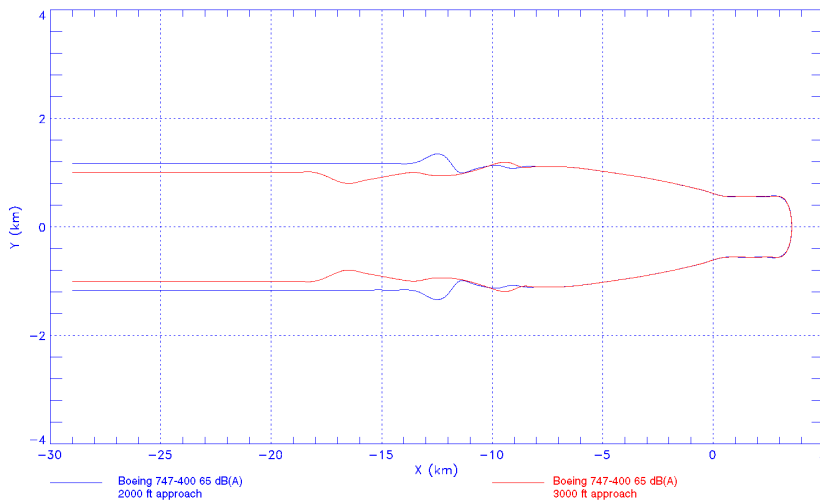
Results

An inventory of the current regulations and practices concerning aircraft noise, and their evolution has been performed together with a study of the operational, safety, capacity and economical constraints that might influence the definition of new procedures. The inventory is available in a public document called "Environment requirements and operational constraints".

In a second step, five existing noise models have been described.

The different characteristics of the observed models led to the following choices:

- the Airbus NLCP model for vertical procedure optimisation of aircraft departure and arrival flight paths, single event benefit analysis, and horizontal procedure optimisation of departures;
- the INM or Kosten unit / Laeq models to carry out noise level assessment from the above optimised departure and arrival flight paths, and for horizontal analysis of aircraft arrival flight paths and global noise exposure benefit for a given airport.



Single event 65dBa footprint, B747-400, 2000 vs. 3000ft glide slope intercept altitude

The above descriptions, together with the key elements drawing up, are detailed in a public document called "Study of key elements acting on noise impact of aircraft in operation". In particular, a variation of the following parameters was proposed:

- take-off configuration and speed, looking for a better climb gradient;
- thrust reduction height marking the initiation of the noise abatement phase;
- climb thrust;
- acceleration height to en-route climb speed, and retraction of slats / flaps configuration;
- combination of high speed / low slats / flaps setting flight path;
- execution of a two segments approach, the first with a glide path higher than 3 degrees, the second with the normal value of 3 degrees.

In a third step, noise abatement procedures have been selected and assessed for short-term and medium-term. For the short-term, the selected noise abatement procedures were:

- an increased glide slope intercept altitude,
- a reduced landing flap setting,
- a lower final stabilisation altitude,

- an optimised take-off procedure,
- a continuous descent approach procedure.

For the long-term, the selected noise abatement procedures were:

- a continuous descent approach in an advanced application retaining normal landing capacity,
- a dual landing threshold,
- an accurate RNAV based routing,
- an increased glide slope angle.

The short-term solutions were assessed for the Amsterdam, Madrid and Napoli airports. The results are detailed in a public document called "Establishment of Noise Abatement Solutions".

In parallel, the tools required to support the new procedures in terms of environment simulation, measurement tools and automation tools assisting the end-users have been studied. The study includes a survey and evaluation of the existing tools.

Finally, the elaboration of the conclusions of the Sourdine project, including the cost / benefit analysis, the final report and the dissemination have been addressed, notably through a workshop.

Conclusion & future work

The consortium has defined requirements, achieved critical investigation about noise modelling, established and evaluated a number of potential noise abatement procedures, specified simulation tools and assessed cost / benefits of promising procedures. The results of this pilot phase should be used to define which of the considered operational procedures will be worth pursuing in a further phase included in the 5th Framework.

Such decision should be based on criteria of predicted aircraft noise impact reduction or traded airport capacity increase, but also relative to feasibility and anticipated costs of their application in connection with safety and air traffic control issues, need for ground and airborne system developments...

Contact details

Sourdine / DG VII - Transport
Time scale: 01.12.98 - 30.04.00
Overall cost: 1 MECU
EC contribution: 0.5 MECU
Keywords: transport, airport, noise, procedures, environment

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3. Setting the scene

Since the entry into service of the jet transport aircraft at the end of 1950's, the increased number of flights in and out of airports and the increased density of the urbanisation have given rise to much greater intrusion of aircraft noise on community life and hence to noise exposure. Community noise is today cited as a major problem to be solved by the aircraft transport industry if its current growth is to be pursued.

International standards governing the noise of newly manufactured aircraft have been developed by ICAO (International Civil Aviation Organisation). The current standards, originated in 1977, are contained in Chapter 3 of the annex 16 to the convention on International Civil Aviation. Since 1991 a major review has been undertaken within the ICAO Committee for Aviation Environmental Protection (CAEP) which will eventually lead to the application of more performing stringent noise limits. In addition, recommendations were made in favour of a balanced approach (also labelled "the three point programme") to address the airport noise problem, challenging the ICAO member states to "*study and prioritise research and development of economically justifiable technology*", including notably airport land-use planning and noise abatement operational procedures. However, a significant number of airports have already implemented their own rules prohibiting some types of operations even of aircraft certified to the international standard. There are strong signs that these local rules may proliferate in the near future caused by specific difficulties encountered in the parallel developments of airport activities and neighbouring communities. Resolving this important environmental issue has in fact become vital to ensure harmonious growth of the Air Transport business in the future, through the non degradation of the noise situation faced by these communities.

The introduction, in the early 70's, of the High Bypass Ratio (HBR) turbofan generated a major advance in engine technology and jet aircraft noise reduction. These engines were, by design, a significant 15 dB quieter than their immediate Low Bypass Ratio (LBPR) predecessors certified to the Chapter 2 1972 standard. In the following 20 years, aviation has seen the refinement and optimisation of a proven noise control technology, rather than the introduction of any novel noise reduction techniques. The noise control features of a current baseline power plant (engine and nacelle) are based on a design optimised for low noise under well-established rules. These design rules are now applied throughout the manufacturing industry and have resulted in an almost uniform standard of noise control, albeit tailored to specific engine and nacelle designs by each manufacturer. This situation has produced an homogeneous achievement level and further improvements through more extensive application of these technologies seem unlikely without affecting competitively the current aircraft in terms of operating costs. This would clearly call for a technology breakthrough in several areas to favour the development and application of novel, more effective, noise reduction technology at acceptable economic cost.

Considering this currently achieved noise reduction technology level, it would be beneficial to the air transport industry if additional noise exposure reduction were achieved by the mean of optimised operational noise abatement procedures.

Within the Aeronautics Task Force (ATF) set up in 1995 by the European Commission, the European industry has proposed, under the larger label of "The Environmentally Friendly Aircraft" (TEFA), a jet aircraft noise research action plan. In particular, the TEFA report to the ATF, defined the needs and objectives for a very significant technology programme aimed at reducing noise around airports by at least 5 dB. In the proposed scheme (see Figure 1), a strong "proof-of-concept" phase (48 MECU over 3 years) would lead to a further step where all promising technologies would be integrated into large scale demonstrators. Obviously the scale and complexity of the required effort was expected to attract attention, particularly considering the fact that, as the 1996 EC Consultation Paper on the Limitation of the Impact of Noise from Air Transport asserted, "the European effort is now lagging behind the effort initiated two years ago in the US". During the exploratory phase, the only EC funded project launched on jet aircraft noise reduction, FANPAC (Fan Noise Prediction and Control, APAS, 93-96, 3.3 MECU), has been supplemented by significant but very focused national actions. Vital aspects of Novel Technology Proof of Concept have since then been addressed by the projects RESOUND, RAIN, RANNTAC, DUCAT funded by DG XII and launched in January 98.

The development phase concerning operational noise abatement procedures was started with Sourdine (task 12.5 of the 4th Framework Programme).

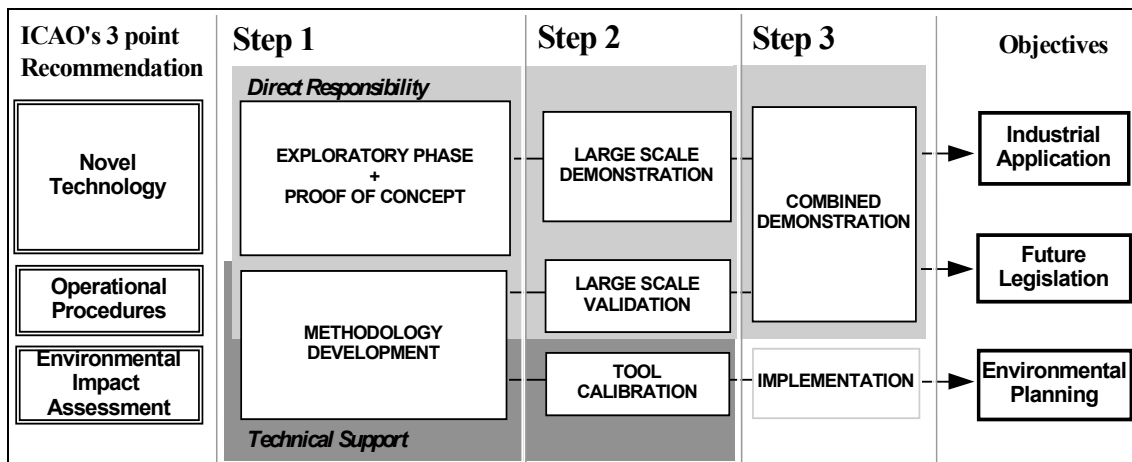


Figure 1: The « 3 point- 3 step » scheme

This translates the balanced approach concept recommended by ICAO for noise reduction research effort into adequate co-ordinated research actions covering novel engine technology and operational noise abatement procedures.

4. Approach

In order to define and evaluate procedures related to noise abatement around airports, the Sourdine team has followed a method that is initiated with the Sourdine project and is to be completed during the 5th Framework Programme:

- 1) Study of the key elements acting on the aircraft noise level around airports and on the noise propagation.
- 2) Identification of solutions for noise reduction, by the development of new arrival and departure procedures.
- 3) Test of these new arrival and departure procedures in a simulated environment for measuring their contribution to reduce environmental impact without decreasing airport capacity or flight safety. This is decomposed in short-term and medium-term solutions, as it depends on the set of available simulation tools.
- 4) Test of the candidate arrival and departure procedures in a real environment, using measurement tools and methods that have to be defined. This supports the calibration and improvement of the numerical models used in the simulation with real measures, which guarantees reliable results.
- 5) Specification and development of automation tools supporting air traffic controllers and pilots in the application of the new procedures.
- 6) Operational global validation with the operational community, in order to verify the impact and feasibility of these procedures.

Flight safety, efficiency and capacity are key features that were considered throughout this process.

The method investigates the noise reduction generated by individual aircraft in the take-off and approach phases, the overall noise perceived by the airport neighbours as well as the level of service.

This ambitious method is not feasible in the context of Task 12.5 of the 4th Framework Programme. The development of the simulation tool and its calibration, the operational validation and the development of the automation tools for end-users should be carried out in the 5th Framework Programme. The method and the allocation to the 4th and 5th European Commission Framework Programmes is depicted in the Figure 2.

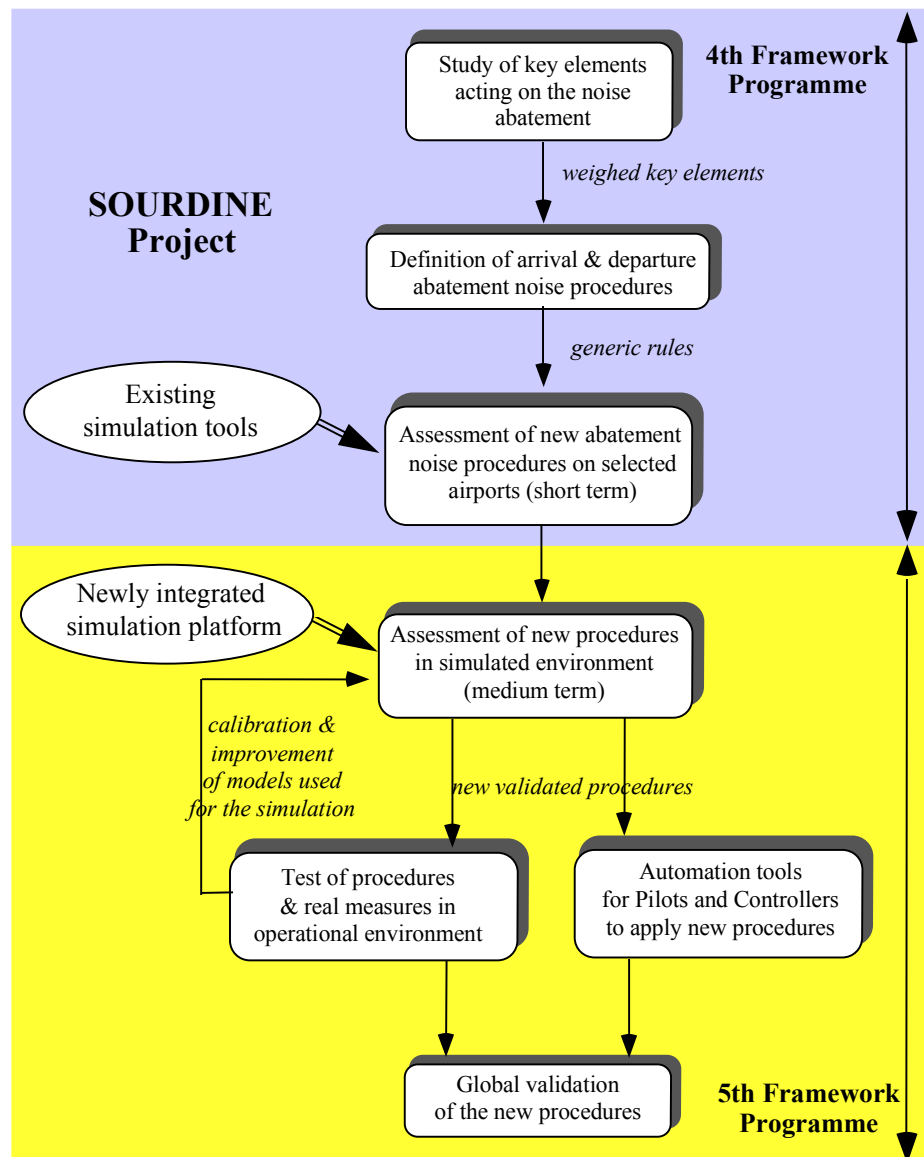


Figure 2: Noise abatement procedure methodology

The Sourdine project was the first step towards the definition, validation and use of noise abatement procedures, emphasising on new arrival and departure procedures.

Sourdine had the following objectives:

- 1) Study and propose alternatives to reduce noise levels around airports, by:
 - elaborating generic rules for updating the existing approach and take-off procedures for short-term improvement (such as reduced flaps and delayed landing gear lowering, higher descent speed) applicable to most of the existing aircraft,
 - investigating new procedures taking benefit from new airborne and ground technologies (RNAV, MLS (Microwave Landing System), GNSS, Enhanced FMS...),
- 2) Apply those rules to define new procedures for selected airports (Schiphol, Madrid and Napoli), considering the feasibility of such procedures, providing data on the qualitative effect in noise reduction.
- 3) Identify the simulation tools and their capability of being integrated in a global simulation platform aiming at carrying out the operational validation of the new procedures within the scope of the 5th Framework Programme.

5. Results and achievements

In Sourdine, work was organised in 5 main technical work-packages, each delivering a document containing the essentials of the work results (see Figure 3).

The first document (D1) is an inventory of the current regulations and practices concerning aircraft noise, and of their future evolutions. It describes the operational, safety, capacity and economical constraints that might influence the definition of new procedures.

The second document (D2) describes existing noise models and justifies the selection of those that were used in later stages of the project.

The third document (D3) defines and assesses procedures for short-term and medium-term. The most interesting results of the project are in this document.

The fourth document (D4) covers the study of tools required to support the new procedures in terms of environment simulation platform, measurement tools and automation tools assisting the end-users. During the course of the project, the focus of this study was slightly changed, since the specification of a global simulation platform did not seem desirable nor feasible. It includes a survey and evaluation of the existing tools.

Code	Date	Release number	Type	Name	Custodian	Document status
D1	21.02.2000	3.1 ¹	Technical Note	Environment requirements & operational constraints	AENA	Public
D2	30.06.1999	1.3	Technical Note	Study of key elements acting on noise impact of aircraft in operation	ASP	Public
D3	31.03.2000	8.2	Technical Note	Establishment of noise abatement solutions	NLR	Public
D4	19.05.2000	2.4	Technical Note	Requirements for tools	ISR	Public
D5	30.05.2000	1.6	Report	Final report	ISR	Public

Figure 3: List of deliverables

The last document (D5) is the present "Final report". It addresses the elaboration of the conclusions of the Sourdine project and includes the cost / benefit analysis.

5.1. Environment requirements & operational constraints

Deliverable D1, "Environment requirements and operational constraints", has two main objectives:

- the inventory of the regulations and practices concerning aircraft noise and their future evolution *in order to know how stringent regulation is in different countries and see how different countries cope with noise problems;*
- the study of the operational, safety, capacity and economical constraints that might influence the definition of procedures *in order to know which 'boundaries' we have to take into account when developing a new procedure.*

¹ Release 3.0 delivered 15/3/99. Release 3.1 just contains a new annex on existing rules and regulations to construct instrument flight procedures.

Aircraft noise is a subject dealt with in most developed countries. In Europe, there is a common legislation from the EC but every state has its own special characteristics, so there is a lack of harmonisation (see D1, §2.1). The main differences are due to the employed calculation methods and noise indicators (see D1, §2.2).

Deliverable D1 recognises that some work has been done related to aircraft / airport noise reduction but concludes that it is necessary to improve the studies and to harmonise a global implementation. For the Sourdine follow-on work (see D1, §2.4), it is proposed to use existing and operational noise prediction models to investigate theoretically a large range of possibilities. The procedures could then be made operational by being specifically designed to reduce noise around a given airport (see D1, §2.3).

Four different types of constraints are considered (see D1, §3):

- aircraft operational constraints: the aircraft performances are improving but fleet renovation is expensive, so a mixture of different aircraft (and old fleets from less developed countries) has to be taken into account for the near future;
- ATC / airport operational constraints: airport and ATC operations are directly involved in the noise reduction procedures;
- safety operational constraints: this is the main (i.e. vital) constraint;
- economical constraints: they are very important because quieter aircraft imply costs for airlines, airports and the surrounding community; noise abatement procedures mean higher fuel consumption and a reduction in the airport capacity; in addition to that, noise insulation has to be considered when procedures do not reduce noise.

A quick overview of future requirements (for the new century) is also provided, focusing on new aircraft types and new CNS/ATM systems (see D1, §4).

The conclusions are as follows (see D1, §5).

Environmental benefits as well as traffic constraints must be evaluated at two stages:

- short-term, when no change of aircraft and ATC systems is required;
- long-term when a review of these systems' specification is mandatory to allow application of operational procedures featuring significant noise benefits.

The set of parameters to be taken into account for the rest of the Sourdine project for the operational procedure optimisation study is:

- category of aeroplanes: commercial jets only must be considered for noise studies but propeller aircraft must be taken into account only for traffic constraints;
- operational phases: the study must be limited to the following operational phases²:
 - initial climb,
 - intermediate climb, to a distance where the noise impact on the ground is no longer considered,
 - approach, from a distance where the noise impact on the ground is considered as non significant,
 - final approach;
- atmospheric conditions: only one set of standard conditions (pressure, temperature and humidity) must be selected; applicability of procedures in hot day and high altitude conditions must be checked if necessary; no wind and homogeneous atmosphere must be taken into account for general parametric studies; sensitivity of noise perceived on the ground to atmospheric conditions (pressure, temperature, humidity, wind speed and direction) and atmosphere layering must be assessed on a single typical case;
- runway: a runway with standard equipment, unconstrained by length or obstacles, with no slope, must be considered; applicability of procedures from short runway must be checked if necessary; implication of the use of noise abatement procedures to runway equipment requirements must be assessed;

² The phases of taxi, take-off roll, en route, and landing roll with or without reverse thrust will not yet be addressed.

- control point in surrounding environment: a standard control point environment must be defined as a flat and soft ground with no surrounding obstacle to noise propagation;
- procedures: the parametric studies aimed at optimising take-off and landing procedures for noise reduction must take the horizontal as well as the vertical plane into account; this is a first approach that must be refined during the project; since specifically designed curved flight paths are in many cases an excellent way of reducing noise exposure over selected areas, the capability of an aircraft to follow precisely a curved flight path and the associated benefits to environment and constraints to operations must be assessed in general; the constraints retained to select the range of procedures to be studied must be imposed by Air Traffic Control and aircraft system, in addition to safety and environmental issues, for the short-term study; the safety constraints only must be kept for the long-term study;
- noise metrics: the selected metrics are EPNL and L_{Amax} ;
- optimisation criteria: the procedures must be selected to minimise:
 - noise perceived under the flight path beyond a certain distance from the runway,
 - equal noise level (level to be defined) footprint areas;
- assessment of community noise benefits: the benefits provided by noise abatement procedures must be quantified in term of single event equal level noise footprints and equal level noise exposure for a limited number of fleet mix and scheduling combinations representative of:
 - Amsterdam-Schiphol,
 - Madrid-Barajas,
 - Napoli-Capodichino.

5.2. Key elements acting on noise

Deliverable D2, "Study of key elements acting on noise impact of aircraft in operation", has three main objectives:

- describe and evaluate the merits of existing tools enabling to predict and evaluate noise exposure around airports,
- select tools to be used in Souridine for the determination of optimised noise abatement procedures and evaluation of environmental benefits,
- define a number of parameters that could be varied with regard to current operational practices in order to achieve noise reduction, for short and medium-term.

The calculation models used to predict noise exposure around airports were described (see D2, §2) and evaluated (see D2, §3.2). The existing and operational noise models are simulation tools that assess the predicted aircraft noise levels around airports during the arrival and departure procedures. The choice was made among the five following models:

- NLCP (Noise Level Computation Program): the Airbus operational noise model, developed by Aérospatiale, used for single event noise studies specific to Airbus aircraft;
- INM (Integrated Noise Model): the FAA (Federal Aviation Administration) noise model commonly used world-wide for noise airport exposure studies;
- Kosten Unit Model: used for the calculation of the noise exposure around Dutch airports;
- LAeq model: used for the calculation of the noise exposure around airports caused by air traffic during night time;
- DANSIM (Danish Airport Noise Simulation Model): used for calculating noise contours around airports.

The evaluation of noise models to use in Souridine took into account the horizontal and vertical optimisation possibilities of aircraft flight paths on take-off and landing phases, as well as the environment parameters of the airport, the parameters of the aircraft, and the processing and expression possibilities of noise data. In particular, the following criteria relevant to operational noise studies were considered:

- noise source components modelling,
- representation of individual aircraft performance and noise signatures,
- simulation of operational take-off and landing 3-D flight paths,
- representation of sound propagation in the atmosphere,
- representation of ground effects on noise perception,
- noise levels, scales and indices calculation capabilities,
- noise contouring capabilities (footprints),
- multiple events and fleet-mix integration capabilities,
- statistical handling of dispersion around nominal conditions (aircraft weight, performance, profile and route, meteorological conditions, obstacles...).

Special care was given to the representation of atmospheric conditions in noise propagation models. A current assumption in most models is that of homogeneous / uniform atmosphere between aircraft and receivers. Sourdine took one step beyond with the introduction of a sound velocity gradient³ (see D2, §3.3):

$$\frac{\partial c}{\partial z} \approx \frac{1}{2} \frac{c}{T} \frac{\partial T}{\partial z} + n \frac{\partial v}{\partial z}$$

where: c = sound velocity T = temperature z = altitude
 v = wind velocity n = unit vector, in the direction of the propagation

The different characteristics of the observed models show inequalities in calculation capabilities and result precision, the means of taking into account the noise and flight path data, the format of results, the possibility for each model to be adapted to various procedures and future regulatory evolutions. Some of the models allow to optimise take-off and landing procedures.

The features required for an advanced model were established as follows (see D2, §3.4):

- ability to sub-divide the database into take-off and approach powers or airframe and engine related sources with handling of speed effects with different sources;
- availability of a noise database stored as spectral information incorporating both field shapes and azimuthal directivities;
- propagation (including ground, and some meteorological effects) computed in spectral form and only converted to the relevant noise metric at the final stage;
- improved flight path simulation (flexible take-off, derated climb powers, correct allowance for power increase due to turn, non standard day performance...).

Requirements were made for procedure optimisation in the vertical and horizontal planes and for benefit assessment (see D2, §3.5).

For the vertical plane, the models were required to be able to undertake the following simulations:

- for take-off:
 - optimisation of thrust reduction altitude;
 - optimisation of reduced thrust setting;
 - optimisation of slats/flaps retraction altitude;
 - maximal take-off thrust, or flex take-off for initial climb;
 - variations of climb speed;
 - acceleration phases handling;
- for approach:

³ Sourdine retains a theoretical approach with a linear gradient.

- increase of the interception glide slope altitude;
- increase of the intermediate approach segment altitude;
- increase of the glide angle;
- slowed approach;
- variation of the flap deflections for final approach;
- delayed exit of the landing gear;
- variation of landing configuration stabilisation altitude;
- displaced landing threshold.

For procedure optimisation in the horizontal plane, requirements included the ability to undertake the following simulations:

- for take-off:
 - statistical impact of deviations from targeted flight path;
 - flight paths with turns avoiding the noise sensitive zones;
 - optimised take-off runway allocation;
 - for a given airport, adjustment of cross and face winds;
- for approach:
 - statistical impact of deviations from targeted flight path;
 - flight paths with turns avoiding the noise sensitive zones;
 - optimised landing runway allocation;
 - minimisation of distances between aircraft.

Chapter 3 of deliverable D2 concludes that it will be possible for Sourdine to reply to the European programme demands by joining the following tools:

- a manufacturer's model, e.g. the Airbus NLCP model, to be used for vertical procedure optimisation of aircraft departure and arrival flight paths, single event benefit analysis, and horizontal procedure optimisation of departures;
- an airport / civil aviation model, e.g. the INM or Kosten unit / Laeq models, to carry out noise level assessment from the above optimised departure and arrival flight paths, and for horizontal analysis of aircraft arrival flight paths and global noise exposure benefit for a given airport.

The selected models should allow to optimise⁴ procedures with respect to the noise produced on the ground by varying flight path parameters expected to generate a significant noise reduction (see D2, §4.2).

At take-off, the aircraft must reach an altitude as high as possible over the ground and decrease the engine thrust to minimise the noise nuisance on the sensitive area. The procedure optimisation study should result from variations of the following parameters:

- take-off configuration: looking for a better climb gradient;
- take-off speed: associated with the take-off configuration, the take-off speed will influence the achievable climb gradient;
- thrust reduction height, which will mark the initiation of the noise abatement phase;
- climb thrust, which is reduced from take-off go-around thrust (max take-off, or flexible take-off, or derated take-off), to climb thrust (max climb, or derated climb, or optimal climb), or max continuous thrust;
- acceleration height to en-route climb speed, and retraction of slats/flaps configuration; this take-off phase may take place before or after the thrust reduction phase.

⁴ With respect to reference procedures representative of current practices (see D2, §4.1).

In the approach configuration, the distance must be, as for the take-off configuration, as high as possible over the sensitive area. The parameters that can influence the noise levels perceived below the glide path are the glide slope angle, the configuration and the speed. Two types of approach can be optimised, using the variation of the following parameters:

- combination of high speed/low slats/flaps setting flight path, which allows the pilot to keep a minimum engine thrust;
- execution of a two segments approach, the first one with a glide path higher than 3 degrees, and the second with the normal value of 3 degrees; this method keeps the aircraft high as long as possible.

The optimisation study must be carried out by using the dBA and SEL units. Because practised in acoustic certification, the EPNL unit must also be calculated on the selected procedure. The optimisation method by using a single point below the vertical path could be compared to the optimisation for a minimum footprint.

The current fleet mix representation will be possible by using a dual solution: building a noise level equivalent fleet of Airbus aircraft to compare the noise impact with the current and new procedures, and/or using a fleet mix closer to the actual traffic situation.

5.3. Establishment of noise abatement solutions

Deliverable D3, "Establishment of Noise Abatement Solutions", investigates⁵ generic solutions and procedures aimed at noise abatement around an airport. Initially, procedures are defined on the essentials of typical noise abatement measures, and not on typical airport environments. In a second step, when a measure is selected for application to a particular airport, the actual shape is defined.

The development of alternative noise abatement procedures by merely changing the operation of the aircraft around the airport should be an integrated process involving all concerned parties, such as the operators, ATC, aviation authorities and environmental specialists. Successful implementation will only be achieved if all these parties are convinced of the idea and benefits of a new measure. A new procedure can only be introduced with success when the current level of safety is maintained and the airport capacity is not significantly reduced. Deliverable D3 therefore used the following approach to look at potential noise abatement measures:

- as a first step, investigate possibilities for noise reduction generically, i.e. without regard of local restrictions and limitations:
 - look at current operating procedures and regulations as provided by for example in ICAO PANS-OPS and current operating procedures (see D3, §2);
 - consider new technology and avionics/ATC upgrades that will be required anyway within the coming years and that can be used also with advantage for noise abatement (see D3, §3);this will help to identify potential noise abatement measures that could be applied;
- select the most promising measures for further investigation (see D3, §4);
- then, start to assess individual measure in more detail:
 - evaluate the flight's operational, safety and ATC aspects;
 - evaluate the noise effects of single aircraft movements (see D3, §5);
 - evaluate the qualitative impact on capacity and noise for an airport (see D3, §6).

This is of course an iterative process where the measure may have to be adjusted depending on the results of each step. At a certain point, the detailed impact on noise and capacity for a specific airport situation can be computed. Within Souridine, we have made initial calculations to get indication of the obtainable noise benefits on an airport scale for three different European airports, namely Amsterdam-Schiphol, Madrid-Barajas and Napoli-Capodichino.

⁵ Do note that D3 forms the core of the Souridine study: the size of the summary below does not always reflect the amount of work and the relative importance of the results, with respect to the other deliverables.

The introduction of new procedures can take a lot of time, especially when they require extra equipment or modifications to onboard systems or new tools for the ATC controller. Within Sourdine, we have focused on measures that could be achieved within the next 5 to 10 years:

- *short-term noise abatement procedures* (see D3, §5.1), being flight procedures which can be realised without the need for additional equipment (or modification of existing equipment) or tools for the aircraft or air traffic controller;
- *medium-term noise abatement procedures* (see D3, §5.2) which may require re-certification or modifications in aircraft and/or air traffic control equipment or for which new tools or equipment have to be developed (e.g. GNSS, new cockpit developments and advanced ATC planning and monitoring tools).

5.3.1. Promising short-term noise abatement procedures

For short-term approach noise abatement procedures, have been considered flight procedures with:

- increased final approach altitude,
- (slightly) increased glide slope angles,
- delayed flaps and/or gear approaches,
- reduced final landing flap settings,
- continuous descent approach.

When looking at a typical instrument approach procedure, which is usually an ILS procedure, there exists a horizontal flight segment to intercept the final descent gradient. This level portion of flight is usually combined with flying at a relatively high thrust setting when the aircraft is approaching the ILS glide slope from below.

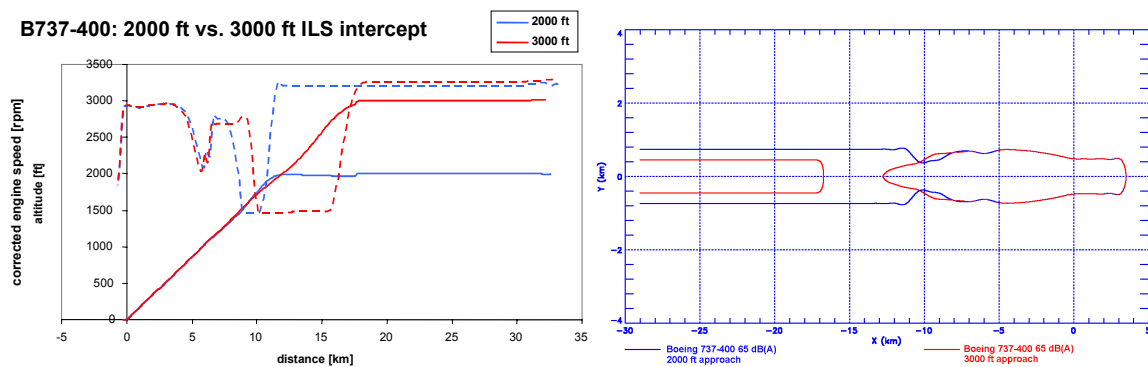


Figure 4: (a) Altitude and Thrust vs distance to threshold (b) 65 dB(A) noise footprint: 43.1 vs 28.5km²

A direct measure to move this noise away from the ground would be to use a **higher ILS intercept altitude** (e.g. 3000ft instead of 2000ft). The distance to the noise would be immediately increased, which should lead to a lower noise exposure and footprint area on the ground. The impacts are as follows:

- noise:
 - considerable reduction of noise footprints,
 - however, arrival flight tracks will change, i.e. exposed area;
- operational implementation:
 - procedural change;
- ATC aspects:
 - more attention to monitor traffic on longer final approach,

- earlier anticipation for speed reductions;
- flight operational aspects:
 - longer period of higher workload on final approach,
 - earlier speed reduction required, reduced flexibility on glide slope.

Another very promising approach noise abatement procedure is the **continuous descent approach**. The procedure makes full advantage of the onboard Flight Management System by planning an uninterrupted idle decelerating descent to intercept final approach landing.

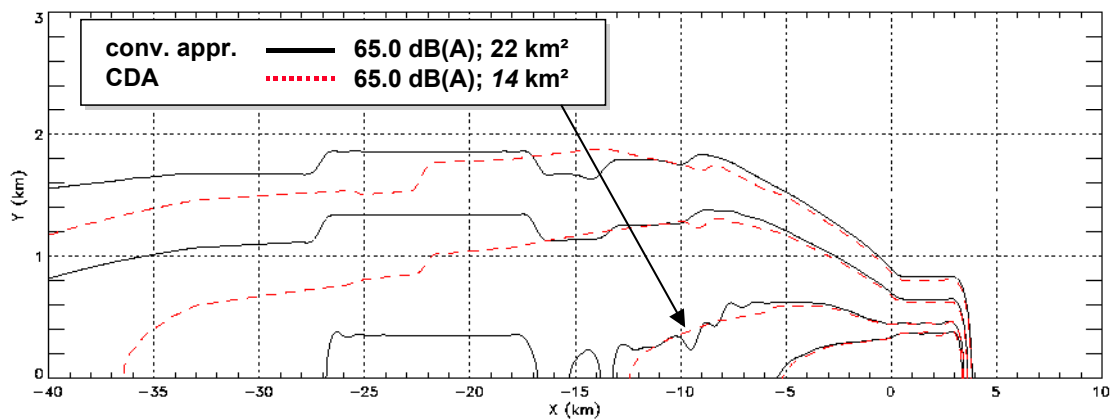


Figure 5: Airbus A320 (calculated noise footprint based on performance data) conventional 2000ft approach vs. CDA

The environmental advantages (at Schiphol) are:

- a reduced noise footprint area,
- a drop in noise complaints,
- actual fuel saving indicated by ACMS (Aircraft Condition Monitoring System) data analysis.

The drawbacks are:

- no ATCo (Air Traffic Controller) intervention allowed for optimum descent,
- arrival planning difficulties require increased separation,
- reduced landing capacity (i.e. application during off peak hours only).

For **take-off procedure optimisation**, improvements of the climb profile are based on ICAO-A and B noise abatement procedures (ICAO-A is frequently applied in Europe). The main lines are:

- take-off thrust until 1500 ft, climb thrust above 1500 ft,
- maintain $V_2 + 10-20$ kts until 3000 ft.

The results depend on the areas to be protected. Optimum noise reduction are achieved by climbing as high as possible before take-off thrust reduction but the moment of take-off thrust reduction is balanced by engine maintenance costs for high thrust settings.

Please refer to D3, §5.1 for a more detailed description of the studied short-term noise abatement procedures.

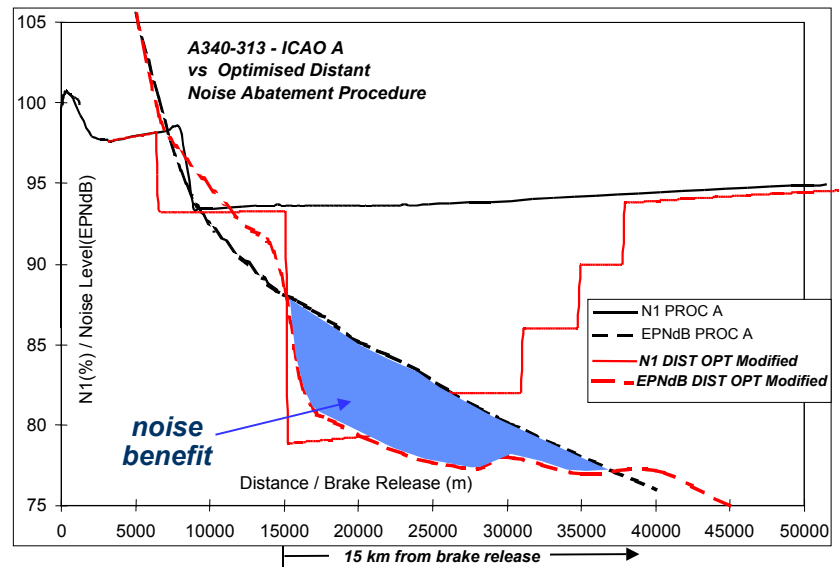


Figure 6: A340-313 ICAO A vs. optimised distant take-off noise abatement procedure

5.3.2. Promising medium-term noise abatement procedures

In the medium-term noise abatement procedures, the following flight procedures have been considered:

- advanced approach and departure procedures using new FMS functions:
 - accurate RNAV based SID/STAR routing,
 - advanced application of continuous descent approach with improved landing capacity,
 - dual landing threshold,
 - increased glide slope angle;
- application of new planning or monitoring tools for ATC.

RNAV based departures and arrival routing consists in the application of the **area navigation (RNAV)** system with a Required Navigation Performance (RNP1) accuracy of 1 NM or better in the terminal area.

The potential noise benefits are flexible ground tracks and, close to the airport, a more accurate track keeping.

The effects on capacity are:

- for departures: enable to perform earlier turn on track;
- for arrivals: no benefits without advanced tools.

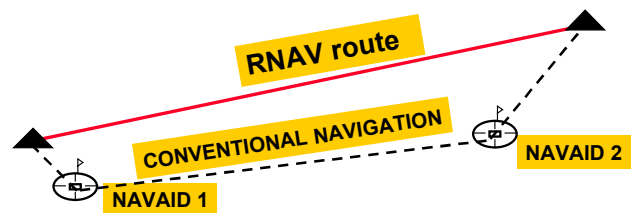


Figure 7: RNAV

ATC aspects:

- new operational concept,
- redistribution of workload between 2 controller positions (importance of the tactical position).

Airworthiness: certification of the 4D-FMS, similar concept of certification to the safety issues for ATM, PANS-OPS for RNAV RNP1.

The safety aspects are not affected.

Implementation:

- availability of new CNS equipment,
- technological and procedural changes.

Another promising procedure is the **advanced continuous descent approach (A-CDA)**. It integrates the following concepts:

- curved approach with continuous lateral and vertical path guidance,
- decelerated approach, speed is controlled via an energy management algorithm (within the FMS),
- 4-D RNAV: prediction and control of aircraft track in position and time,
- advanced arrival tools for ATC.

The potential noise benefits are, for distant flight path, an approach with flight idle thrust and the absence of horizontal approach segments (CDA).

The effect on capacity is a reduction in the current large separation. Good separation figures similar to the published wake vortex separation standards should be reached. Additional studies are already on the agenda of EUROCONTROL and ICAO CAEP.

The ATC aspects of A-CDA are:

- a change of the operational concept (AMAN – Arrival Manager);
- a reduction in controller workload.

The safety aspects are not affected.

Airworthiness: certification of the 4D-FMS.

Feasibility and implementation: CDA is already in force at Heathrow and Schiphol airports (during night). The implementation of the new operational concept is affected by ATM/CNS equipment for both ground services and aircraft.

Dual landing threshold allows the overall noise contour to be shifted towards the airport by enabling light and medium aircraft to perform approaches to a displaced threshold.

Reducing the final approach spacing and the runway occupancy time increases the arrival capacity.

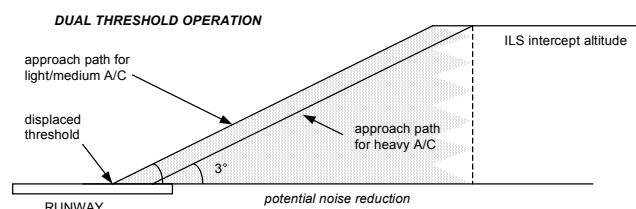


Figure 8: Dual landing threshold

Dual landing threshold requires a dedicated implementation study for suitable runways. Evaluation is at its trial phase at Frankfurt airport (HALS-DTOP).

ATC aspects: Traffic segregation by ATC.

Airworthiness: a safety study is required.

Safety aspects: there are operational limitations (visibility, wind, turbulence,..).

Feasibility: Applicability will depend on the airport.

The application of an **increased glide path angle** for a given aircraft type at a constant airspeed in the given (landing) configuration implies a reduction of the required engine thrust to maintain that constant speed. In addition, the aircraft will fly over the ground at a higher altitude thus increasing the distance (altitude). Since a reduction of the engine thrust also implies a reduced engine noise output (at the source), such a measure could possibly result in a smaller noise footprint below the aircraft.

Effects on capacity: slight negative effect (speed control).

ATC aspects: missed approach number could be higher.

Airworthiness: today, the glide path angle for CAT III must be 3°. A long campaign of flight test will be required before ICAO approval.

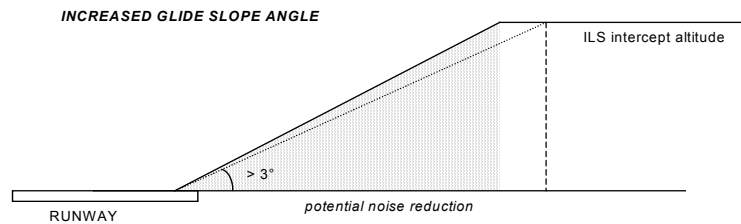


Figure 9: increased glide path angle

Safety aspects: pilots could perceive this procedure as unsafe.

Feasibility is constrained by manoeuvrability and operability restrictions of some aircraft. Some modification will be required in the software of the autopilot to perform autolandings with higher glide-slope angles (3.5° or even higher).

Implementation: it is not suitable to have different glide-slopes at one or even at different airports. Limitations will come from the present fleet and the necessity of increased runway lengths.

Please refer to D3, §5.2 for a more detailed description of the studied medium-term noise abatement procedures.

5.3.3. Airport implementation studies

As a demonstration of the potential benefits in actual airports, a selection of promising short-term solutions has been applied to the Amsterdam-Schiphol, Madrid-Barajas and Napoli-Capodichino airport environments. The results in terms of noise and capacity are presented in the final sections of the D3 document, §6.3 through to §6.5.

It is important to note that the airport implementation studies carried out within the SOURDINE project were limited by the fact that optimised noise abatement procedures were only available to the project partners for specific aircraft types, i.e. Airbus aircraft. Therefore, in order to still be able to perform an airport noise implementation study of the proposed procedures⁶, a surrogate aircraft fleet was constructed (using conversion factors) in which other aircraft types were replaced as far as practical by available and representative (Airbus) aircraft types (see D3, §6.1 and §6.2). Due to these assumptions, any results obtained with this approach therefore can only provide a comparison of the implications between the original and alternative situation and should not be looked at in an absolute sense.

The Amsterdam-Schiphol baseline scenario set-up was:

- day: 2000ft approaches / full flaps,
- night: 3000 ft approaches / full flaps,
- ICAO-A take-off.

The alternative scenario was:

- day: 3000 ft glide slope intercept altitude on runway 27 and 19R, 2000 ft on other runways:
 - reduced flaps,
 - delayed stabilisation;
- night: continuous descent approaches with:
 - reduced flaps,
 - delayed stabilisation;

⁶ The assessment of impact of measures on airport capacity was performed using SIMMOD & TAAM simulations with the actual fleet mix.

- ICAO-A take-off.

The following conclusions were drawn from the Schiphol noise (see D3, §6.3.4) and capacity (see D3, §6.3.9) simulations:

- approach procedures using delayed stabilisation offer noise benefits compared to normal stabilisation procedures; the noise benefits are relatively greater for an ILS intercept at 3000 ft;
- delayed stabilisation show effect in the range from 11 till 6 km before threshold;
- based on the results of the Kosten unit (Ke) calculations, the effects of 3000 ft versus 2000 ft localiser interception show substantial noise benefit in the range from 7000 ft till 11 km before threshold;
- based on the results of the Kosten unit (Ke) calculations with no threshold value, the effects of 3000 ft versus 2000 ft localiser interception show noise benefits in the range between 20 km till threshold, but there are negative noise effects for the area before 20 km where the localiser is intercepted;
- effect of a reduced versus full landing flaps procedure does not indicate noticeable noise benefits;
- the given restrictions involved to the simulation provide unexpected and beneficial results for the continuous descent approach procedure during night;
- approaches with a 3000 ft glide slope intercept altitude can be implemented without an increase of delay, if adaptations are made to the available vertical airspace and to the other bottlenecks involved;
- unexpected capacity results have been found, which might be caused as a result of the 60% fleet mix distribution⁷: in particular, the reduced flap procedures have a negative effect on the total average delay if not all aircraft comply with it;
- the more the traffic volume increases, the smaller the relative delay difference between the scenarios;
- implementing a procedure with an altered ground trajectory causes a change in footprint and this may have more effect (either positive or negative) than the gain of the noise abatement procedure itself;
- the individual effect on delays, due to reduced landing flap settings, cannot be substantiated because of the applicable noise abatement approach procedures;
- succeeding studies concerning the impact of the proposed noise abatement procedures on airports are recommended.

The Madrid-Barajas baseline scenario set-up was Northerly Operations, i.e.:

- ILS arrivals on runway 33;
- Departures:
 - 23:00 to 07:00: runway 36R,
 - 07:00 to 23:00: runway 36L,
 - modified ICAO A take-off.

The alternative scenarios were:

- 3000 ft approach, reduced flaps, late stabilisation;
- continuous descent approach;
- optimised close-in noise abatement take-off.

The following conclusions were drawn from the Madrid-Barajas noise and capacity simulations (see D3, §6.4.6):

- the conversion factors (for non-Airbus aircraft type to Airbus aircraft) are not very accurate for INM departure procedures; better results are obtained for INM arrival procedures;
- the impact of the new optimised departure procedure is not very significant;

⁷ The procedures have been studied for the following types of aircraft: A300, A310, A320, A321, A330, A340, B737, and B747. The affected aircraft represent 60% of the total traffic volume.

- the 3000 ft approach procedure with reduced flaps setting yields good and significant results, in terms of both noise level and capacity; indeed, a slight decrease on the average delays on arrivals is observed for higher levels of traffic;
- the CDA (Continuous Descent Approach) procedure also leads to significant noise reduction; the noise reduction is slightly better than what would be obtained with the 3000 ft optimised procedures;
- arrival continuous descent approach, applied throughout all the day to all aircraft categories, have a strong degrading effect over the capacity of arrival operations at Madrid-Barajas Airport; this effect is even worst at the final hours of the day, due to the cumulative effect of saturation;
- the optimised ICAO-A procedure close-in flight path n° 4, working together with the 3000 ft reduced flap approach, will not have any appreciable influence over the number of departures per hour at the airport;
- the optimised ICAO-B procedure distant flight path n° 7, applied together with the 3000 ft reduced flap approach, will not have any appreciable influence over the number of departures per hour at the airport; it could allow a reduction on the average departure delays of half a minute throughout the day for a level of traffic around 1100 flights/day.

The Napoli-Capodichino baseline scenario set-up was:

- ILS approach angle of 3.3 degrees (due to terrain);
- continuous descent from 7000ft;
- preferential take-off runway 06.

The alternative scenario was:

- increased glide slope angle (4 degrees),
- optimised take-off procedure (rwy 06/24).

The following conclusions were drawn from the Napoli-Capodichino noise and capacity simulations:

- considerable noise reduction (especially for low noise levels) can be obtained through an optimised departure procedure; moreover, the optimised departure procedure had no effect on current capacity at present traffic volume;
- for arrivals, an increased glide slope angle leads to considerable noise benefit (55% 75 dB footprint reduction) and a slight improvement of departure capacity.

As a whole:

- it should be remembered that the absolute results obtained from the noise contour calculations are not representative of the actual noise contours, due to the fact that a surrogate aircraft fleet mix of only Airbus A320 and A340 had to be used due to the absence of accurate data for other types of aircraft; however, the comparative results between the defined baseline case, representative to current operation, and the alternative procedures indicate certain noise benefits around the airport;
- results indicate that the implemented short-term procedures do not appear to affect the airport capacity at current traffic levels, except the application of Continuous Descent Approaches; although this type of approach provides the minimum obtainable noise footprint, it can currently only be implemented with success during hours of low traffic demand at the current level of aircraft and ATM equipment.

5.3.4. Conclusions

Aircraft noise reductions are certainly achievable in the short-term through operational measures only. Modest reductions (but avoidable noise) can be reached close to airports through:

- reduced landing flap settings,
- delayed establishment of landing configuration.

Clear benefits further away from the runways can be obtained by:

- increasing ILS interception altitudes,
- introducing Continuous Descent Approaches outside peak hours making best use of existing FMS planning functions.

Furthermore, additional benefits appear feasible by:

- making better use of current RNAV capabilities,
- improved runway allocation with respect to noise.

Additional noise reduction relative to take-off and departure procedures is clearly achievable in designated protection areas even though implementation restrictions by JAR-OPS exist.

In the medium-term, the potential for noise abatement lies in:

- advanced operation of continuous descent approach,
- approach and departure routes using precision navigation,
- gradual increase of cutback thrust during climb out,
- application of increased glide slope angles.

Future work should include:

- cockpit tools for energy/profile management and monitoring,
- advanced ATM planning and monitoring functions,
- automated thrust management,
- air-ground interaction between FMS and arrival manager.

5.4. Requirements for tools

The purpose of deliverable D4, "Requirements for tools" is to define requirements for tools supporting the validation and implementation of new noise abatement procedures:

- simulation tools to be used during the validation phase,
- measurement tools for the control and monitoring of the procedures,
- automation and operator assistance tools supporting their implementation.

5.4.1. Methodological issues

Before the requirements, D4 addresses methodological issues with the description of a method for noise abatement procedure validation.

The conclusions of this study are (see D4, §2):

- 1) Sourdine should address as accurately as possible the impact of new procedures on actual noise levels, rather than nominal, official ones;
- 2) considering the complexity and possible number of noise abatement procedure evaluations, requirements listed in Sourdine should be as generic and synthetic as possible, and should sacrifice level of detail for breadth of scope whenever necessary;
- 3) since validation tools generally depend on the type of noise abatement procedure considered (airport-specific vs. aircraft-specific) and since the validation issues identified (i.e. noise exposure, safety, efficiency and capacity, economics, feasibility) can be considered independently from one another, noise abatement procedure validation requires a collection of independent simulation tools, rather than an integrated platform.

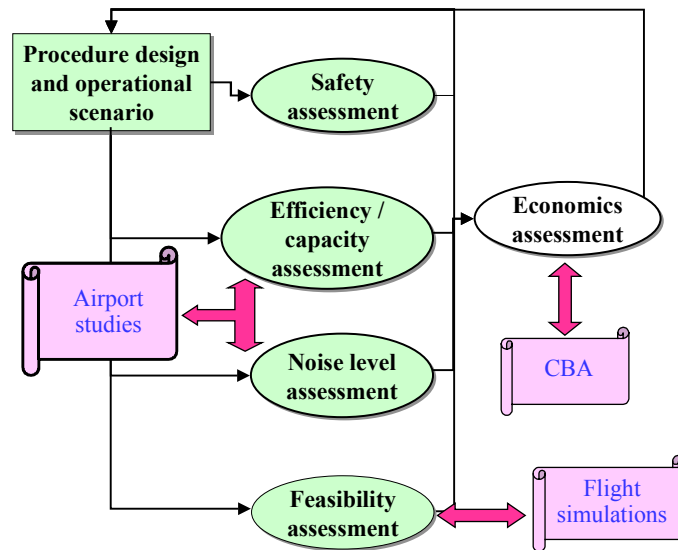


Figure 10: method for noise abatement procedure validation

5.4.2. Simulation and modelling tools

In terms of simulation and modelling tools, section 3 of D4 considers four categories:

- safety (see D4, §3.3): focus is set on a safety validation of changes to operations in ATM by building modern and joint safety cases;
- efficiency and capacity: a brief overview of the state-of-the-art in efficiency / capacity assessment tools is given;
- noise exposure: an upgrade to current noise contouring models, which would allow them to explore the effects of aircraft settings (thrust and configuration) and atmospheric conditions on actual noise levels is proposed;
- feasibility: the general concept of a hardware and software platform for assessing the technical and operational feasibility of noise abatement procedures is proposed.

Current procedures are constrained by **safety** requirements related to flight envelope restrictions and engine failure at take-off (for profile optimisation NAPs), obstacle avoidance and missed approaches. The classical safety case could be produced by the manufacturer of a technical system, as part of a procurement process. The joint safety case should provide the high level arguments and evidence for the total operation, while each modern safety case should provide the evidence and these high level arguments for that part of the operation that falls under the responsibility of one specific service provider.

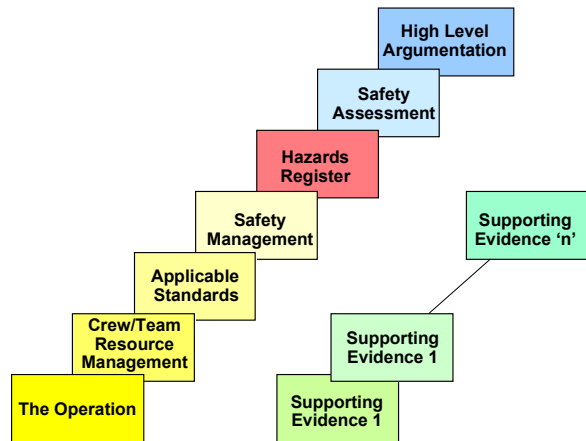


Figure 11: Safety assessment

Efficiency / capacity can have a quite different meanings for airlines & airports. For airports capacity is important while for airlines it is flight duration and fuel consumption. There are numerous capacity and delay assessment tools for airports, and it is useful to classify them according to an aspect or another:

- macroscopic – used for policy and cost benefit,
- mesoscopic – used for traffic flow capability and cost benefit analysis,
- microscopic – used for detailed analysis & preliminary design.

Airport authorities are restrained by current noise contours, while requiring increasing airport capacity.

Noise impact is a complex function of:

- the fleet mix,
- each aircraft performance and operation,
- its noise (engine and airframe),
- its propagation distance,
- and the number of operations.

Different models are required for:

- aircraft performance,
- engine-power & airframe noise source,
- propagation.

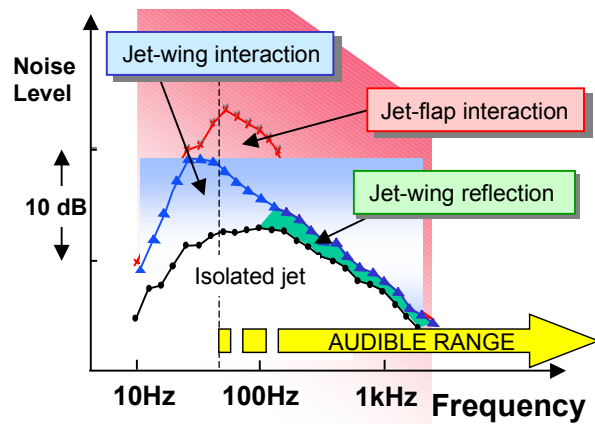


Figure 12: Aircraft's source noise characteristics

An aircraft's source noise characteristics, level and frequency, are a summation of the various individual noise sources existing within the engines and on the airframe together with any interaction between the engine and airframe (often referred to as installation effects).

“NPD curves” (Noise-Power-Distance) provide at various distances a set of data points, sometimes as few as three, the relationship between engine power and overall aircraft noise.

The noise at other powers is determined by interpolation / extrapolation. At high powers the aircraft configuration is likely to have a relatively low flap setting with the undercarriage stowed.

The airframe sources are unlikely to contribute to the overall noise but installation effects will generally increase the engine noise by a few decibels.

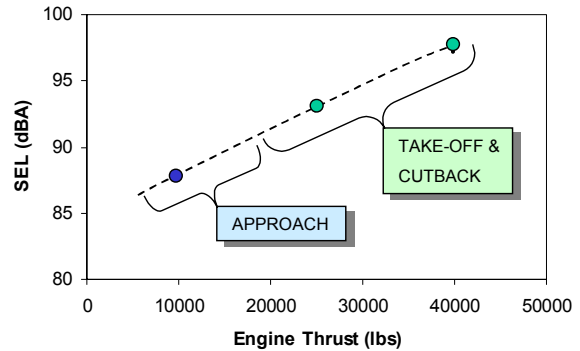


Figure 13: NPD curves provide the relationship between engine power and overall aircraft noise

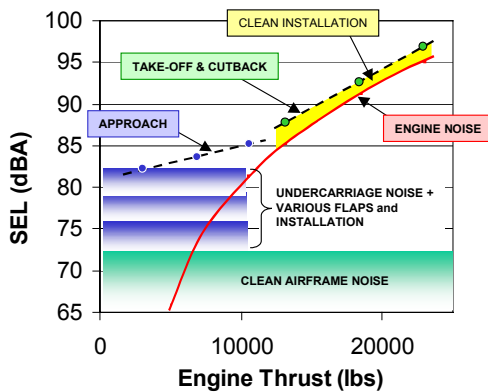


Figure 14: New NPD for specialised operation based on aircraft manufacture data

Hence the high power engine noise can be deduced which will decay with engine power according to fairly well defined rules.

At approach powers the situation is extremely complex. Extra and significant noise sources will be present to varying degrees caused by the deployment of high lift devices (flaps and slats) and the undercarriage.

Furthermore the installation effects are likely to be increased due to the interaction of the engine exhaust with the deployed flaps.

Thus the exact shape of any NP curve will depend upon the aircraft configuration.

For **feasibility**, operational validation encompasses simulated-environment and real-environment testing. Simulated-environment testing will allow concerned operators to be “in the loop”. The EUROCONTROL Experimental Centre (EEC) currently operates an ATC real time simulation facility called SIM5+ (5th generation of EEC simulation facilities). The ESCAPE (EUROCONTROL Simulator Capability And Platform for Experimentation) project concerns the re-engineering of SIM5+ to provide a generic, portable, and open platform. The project is scheduled for completion by mid-2001, with the ground part being ready in late 2000. Its objectives are the following:

- easy integration of third party components (‘Plug and Play’ architecture),
- experimental platform available not only to EEC but also to other research establishments and ATM industry in general;
- validation framework for the validation of ATC concepts, ATM systems architecture and functions.

Other candidate platforms are NLR’s Narsim, Avenue, Aramis...

5.4.3. Measurement tools

In terms of measurement tools, the main purpose of D4 is to examine the need for upgrade of existing airport noise measurement systems for them to support the implementation of new noise abatement procedures. The document does not therefore provide an extensive description of all functions in an airport noise measurement system. It does instead, in §4.1, “Review of existing systems”, present an overview of systems installed throughout the world, and the specifics of representative European systems, namely those installed at Amsterdam Schiphol, Madrid Barajas, and Paris (Charles-de-Gaulle and Orly) airports.

Subsection 4.2, “Monitoring of noise abatement procedures” is dedicated to a two-step analysis of the new requirements induced by the Sourdine-proposed noise abatement procedures. First, a user-level analysis is presented, which focuses on the organisational and operational side of NAP monitoring. Second, a technical analysis is conducted to determine which functions of current systems need upgrading, and why.

The monitoring of currently implemented noise abatement procedures is only a function among others of fielded airport noise measurement systems. Indeed, the high-level functions of these systems are advertised by their makers as follows:

- aid in the management of airport environment monitoring programmes,
- assist in the planning of airport expansion,
- provide airports with the facility to enhance their public relations programme.

These high-level functions translate into many more lower-level functions:

- noise and weather sensor management,
- noise, track and weather data gathering,
- noise and track data association,
- data recording,
- data visualisation,
- basic NAP monitoring,
- neighbour noise-related complaint handling,
- yearly noise level monitoring,
- noise contour computation,
- data analysis capabilities,
- automated report generation.

Our investigation of current noise measurement systems made clear that, while these systems were collecting a wealth of noise information, this information was somewhat under-analysed and under-utilised. The additional §4.3, “Noise data mining”, outlines data analysis applications that the emergent “data mining” techniques now put within the realms of possibility.

5.4.4. Operator assistance tools

In terms of operator assistance tools, D4 examines the need for new tools to assist aircrews, and ATC controllers in the performance of new noise abatement procedures, and in the control thereof. Subsection 5.1, “ATC controller planning tools”, focuses on arrival planning tools; such tools are indeed required by the advanced CDA and RNAV medium-term NAPs.

Subsection 5.2, “ATC controller monitoring tools” provides an overview of the different ATC tools that can be implemented in an ATM system to improve the workload and situation awareness for the ATC controller for those phases of flight in the terminal area, i.e. approach and departure.

Subsection 5.3, “Pilot assistance tools” presents the pilot assistance tools to apply the selected low noise procedures and their integration into the advanced airborne navigation equipment (FMS). For the take-off procedure with a progressive thrust increase after the cut back an automatic thrust management (to reduce from climb to cut-back power and then to increase progressively from cut back to climb thrust again coupled together with a pitch management) is compulsory. For approach and take-off, the FMS should display the real time parameters, associated with the targets to achieve, in order to perform the profile that optimises the noise and provide solutions to correct deviations.

As a conclusion, it is possible to state that:

- validation tools generally depend on the type of NAP considered (airport-specific vs. aircraft-specific);

- the validation issues, which can be considered independently from one another, are:
 - noise exposure,
 - safety,
 - efficiency and capacity,
 - economics,
 - feasibility;
- no simple requirement can be written for a "noise & capacity simulation platform".

5.5. Cost-benefit analysis

Investments in the aviation infrastructure are continuously required in order to maintain safety and reliability, improve the quality of service and match system capacity with the expected traffic growth.

It is equally vital that the environmental impact, which in the aviation industry is primarily to do with noise reduction, but also with engine emissions, is maintained under defined limits.

To reach a significant improvement in the airport noise situation, contour aspects going beyond the successful application of novel noise reduction technology should also be considered to address the social dimension of the problem.

Of course, in evaluating any new concept providing changes in Air Traffic Management at an operational level, not only the technical/safety feasibility has to be assessed, but it is equally essential to compare the estimated costs for implementing and putting in operation of the "concept", with the expected benefits.

To this purpose, Cost-Benefit studies are a means by which quantitative projections of both costs and benefits can be realised. In particular, appropriate Cost/Benefit models can permit the extrapolation of costs over time as well as projections of financial measures of the benefits that may be expected.

The objective of this section is to describe the approach followed in Sourdine for conducting the CBA. It is shown how the expected costs and benefits deriving from the implementation of the proposed Noise Abatement Procedures (NAPs) have been estimated and, where possible, evaluated.

5.5.1. Approach

The financial analysis here below has been written with the 'collected minds' of an airline, an airport authority, a CAA and the "community" point of view.

In general, the introduction of new NAPs is an additional constraint for the management of air traffic and the solution investigated should represent a compromise between noise and capacity/efficiency. In this case, Airport Service providers and Aircraft Operators may be identified as the investors.

The European Commission (DG VII)⁸ is the institutional sponsor of Sourdine.

On the other side, the main beneficiary is identified as the general community living around the airport.

It has to be highlighted that noise benefits are inherently difficult to quantify directly. This is because they are mainly non-monetary benefits that result from increasing the quality of life in the vicinity of airports, for which no value can be precisely given.

In order to identify and evaluate costs and benefits deriving from the implementation of the noise abatement procedures, the following items were considered:

- noise level,

⁸ The DG VII has co-financed this study to investigate on new noise abatement procedures.

- efficiency/capacity (average delays, aircraft movements, slots per day),
- aircraft operators costs (fuel/oil consumption, personnel, aircraft costs),
- environment (flight path duration, engine gaseous emissions),
- human workload,
- airborne and ground equipment costs,
- cost savings for the house insulation.

The translation of the identified costs into strict monetary revenue will be quantified through the usual ways (i.e. airline databases, service providers fares, etc.).

Have also to be taken into account other costs common to all proposed procedures, such as costs for:

- safety checking (compliance with standards, airworthiness, certification, legal),
- simulating the procedure,
- trials on the operational site,
- personnel training before implementation,
- impact on aircraft documentation,
- delivery of the new procedure.

As described in §5.3, two typologies of NAPs were proposed:

- short term procedures, based on present-day airborne and ground systems;
- medium term procedures, based on technologically advanced tools for both pilots and controllers.

Noise constraints generally impact on the efficiency of airport operation. This is the reason for which capacity has been considered as the most relevant cost factor for the implementation of a noise abatement procedure.

The influence of short term NAPs on the airport capacity has been evaluated through fast time simulations. On the contrary, for medium term NAPs an estimation of the airport capacity is provided only on a higher level.

5.5.2. Short term noise abatement procedures

It has to be noticed that implementing a specified noise abatement procedure provides variable levels of benefits dependent on:

- the simulation tool on which it is implemented,
- the airport layout / operational configuration of reference,
- the fleet mix chosen for simulating real traffic.

Therefore, the evaluation of the NAP under investigation is to be intended for that specified airport, tool and traffic data. Limitations mentioned in §5.3 have also to be kept in mind.

In the following, short-term noise abatement procedures are grouped into arrival and departure NAPs.

5.5.2.1. Arrival NAPs

The following NAPs were considered as short-term procedures for the approach [see deliverable D3]:

- increased glide slope intercept altitude (2000→3000 ft),
- reduced landing flap setting,
- delayed stabilisation,
- continuous descent approach (CDA).

Increased glide slope intercept altitude, reduced landing flap and delayed stabilisation

To get the maximum noise reduction, the first three NAPs listed above have been simultaneously implemented both on Madrid and Amsterdam simulating scenarios.

A preliminary information characterising this arrival procedure is the higher speed taken by the aircraft, with respect to the approaches currently in operation.

Benefits

Simulating the procedure under study provides significant noise benefits compared to the basecase.

A quantification of such benefit was estimated, for the Madrid study [D3], in a decrement of the overall noise contour area. In particular, a reduction of 11% for the 55 dB noise level and 25% of the 65 dB noise contour area were observed.

To fly the NAP, aircraft are required to descent with lower engine speeds, maintaining the clean configuration for a longer time and delay the stabilisation at the lowest possible altitude.

As a consequence, a significant reduction of the fuel burnt and gaseous emissions can be appreciated, thus providing cost savings for the aircraft operators and additional environment benefits for the community.

As far as efficiency / capacity is concerned, the emulated procedure returns slightly lower delay figures, demonstrating a small improvement of the airport capacity, presumably due to the higher approach speeds. In particular, if a traffic level of about 1150 movements a day is selected, such decrease of the average delay is quantified to about half a minute. Translating this half a minute into a strictly monetary evaluation of the costs saved⁹, it returns (see [D3] for the traffic sample details, based on Madrid data for the year 1998):

- aircraft operator cost saving for the A-320: 10360 Euro/day;
- aircraft operator cost saving for the A-340: 8458 Euro/day;
- average value of the benefit imputable to passengers: 24066 Euro per day¹⁰.

The same, projected on one year of operation returns:

- aircraft operator cost saving for the A-320: 3781 KEuro,
- aircraft operator cost saving for the A-340: 3087 KEuro,
- value of the benefit for passengers: 8784 KEuro,

for an estimated total cost savings of about 15652 KEuro/year.

Costs

If, from one side, higher approach speeds reduce the time to fly the procedure, on the other side, faster operations lead to a smaller margin within which the controller is able to do adjustments and ensure separation. Hence, controller workload could be stressed in case the 3000-ft approach procedure is implemented.

This also might subsequently cause a further reduction of capacity, if controllers are not adequately supported by “advanced” tools (e.g. the “arrival manager”).

However, as result of the evolution of the CNS/ATM system [EATCHIP 4], controllers working at most of congested airports will be supported by collaborative decision making tools based on emerging technologies. Therefore, the usual costs required by the installation (and training / maintenance) of this type of equipment cannot be charged specifically to the noise abatement programme.

⁹ Supposing one flight hour of the A320 equal to 3333 Euro, 5000 Euro for the A340 and one hour of the passenger time equal to 26.7 US \$

¹⁰ 1 Euro = 0.9 US \$ (May 2000)

In conclusion, the implementation of the increased ILS intercept altitude requires investments almost exclusively by service providers. Such investments could be partially balanced by an eventual increase of traffic movements.

Continuous descent approach (CDA)

The most relevant characteristic of a CDA is just the uninterrupted idle descent of approaching aircraft, with the final stabilisation at the lowest possible altitude.

Benefits

Effects deriving from the implementation of CDA are well known: the overall noise contour is significantly abated as observed from real noise monitoring on the airports where it is in operation, and from all simulations results.

The descent trajectory is designed in such a way that the aircraft flying a CDA will maintain an optimised flight profile also in terms of fuel burnt, thus providing additional cost savings for the aircraft operators.

Costs

Presently, the most significant limitation for the CDA implementation is the strong impact on the airport capacity. In fact, in order to safely perform the procedure, larger separations among aircraft are required.

From the study (and operational data) carried out for the Amsterdam Schiphol airport, it is experienced that capacity is not affected if the approximate limit of 15 arriving aircraft per hour (depending on the applied separation) is not exceeded. Therefore, CDA may be in operation without affecting airport efficiency only during low traffic periods (e.g. at night).

5.5.2.2. Departure NAPs

The following departure procedures were considered as short term NAPs:

- close-in flight path No. 4 as optimised take-off from the ICAO A procedure,
- Sourdine distant Flight Path No. 7 as optimised take-off from the ICAO B procedure.

The difference between the departure NAPs mentioned above is that the “close-in” has been designed in such a way to provide most of noise benefits in the area close to the airport, where the noise level perceived is very loud. Vice-versa, the “distant” NAP has been built with the objective to decrease the noise annoyance over more distant zones, where the noise level is high, but not very loud.

These NAPs have been implemented only for the Madrid study.

Unfortunately, while simulating the NAPs proposed for departure, some unexpected results in the evaluation of noise levels were observed: noise reduction was not as evident as expected. Since this is reasonably not related to the NAPs themselves, no conclusions should be drawn about a precise quantification of the noise levels.

On the contrary, results coming from the capacity analysis can be considered as reliable, thus providing a substantial input for the estimation of the costs.

Benefits

The optimised “close-in” NAP did not demonstrate a significant impact on the airport capacity, even if a lower speed in the operations is required. In fact, all the examined capacity figures were found to be more or less the same as the basecase.

Differently, the “distant” optimised take-off procedure requires higher speed for departure operations with respect to the ICAO A. As a consequence, reduced blocking intervals between successive departures were noticed, thus allowing, as final result, a more efficient departure sequencing.

Costs

It is important to note that the departure NAPs mentioned above require a progressive thrust increase that is only manually feasible with today's technology. To obtain an automatic progressive thrust increase, further developments and flight tests still have to be performed. Consequently, other investments are to be expected on this field.

The optimised take-off NAPs also require a reduction of power, but, due to safety reasons, no turns are allowed in coincidence with any power reduction. Therefore, in case aircraft are required to perform an early turn after taking-off from a defined airport runway, the implementation of these NAPs could result in an extension of the time interval between two consecutive take-offs, thus limiting the operational efficiency of the airport.

5.5.2.3. Conclusion for short term NAPs

Based on the observed noise footprints, it can be concluded that the approach procedure using delayed stabilisation, reduced landing flap setting and ILS intercept at 3000 ft, offers significant noise benefits if compared to the procedures currently in operation. In addition, the mentioned procedure doesn't affect the airport capacity if implemented with present traffic. On the contrary, an increase of capacity is experienced if a higher traffic volume is introduced. Hence, the proposed procedure is seriously recommended while designing new approaches.

A strong reduction of the noise level may also be achieved through the utilisation of continuous descent approach. But such a procedure is limited by the negative impact on the airport capacity. Therefore, CDA has to be recommended for low traffic airports or periods (e.g. at night).

Unfortunately, this particular study does not provide analogue conclusions for departures (as it did for arrivals). However, both for the approach and for take-off, further investigations on the impact of the proposed noise abatement procedures on airports are recommended.

5.5.3. Medium term noise abatement procedures

Noise abatement procedures identified as "Medium-Term" are also detailed in deliverable D3.

The considerations concerning the general costs of the short-term NAPs (see §5.5.1) still apply.

From a strictly economical point of view, unlikely for the short-term NAPs, investment costs necessary to upgrade ATC systems and avionics have also to be taken into account.

5.5.3.1. RNAV based departure and arrival routes

This innovative procedure consists in the application of the Area Navigation (RNAV) concept with a Required Navigation Performance capability in the terminal area of RNP1 or better.

Benefits

The use of an advanced and more accurate navigation technique such as RNAV for approach and departure operations will offer significant noise benefits with respect of current "traditional" routes [D3, annex F]. In fact, RNAV allows to define more flexible flight trajectories, including turning manoeuvres with prescribed radii, based on desired ground tracks.

As an example, RNAV positioning on final approach will bring slight advantages over "radar vectoring" due to the possibilities of performing curved approaches. Such trajectories will produce a narrower overall noise contour around the "nominal" route thus facilitating the avoidance of noise sensitive areas as much as possible.

Moreover, if the RNAV technique is implemented in conjunction with advanced tools and more accurate wind predictors, a better optimisation of the arrival/departure sequences (and therefore capacity) is expected.

Finally, implementing the above outlined scenario, a reduction of controller workload is expected, because it will no longer be necessary to transfer ATC instructions for traffic guidance.

Costs

The implementation of RNAV procedures is a measure that relies on the availability of a certain aircraft equipment level. Benefits will only become evident through the overall noise contour of a specific route implementation.

RNAV implementation requires the following functions to be considered:

- a minimum level of Required Navigation Performance, i.e. accurate navigation and tracking capability,
- curved operation with tracking capability of turns with prescribed radius.

Hence, to design new routes based on the “precise” RNAV (P-RNAV) capability, investments for both ground systems and avionics are mandatory.

In the envisaged medium term scenario it is reasonable to suppose that the P-RNAV will be in operation [EATCHIP 4] and that controllers working at most congested airports will be supported by collaborative decision making tools. Therefore, as anticipated above, typical costs required by this type of equipment cannot be charged specifically to the noise abatement programme.

In case an improvement of RNAV capabilities should be required particularly to cope with noise obligations, the costs for the necessary equipment (e.g. DME-P Precise Distance Measuring Equipment) and avionics have to be considered.

The following table shows the cost data of a DME system (siting, installation and certification costs are not included). All figures are in thousands of Euros (2000):

Equipment	Unit Price	Annual Maintenance & Operating Costs
DME-P	250	25

Figure 15: Price and Maintenance & Operating Costs for a DME.

With respect to the required avionics, the table shows economical data in thousands of EUROS (2000):

Equipment For Commercial Aircraft	Unit Price	Annual Maintenance & Operating Costs
P-RNAV upgrade (differential cost compared with B-RNAV)	383.625	22.443

Figure 16: Prices and Maintenance & Operating Costs for Avionics Equipment

Nevertheless, it is expected that most RNAV based procedures will provide significant noise and efficiency benefits without introducing additional costs attributable to noise needs.

5.5.3.2. Advanced continuous descent approach

The concept of the Continuous Descent Approach (CDA) and the feasibility of an “Advanced” implementation of such a procedure are discussed in deliverable D3.

Benefits

Noise benefits deriving from the CDA implementation are recalled on page 38.

The strong limitation of the larger separation required by the CDA today in operation could be reduced. In fact, in order to minimise the loss of capacity in the medium/long term, it is necessary to modify the operational concept integrating the CDA in the new ATM scenario under development [EATCHIP 4].

Costs

The implementation of the A-CDA concept will be strongly affected by the communication, navigation and surveillance equipment for both ground services and aircraft. The consequence is that pilots and controllers will be influenced by the technological and procedural changes that accompany the introduction of these new concepts.

In the suggested CDA operational concept, controllers only act as monitors and the loss of basic control skills can become a safety issue in case of system breakdown.

However, as mentioned for the RNAV concept, the evolution towards new ATM systems is already in act, independently from noise. Therefore, costs deriving for upgrading ATM/CNS systems cannot be charged on noise abatement procedures.

5.5.3.3. Dual landing threshold

Obviously, to enable dual landing operation, a runway with an adequate length shall be available.

Trials for evaluating this kind of procedure are already under testing at Frankfurt Airport (known as High Approach Landing System / Displaced Threshold Operation Procedure - HALS / DTOP). Such investigation is principally aimed to increase the runway capacity.

However, implementation aspects of applying two ILS (Instrument Landing System) glide slopes simultaneously on the same landing runway have not yet been validated against safety.

Benefits

Since the noise contour produced by approaching aircraft, as a result of the displaced threshold, is merely shifted, the evaluation of noise benefits achieved by this measure require a dedicated study.

Positive effects should become significant if the aircraft category using the displaced runway threshold is the most frequent one for that particular airport.

Other than noise benefits, an increase of capacity is also expected by dual landing operation. In fact, medium/light aircraft can fly behind and sufficiently above the wake of the trailing aircraft, thus allowing closer spacing on the final approach.

Tests performed on Frankfurt airport showed that, distributing a predefined traffic sample between the two runways (thresholds), an improvement in capacity of 4 approaches per hour is obtained.

Costs

The implementation of the procedure under study requires the installation of dual instrument approach equipment, enabling a more dynamic management of the runway in use.

Just to provide a lowest estimation of the ground equipment costs, a rough evaluation of an ILS equipment is provided in the following table. Figures are in thousands of Euros (2000).

ELEMENT	MATERIAL PRICE	INSTALLATION COSTS	Annual Maintenance & Operating Costs
Light emitting visual aids	1472,480	144,243	
Signs	42,071	4,261	
Two-frequency LLZ	204,344	20,434	
LLZ stand	28,248	2,825	
Two-frequency GP	126,213	12,621	
GP stand	28,248	2,825	
Display in TWR	9,015	0,902	
Service setting	40,268	4,0268	13,223.697

Figure 17: Costs for ILS radioelectrical equipment.

Due to the high complexity of the lighting system, any estimation proposed for such a system would be far from reality. Therefore no figures are provided.

From an ATC point of view, the workload of the tower controller should be indubitably greater with respect to the usual “single” threshold operation and, therefore, additional personnel costs are foreseen.

Moreover, if an arrival manager is unavailable, costs for a suitable tool helping controllers in the management of the runway in use, have also to be considered.

5.5.3.4. Increased glide slope angle

Approach procedures based on higher glide slopes (i.e. 3.3° at Naples Airport, 5.5° at London City Airport) are already in operation, with a set of specific restrictions.

The application of an increased glide path angle for a given aircraft type at a constant airspeed in the given landing configuration implies a reduction of the required engine thrust to maintain that constant speed.

In addition, aircraft are required to fly at higher altitudes, thus increasing the distance from the terrain.

Benefits

Since a reduction of the engine thrust implies a reduced engine noise output at the source and since aircraft fly at higher distance over ground, such a measure should reasonably result in a smaller noise footprint below the aircraft.

Another positive aspect to consider is that a 3.5°-4° glide slope, for CAT III approaches, should not present many differences from current practice. Only the steeper descent could require setting the aircraft’s final configuration earlier and, probably, change the flap deployment schedule.

A NAP based on a 4° glide slope was implemented in the Napoli airport scenario. It provided noise benefits without affecting capacity.

Costs

It is mandatory to fly CAT III approaches with the autopilot engaged and major changes should take place in this field. New software is required to adapt its operation to the new requirements.

Being the procedure performed with the autopilot engaged, an increase of the landing distance, with respect to the usual 3 degrees approach, could also affect runway capacity. Nevertheless, the increment of separation between aircraft, during the application of low visibility procedures, would possibly absorb the increment of time taken during the rollout operation.

Most of the investments required for implementing higher glide slope approaches are presented hereafter. Figures are in thousands of Euros (2000).

Concept	Costs
ILS certification	36,061
Modification of the lighting system	166,3055
Service setting	4,027

Figure 18: Ground equipment costs

To verify that the above procedure is flyable and that the new equipment complies with all safety requirements, a long campaign of flight test is still to be performed.

Pilot acceptance of the increased glide slope approach procedure could also represent an obstacle to overcome. At present, pilots seem very reluctant to modify the 3° glide slope. In fact, an experienced pilot does not need an ILS to perform the 3° approach.

A global view of the investigated medium-term procedures is provided in the following table.

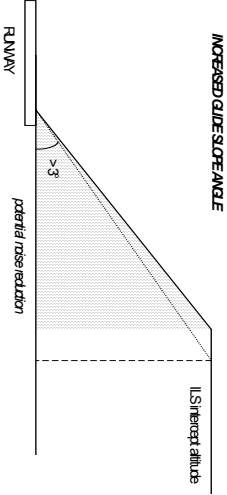
Further studies have to be carried out in order to have more detailed knowledge about the effects deriving from the implementation of the examined procedures.

5.5.3.5. Conclusion

PROCEDURE	DESCRIPTION	ATC ASPECTS ¹¹	UPGRADES OF ATC SYSTEMS
<p>RNAV based departure and arrival routes</p>	<ul style="list-style-type: none"> Application of the area navigation (RNAV) system with Required Navigation Procedure (RNP1) accuracy (or better), in the terminal area. Curved operation with tracking capabilities of turns with prescribed radius. 	<p>OPERATIONAL CONCEPT</p> <ul style="list-style-type: none"> Establishment of new operational concept based on optimum routing to an instrument approach via an extended downwind waypoint. Separation accomplished by RNAV procedures rather than controller intervention techniques (radar vectoring). Pilots and controllers influenced by technological and procedural changes that accompany introduction of new concepts. <p>CONTROLLER WORKLOAD</p> <ul style="list-style-type: none"> Reduction of controller's workload. It will not be any longer necessary to transfer ATC instructions for traffic guidance. Redistribution of the workload between the two controllers' positions (biggest importance of the tactical position). 	<p><u>ATC systems:</u></p> <ul style="list-style-type: none"> Needed DMES. <p><u>Avionics:</u></p> <ul style="list-style-type: none"> Advanced FMS (Flight Management System). RNAV Computer. <p><u>Design:</u></p> <ul style="list-style-type: none"> Design new routes. <p><u>Training:</u></p> <ul style="list-style-type: none"> Pilots and Controllers training.

¹¹ "ATC constraints" has been used as a parameter to analyse the new procedure respect to the current ones. In this assessment, the controllers workload and his perception of the new procedure has been taken into account.

PROCEDURE	DESCRIPTION	ATC ASPECTS ¹¹	UPGRADES OF ATC SYSTEMS
<p>Advanced use of Continuous Descent Approach</p>	<ul style="list-style-type: none"> Requires uninterrupted descent without horizontal segments from an initial altitude to the runway. 	<p>OPERATIONAL CONCEPT</p> <ul style="list-style-type: none"> Arrival Manager predicts 4D descent trajectory. Flight Path is constantly monitored and updated. Arrival Manager negotiates directly with the FMS of the aircraft via datalink. Optimal scheduling and sequencing of aircraft trajectories. <p>CONTROLLER WORKLOAD</p> <ul style="list-style-type: none"> The workload is effectively reduced (ground-air voice communications reduced). 	<p><u>ATC systems:</u></p> <ul style="list-style-type: none"> Arrival manager that contains: arrival time predictor, sequencer, 4D-Descent Manager and approach problem solver. Trajectory Predictor. Conflict Probe. Flight Path Monitor. Negotiation Manager. <p><u>Avionics:</u></p> <ul style="list-style-type: none"> Advanced FMS. Control Display Unit (data-link included). <p><u>Design:</u></p> <ul style="list-style-type: none"> Design new routes. <p><u>Training:</u></p> <ul style="list-style-type: none"> Pilots and Controllers training.
<p>Dual Landing Threshold</p>	<p>DUAL THRESHOLD OPERATION</p>	<ul style="list-style-type: none"> Traffic segregation by ATC between normal and displaced threshold. Workload of the tower controller will be increased. 	<p><u>ATC systems:</u></p> <ul style="list-style-type: none"> Sequencer. Arrival manager (including flight data processing). Additional runway lighting and a separate ILS (only GP) and PAPI (Precision Approach Path Indicator) shall equip the new runway (displaced threshold). New marks and lights will assure the difference between the two thresholds.

PROCEDURE	DESCRIPTION	ATC ASPECTS ¹¹	UPGRADES OF ATC SYSTEMS
<p>Increased Glide Slope Angle</p>	 <p>Reduction of the required engine thrust to maintain that constant speed. In addition, the aircraft will fly over the ground at a higher altitude thus increasing the distance (altitude).</p>	<ul style="list-style-type: none"> Missed approach number could be higher (A/C will fly less time in their final landing configuration). Landing distance (from threshold) is greater because flare height increases. Airliners and pilots will not wish to have more than two approach procedures and it would not be suitable to have different glideslopes at one or even at different airports. 	<p><u>ATC systems:</u></p> <ul style="list-style-type: none"> ILS certification. Modification of the lighting system. Necessity of increased runway lengths. <p><u>Avionics:</u></p> <ul style="list-style-type: none"> Certification of the FMS (new software). Testing the Flight Envelope. <p><u>Design:</u></p> <ul style="list-style-type: none"> Design new Instrumental Approaches procedures. <p><u>Training:</u></p> <ul style="list-style-type: none"> Pilots training.

5.6. Dissemination

Noise is becoming a critical issue for air transport, and the efforts spent and the achieved results in this domain must be largely disseminated. The Sourdine partners are aware of the importance of dissemination issues within the European scientific community and so, all the deliverables of Sourdine have a public level of dissemination. At the end of the project, all the deliverables will be gathered on a CD-ROM.

A first presentation (of partial results) was made at the "Transport Research Conference, Paving the way for sustainable mobility", in Lille, in November 1999.

The Sourdine results were shared with the members of the X-NOISE Cluster and its dissemination means were used. In particular, a presentation was performed in Dublin on 14th December 99 by Javier Perez Diestro (INECO).

Moreover, the Sourdine partners organised a dissemination workshop on the 12th March 2000, inviting all potentially interested European bodies, e.g. JAA, ECAC (European Civil Aviation Community), ICAO, ACI (Airports Council International), Ministries of Transport, IATA (International Air Transport Association)... More than 200 invitations were sent out leading to some 60 positive answers. The workshop presented, in a summarised form, all the results of the study, together with recommendations for future work.

A small glossy was produced in large quantities to further promote the merits of the Sourdine project.

WHEN	WHAT	WHO	WHERE	CONFERENCE / PUBLICATIONS
8-9/11/99	Transport Research Conference, Paving the way for sustainable mobility	Stéphane Paul	Lille	ISR-MGT-W6-014
14-15/12/99	X-Noise workshop	Javier Perez Diestro	Dublin	INE-W6-MGT-027
12/04/00	Dissemination workshop	All	Massy	

European industries, whatever their area of application, will have the possibility of using the results of Sourdine. The dissemination policy (through the opening of a WEB site - at the NLR) provides the capability, for organisations and countries which could not be included in the proposals, but have expressed interest in the considered research topics, to access the technical information produced by the Sourdine project and carry out fruitful exchanges with the partners involved.

ASP (Pierre Lempereur) already used some of the Sourdine results during ICAO meetings aimed at defining the future noise standards in air transport. It is felt that there will be many more such occasions to reuse the Sourdine study results.

6. Conclusions and future plans

To achieve the contradictory objectives of increasing capacity and reducing environmental impact, new operational procedures and supporting technologies need to be introduced.

The SOURDINE project was conceived as the first stage of a long-term programme for the reduction of noise around airports. The final outcomes of this programme will be the definition and the assessment of new approach and take-off procedures for all European airports supported by the adequate federation of simulation tools. The automation tools required to assist the end-users (pilots and controllers) in the utilisation of the new procedures also need to be defined.

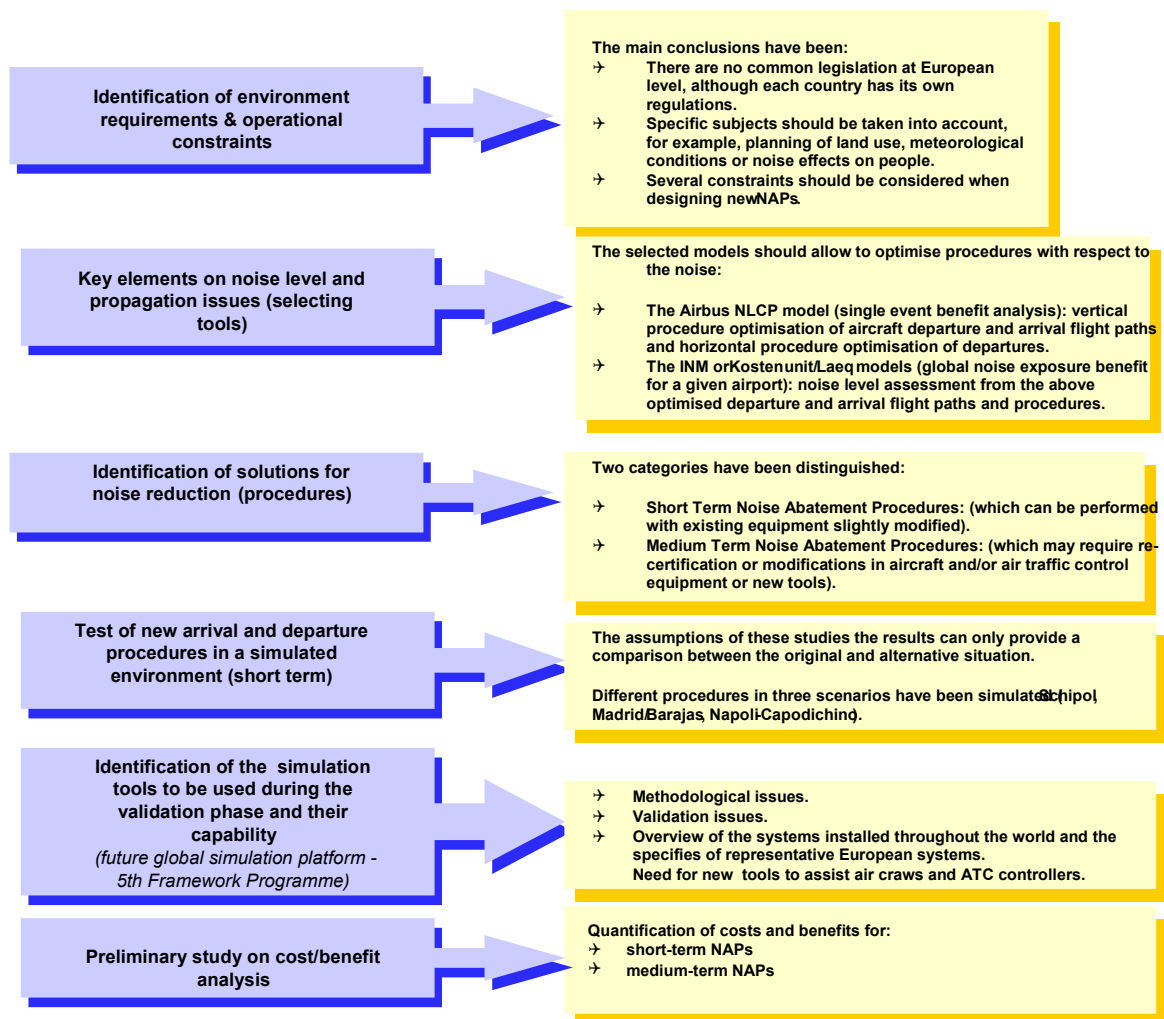


Figure 19: Sourdine method and findings

SOURDINE has achieved the following objectives:

- make an inventory of the regulations and practices concerning aircraft noise, and study the operational, safety, capacity and economical constraints that might influence the definition of new procedures,
- select a set of noise models (amongst the current tools) that allow the optimisation and evaluation of noise abatement procedures and define the frame of the parametric studies to be performed,

- propose alternatives to reduce noise levels around airports:
 - a method for updating the existing approach and take-off procedures for short-term improvement (based on present-day avionics and ground systems and applicable to most of the existing aircraft) was elaborated,
 - innovative procedures for medium-term noise reduction taking benefit from new airborne and ground technologies (GNSS, RNAV, MLS, Enhanced FMS...) were investigated,
- define new procedures for three selected airports (Schiphol, Madrid and Napoli), considering the feasibility of such procedures,
- provide qualitative effects in noise reduction to demonstrate to the community and investors that it is worth investigating in this domain,
- identify simulation tools and their capability of being integrated in a global simulation platform, with the objective of carrying out the operational validation of the new procedures within the 5th Framework Programme,
- define noise measurement systems and automation tools for assisting operators (pilots, controllers, airport personnel) in their decisions,
- involve end-users (i.e. pilots, controllers, handling agents...) in the preliminary validation of the concepts,
- perform a cost benefit analysis (see §5.5 on page 35).

Figure 19 shows the methodology and the findings at each step. Results coming from the Sourdine project have to be viewed as preliminary results for a future implementation, providing only a first investigation of all the work to be carried out.

6.1. Conclusions on noise abatement procedures

The flight procedures evaluated in Sourdine for the short-term were:

- increased final approach altitude,
- (slightly) increased glide slope angles,
- delayed flaps and/or gear approaches,
- reduced final landing flap settings,
- continuous descent approach.

The conclusions of Sourdine with respect to the short-term procedures have shown significant benefits in terms of noise and capacity (see §5.3.3 on page 27). The procedures, and in particular the increased ILS interception altitude and continuous descent approaches, are worthy to be validated in a real environment to confirm and refine the fast time and real time simulation measurements with “in-situ” measures. The experience acquired in Sourdine could be used to build up a full-scale optimisation programme having the on-site implementation of the validated procedures as final objective. This objective would require the participation of airports, civil aviation authorities and airlines willing to involve real aircraft in the experiment.

In the medium-term, the potential for noise abatement lies in:

- advanced operation of continuous descent approach,
- application of increased glide slope angles,
- approach and departure routes using precision navigation,
- gradual increase of cutback thrust during climb out.

For the medium-term, the solutions investigated¹² could bring potential benefits thanks to the capability of flying routes fitting more rigorous requirements. In fact, the development of RNAV routes, supported by enhanced navigation systems, should provide new means to adapt current SIDs and STARs to the local geography, while maintaining the required navigation performance.

The objective for a follow-up would be to perform preliminary simulations on these medium-term procedures, in a manner similar to the one followed for the short-term procedures in Sourdine. For these procedures, before starting the on-site operational testing, the potential benefits should be assessed, through modelling and simulation, against:

- safety,
- technical / operational / certification constraints,
- efficiency/capacity,
- crew/controller workload,
- economical aspects,
- airport layout,
- fleet mix typically operating to/from that airport

These objectives would require the adaptation and/or development of new tools (see below) and therefore the participation of the industry (software and aircraft manufacturer), research laboratories, airports, civil aviation authorities and airlines.

Taking into account the process outlined above, the result of the noise programme (for short and medium-term) should be a set of validated recommendations to be considered while designing the flight procedures of the 2000+ air traffic scenario. Such recommendations would facilitate the compliance with operational and certification requirements, thus achieving the best possible solution, balancing on one side the technical feasibility of the procedure and on the other, the noise and efficiency / capacity benefits.

6.2. Conclusions on noise models and simulation tools

Sourdine has shown several limitations in the existing tools to develop new noise abatement procedures taking into account all the parameters and constraints i.e. noise benefits, flight safety, efficiency and capacity and last but not least, economical aspects.

To assess the potential noise benefits of one specific procedure it is necessary to develop a common and validated noise-modelling tool and to use harmonised noise indicators. The current noise models implement different algorithms and the noise information for each type of aircraft is usually implemented by means of performance and Noise Power Distance (NPD) databases as a function of engine power and the shortest distance to the aircraft flight track.

Several problems have been identified:

- the figures of the NPD curves hide significant effects such as the aircraft configuration in terms of flap setting, undercarriage deployment as well as an assumed aircraft speed and attitude;
- the aircraft manufactures normally are very reluctant to provide the specific details;
- flight path information is not reliable (due to lateral dispersion) and thus actual radar tracking values should be used;
- local temperature and humidity effects are not taken into account;
- the performance data usually corresponds to straight-out or straight-in flight tracks without the inclusion of turns.

¹² All the proposed procedures have been considered according to the overall ATM/CNS Gate-to-Gate concept.

In the framework of the Sourdine project, the flight paths have been simulated from aerodynamic, geometry and performance databases specific to each Airbus aircraft model, however, the same type of information was unavailable from other manufacturers (such as Boeing). Research work should be conducted in order to obtain high quality data from the aircraft manufacturers (aircraft performance) and operators (flight tracks and operational data). The idea is not to develop a new model, but to improve the input data and some of the algorithms included in the model to take into account for instance the meteorological effects, the lateral attenuation, etc.

The existence of sophisticated noise monitoring systems in some European airports (Madrid-Barajas, Schiphol...) encourages a full scale modelling trial at a number of selected European airport in order to obtain high quality data to be submitted to the selected noise model.

The definition of a validated noise modelling tool, together with a valuable database relating to the European fleet mixes and operating conditions, are the main objective of the Eurocontrol Enhance project (results are expected for Spring 2001). The co-operation already in act between the Sourdine consortium and the Enhance team should ensure a reciprocal interchange of technical information with the scope to avoid useless duplication of efforts and take advantage of a wider community of experienced people.

Once a reliable model is available, the impact of implementing a new noise abatement procedure should be assessed taking into account that simulated results are closely related to the real environment data.

6.3. Towards more dissemination and co-ordination

Sourdine has organised a dissemination workshop where quite a large audience was represented. However, apart from IATA and AEA (Association of European Airlines), it should be noted that most of the participants were (more or less) directly involved in noise abatement or noise modelling studies. Participants from aircraft equipment suppliers, the ATC (air traffic control) or A-SMGC (Advanced Surface Movement Guidance and Control) worlds were scarce. If noise abatement procedures are to be applied in everyday control, then the industry must be involved in the loop to design tomorrow's on-board and ground tools.

On a short-term basis, a good example of that are the AMAN (arrival manager) tools. The current generation of AMAN performs some sequencing with poor reactivity to the real traffic: manual interaction is still the rule. The ARAMIS project made a first step in precise TTA (Target Time of Arrival) assignment to inbound aircraft with a fine modelling of meteorological conditions and aircraft performance in approach configuration. The algorithms, data and man-machine interfaces required for continuous descent approach are quite different from the standard approach; their inclusion in the next generation of AMANs will only be possible if the need for such tools is clearly specified to the system providers.

On a longer term, the same could be said about the FMS and other heavy or expensive on-board or ground equipment.

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