



EUROPEAN COMMUNITY  
COMPETITIVE AND SUSTAINABLE  
GROWTH PROGRAMME



# SOURDINE II

## D4-1

### Report on the global results of WP4

Project acronym: SOURDINE II  
Project full title: "Study of Optimisation Procedures for Decreasing the Impact of Noise II"  
Project number: GRD2-2000-30105  
Contract number: G4RD-CT-2000-00394  
Start date: 12 November 2001  
Duration: 45 months

Sourdine II Consortium:

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## Document Change Log

Release	Author	Affected Sections / Comments	Document Nature	Date
0.1	Aena, Alfredo Gómez de Segura	All, Creation	Confidential	19/09/05
1.0	Aena, Alfredo Gómez de Segura	All, Creation	Confidential	12/04/06
1.1	Aena, Alfredo Gómez de Segura	All, included comments by NLR	Confidential	27/06/06
1.2	Aena, Alfredo Gómez de Segura	Acknowledgment of comments by the EC (Executive summary)	Confidential	05/07/06
1.3	Aena, Alfredo Gómez de Segura	All, included comments by AIF	Confidential	07/08/06
1.4	Aena, Alfredo Gómez de Segura	Final draft	Confidential	24/08/06
2.0	Aena, Alfredo Gómez de	EC approved version	Public	04/09/06

## Document Distribution

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## Review and Approval of the Document

Organisation Responsible for Review	Reference of comment documents	Date
AIF	E-mail	7/08/06
Organisation Responsible for Approval	Name of person approving the document	Date
Project Manager	Ruud den Boer	27/06/06
Work Package Leader	Pablo Sánchez Escalonilla	27/06/06
EC Official	Morten Jensen	31/08/06

Document Information	
Document title	D4-1 Report on the global results of WP4
Version	V2.0
Date	31-08-06
Classification	Public
Work package	WP4
Document identification	SII_WP4_D4.1_Report_On_The_Global_Results_V2.0

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## Executive Summary

The following sub-sections provide the detailed summaries of the studies performed for Capacity, Safety, Noise & Emissions and Cost Benefit Analysis (CBA). More complete summaries and details about each study are included in the corresponding sections of this document. For a complete reference of all of the documents used to compile D4.1, please refer to Appendix 6 of this document. Section 1, the Introduction, of this document describes Procedures II, III, IV, V and II-A that are referred to in the following paragraphs.

### Capacity Results

The capacity assessment was carried out within the Sourdine II activities for a series of new noise abatement arrival procedures that included the airports of Madrid-Barajas, Naples-Capodichino, Amsterdam-Schiphol and Paris-Charles de Gaulle and provided the general conclusions about the impact on the airport capacity of the new Sourdine II Noise Advanced Abatement Procedures.

The capacity assessment focused exclusively on the arrival noise abatement procedures designed by the Sourdine II Project. The two departure procedures were also produced but these were similar to the ICAO-A procedures for departures and no capacity problems were foreseen due to the implementation of these procedures in the airport.

Basically, four Noise Abatement Procedures (NAPs) for arrivals were analysed and compared with a conventional 3000ft arrival procedure defined within the baseline scenario. The Sourdine II procedures were based on data provided by Airbus and was simulated in each airport situation in 2015.

The Introduction (Section 1) of this report includes a brief description of the four arrival procedures that were considered.

Two platforms had been used to validate the new set of procedures from the capacity point of view: Total Airport and Airspace Modeller (TAAM) and Airport and Airspace Simulation Model (SIMMOD). They had been used as the fast time simulation (FTS) tools for the different phases of the Sourdine II project. Amsterdam-Schiphol, Paris-Charles de Gaulle and Madrid-Barajas airports validation activities used TAAM for simulation purposes. Naples Capodichino airport selected SIMMOD as the FTS platform to validate the new procedures.

There was a decrease in the arrival airport capacity when NAAPs designed within Sourdine II were implemented in the airport. However, for the traffic foreseen for the year 2015 in the four airports considered in this analysis, there existed no sustained capacity problem. The airports seemed to have problems accommodating the same traffic demand as in the baseline scenario, but these problems were solved in the following hours without causing a great deal of average delay.

Arrival procedure V and II were the most promising procedures in terms of capacity. The Sourdine II procedures II and V were affected by an increased arrival delay caused by the extended separation required to compensate the speed differences between aircraft types. The more speed differences between aircraft types, the more separation was needed. This would affect the arrival delay in a negative way.

- A variant of Procedure II, called Procedure II-A, had been analysed in Amsterdam-Schiphol airport. Procedure II-A was basically procedure II with some speed constraints that increase the homogeneity between speed profiles during approach. Because of the minor speed differences between the speed profiles of the different aircraft types, the performance of this procedure was more in line with the baseline scenario. The speed constraints were selected in such away that all aircraft were able to fly the profile (deduced from a generic CDA).

The Sourdine II procedures showed significant speed differences between the speed profiles defined for each aircraft type. These differences implied extended separation between successive aircraft to comply with the separation criteria within the TMA. The extended separation was calculated during the pre-processing of the simulation. The results showed a consistent increase in arrival delay for the

proposed procedures. The more speed differences between aircraft types during the approach segment, the higher the arrival delay due to extended separation used.

In the baseline scenario there was an extensive use of speed control to adjust separation between successive aircraft and comply with the wake turbulence separation criteria. In the Sourdine II scenarios, from the beginning of the CDA to the runway, controllers should not apply either speed control or holding or vectoring. This means that if the separation based on wake turbulence must be secured; the separation between different aircraft at different stages of the approach would be biased with respect to the baseline scenario.

The Sourdine-II procedures II, III and V were affected by an increased arrival delay. This increase of arrival delay was mainly caused by the extended separation required to compensate the speed differences between aircraft types. Procedure IV showed a significant reduction of performance and capacity. Within this procedure aircraft have to fly the final approach speed (FAS) over the last 15NM.

As a consequence, with the current TMA structure, controllers did not have enough space to sequence the aircraft to the beginning of the CDA:

- ❑ An AMAN was necessary: not only to optimise the arrival sequence before the beginning of the CDA, but also, to calculate the suitable speed for each aircraft in order to optimise separations.
- ❑ Sequencing and speed control actions should begin further away from the airport than in the Baseline scenario.
- ❑ TMA structure should be modified and adapted to the necessities derived from implementing the CDAs in the airport.

The study has shown that the distribution of a fleet mix will influence the performance of the ATM system considerably. A consistent fleet mix does provide positive performance effects of the ATM system. The lower the aircraft type consistency (and therefore speed profile consistency), the more capacity problems occur.

## Safety Results

The safety assessment procedures that were analysed for this report included approach Procedure II-A used at the Schiphol Airport and approach Procedure V and departure Procedure 2 used at the Barajas Airport.

A complete detailed safety analysis would have been a very demanding effort. Therefore, only part of the four approach and two departure procedures were identified to fall within the scope of the detailed safety evaluation. To accomplish such a selection, an initial high-level safety evaluation of all six procedures was first done. It should be noted that these procedure definitions did not include an embedding of the procedure within an operation.

The safety assessment evaluated the approach Procedure II-A for Schiphol Airport by using five conflict scenarios that described ways in which an accident or incident could occur. The risks scenarios were classified as TOLERABLE, NEGLIGIBLE, or UNACCEPTABLE.

Any uncertainty in the results was related to the use of data retrieved from experts who assessed a future operation by using their experience to extrapolate information using the current operation to fill in the details of the operational description that still remained to be specified due to the scarceness of statistical data on model parameter values.

The outcome of the safety assessment for approach Procedure V on Barajas airport revealed a series of safety significant issues that have been recommended for further analysis. A distinction was made between issues related to the inherent characteristics of the Sourdine II approach Procedure V and those for which the particular parallel runway set-up was the determining factor when performing simultaneous and independent Continuous Descent Approaches (CDAs) for both runways.

The qualitative safety assessment showed that the Sourdine II approach Procedure V adapted to the future Barajas Airport parallel runway configuration exhibits some safety significant issues that are in need of a more detailed and quantitative analysis.

The Sourdine II departure Procedure 2 used at the Barajas Airport aimed at reducing the noise impact around the Standard Instrument Departure (SID) footprint closest to the runway, causing the aircraft to operate at reduced performance with One Engine Inoperable (OEI) power settings. The safety assessment has shown that the most significant risks associated with the Sourdine II departure Procedure 2 at the Barajas Airport were due to either engine loss or sudden adverse meteorological conditions that could impair the aircraft airworthiness. However, it has been determined that aircraft could recover from these situations despite flying at reduced power settings and therefore, the procedure would not degrade safety margins.

## Noise & Emissions Results

For this part of the study the Sourdine II procedures were analysed and compared with a conventional 3000ft arrival procedure defined within the baseline scenario, plus specifically for the Schiphol and Madrid-Barajas scenario with current approach procedures.

The Sourdine II Procedures II, III, IV, V and II-a were based on data provided by Airbus and were simulated in each airport situation in 2015.

An analysis was performed using a version of the US FAA's Integrated Noise Model, especially developed by the FAA to cover the needs of the Sourdine II project, with special data supplied both by Airbus and, with funding from NASA, Boeing. This data did not, however, cover the entire fleet at CDG and various substitutions had to be made to enable representative noise analysis.

Also a study has been conducted calculating the variation in the population impacted by noise based on the different procedures used, both for Noise Abatement Departure Procedures (NADPs) and Noise Abatement Arrival Procedures (NAAPs). This study was performed for the Madrid-Barajas scenario for which the necessary population density information was available.

The results showed that:

1. All SII procedures noise benefits have been identified compared to a baseline procedure that was already optimised (FMS approach). It should be noted that this FMS Baseline approach procedure is far less noisy than current approaches.
2. The Sourdine II arrival procedure, which features an increased final glide path angle, (Procedure III) provided the greatest benefit.
3. The distribution of the fleet mix would influence the shape of the noise contours considerably (i.e. unbalanced use of runways).
4. Noise assessment conclusions were the same (i.e. slight differences depending on fleet-mix flow) for all scenarios.
5. Major noise benefits were mainly determined by higher altitudes for approaches while for departures on the thrust settings.

The two departure procedures studied had different aims; one to reduce noise close to the airport and the other one to reduce noise further away. The results of the noise analysis showed that the "close-in" procedure was beneficial only within 3.5NM immediately after the end of the runway, whereas the "distant" procedure provided benefits from 2.5NM after the runway end.

## Framework for Cost Benefit Analysis of NAPs

All major airports have addressed the issue of environmental management or management performance in a sustainable way. Some airports link environmental management closely to necessary compliance with rules and regulations or simultaneously assessment of cost and benefits. However, many of them only do what is required and financially beneficial. That's the reason why a cost benefit analysis is a requirement when a new concept, or new procedure or a new element is introduced in the complex ATM system and that's the reason why a CBA has been planned even in the SII project case.

As a first step the SII CBA methodology has been developed providing guidelines to the SII project, identifying the required input, the case studies, the actors involved, the cost and benefit categories and how to make the final economic assessment. Later the proposed methodology was applied on the SII project on the basis of input collected from other SII WPs (WP4 and WP6) and expert opinions. During the SII CBA some deviations from the original and real methodology had to be done, because not all of the required inputs were available. The results and inputs available from other WPs allowed making a preliminary framework for developing future CBA for NAPs, providing some first ideas about who can benefit and who will have to pay and for what. Further studies are then required to assess a complete picture of costs and revenues, allowing a real financial analysis and giving input to stakeholders on possible choices.

Concerning some preliminary qualitative results, the SII NAPs implementation requires an increase in the equipment and training costs for Airlines and ANSPs. The SII NAPs could generate a loss of capacity during peak hour operations and thereby an increase in the delays that translate into costs for Airlines, ANSPs and Airport Operator Companies. On the other side the reduction in the noise contours sizes, generated by the SII NAPs, is beneficial for the Airport Operator Company and people living around airports. Airport Operators could save money in insulations programs for houses (or other noise reduction programs) and improve the relationship and the discussions with people living in the airport surroundings. For the people living in the airport surroundings the SII procedures can improve their quality of life by reducing the noise impact.

The environmental capacity, meaning the sustainable capacity of an airport being compatible with the environmental requirements, it's clear that the introduction of the SII NAPs allows an increase in capacity guaranteeing the safeguard of the environmental parameters that is a benefit for airlines, ANSPs and Airport Operator Company.

More work is required for making a preliminary CBA analysis and in this case it is highly recommended to define and agree the validation strategy at the beginning of the project and clearly define all data requirements for the simulations. Besides this it is also important to identify all possible risks for the availability of the data and assess the impact of missing data for the validation assessment. When using data from various sources the consistency of the input data should be guaranteed; in the SII project case different input data were available for each NAP and for each airport, not allowing having a complete picture of effects (positive and negative) of each NAP. Last but not least there should be a plan how to translate input data into monetary terms and consult (external when required) experts in an early stage to retrieve this kind of information, as soon as clear requirements are available.

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## 1. Introduction

### 1.1. Background

The goal of the Sourdine II project was to define new approach and departure procedures for noise reduction around airports. With the continuing growth of air traffic as well as the ever-increasing level of urbanisations around most airports in Western Europe, the impact of aircraft noise and emissions on the quality of life for the surrounding communities has become a serious issue that needs to be addressed. Many European airports already face the conflicting problems of increasing their airport capacity to meet the amount of traffic and the increasing pressure from the general public to reduce the environmental impact of the increased traffic volume especially in the areas of noise and emissions. This has already resulted in specific local constraints to the operation of aircraft, not only around major airports such as Schiphol, Gatwick or Frankfurt, but also more regional airports are experiencing the pressure to impose constraints on aircraft movements. Reducing the noise levels for the community is a serious issue facing the airline transport industry if the projected sustained growth is to be pursued.

By modifying or optimizing the operations and traffic flow of aircraft around the airport, it should be possible to achieve a reduction in the noise levels. In Work Package 3 of the Sourdine II project, many new noise abatement procedures were defined [S II D3.1-1]. All of these procedures were assessed with respect to their noise impact by executing very accurate single event simulations for the A320 and the A340 aircraft [S II D5.3]. Based on these simulations, apart from a baseline approach procedure and a baseline departure procedure, four approach procedures and two departure procedures were selected for further evaluation [S II D3.1-2]. All six procedures were flown with Precision Area Navigation (P-RNAV).

The four approach procedures were Continuous Descent Approach (CDA) procedures. Each of these procedures used either a fixed three-dimensional flight path or a vertical flight path that was flown at a constant speed. The configuration flown by each procedure varied according to the procedure that was followed. One of the procedures included a steeper final approach path.

A brief description of the four arrival procedures considered:

- Procedure II: **Basic CDA with 2 degrees initial FPA with a 3 degrees ILS path and a variable speed profile.** This procedure follows a fixed 2-degree path angle from 7000ft up to ILS intercept at 3000ft. The aircraft decelerates at idle thrust in clean configuration during this part of the flight, deploying the cleanest possible landing configuration.
  - Procedure II-A, a variant of Procedure II, was only analysed at Amsterdam-Schiphol Airport. Procedure II-A was basically procedure II with some speed constraints that increased the homogeneity between speed profiles during the approach. Because of the minor speed differences between the speed profiles of the different aircraft types, the performance of this procedure was more in line with the baseline scenario. The speed constraints were selected in such a way that all aircraft were able to fly the profile (deduced from a generic CDA).
- Procedure III: **CDA with 2° initial FPA and increased final glide slope (4°).** The difference between procedure II and procedure III is the steeper flight path angle on the ILS (3° proc. II vs. 4° proc III).
- Procedure IV: **CDA with constant speed, variable FPA segment at landing configuration.** The procedure is largely flown, from 7000ft to ILS intercept, with idle thrust and in landing configuration.

- Procedure V: **CDA with constant speed, variable FPA segment at intermediate configuration.** The procedure is similar to procedure n° IV, with the difference that the variable FP is the result of an idle thrust descent from 7000ft to ILS intercept on an intermediate landing configuration.

The departure procedures considered were optimised versions of the noise abatement procedures NADP1 and NADP2 of ICAO. One of these procedures aimed at decreasing the noise level close to the runway ('optimised close-in'). The other procedure tried to reduce the noise level further away from the runway ('optimised distant').

The "Report on the Global Results, D4.1", includes the results of the different areas that have been studied with regards to the level of noise and emissions along with the possible solutions analysed from the four approach procedures and two departure procedures. The areas of interest included capacity, safety and noise and emissions and a cost benefit analysis (CBA). The specific details for each of these areas are discussed in separate sections of this report including the methodologies used for each study, a summary of the results, and the conclusions reached that were based on actual experiments. Each specific area also described the procedures and the airports used for the particular study. These include Naples-Capodichino, Madrid-Barajas, Amsterdam-Schiphol and Paris-Charles de Gaulle airports.

## 1.2. Document Contents

This document (D4.1) describes the global results of WP4 activities developed within Sourdine II project. Since WP4 activities comprised capacity, noise, emission, safety and CBA assessments this document objective is to be a wrap-up document of all the work done inside WP4. It therefore only describes WP4 results and not for example WP6 (real time simulation) results. Other deliverables generated by the Sourdine II Project, as D7-2 (Comparative Analysis of Results) and D9-1 (Final Report), will provide the overview of all assessment results (including also those not considered inside WP4).

This report includes the following information that is included within the section indicated.

Section 1: Provides the introduction of this report and provides a description of the general assumptions and hypothesis for this study.

Section 2: Contains the the project geographical and time scope

Section 3: Includes all of the information obtained from the study on Capacity carried on within Sourdine II activities of a series of new noise abatement arrival procedures on Madrid-Barajas, Naples-Capodichino, Amsterdam-Schiphol and Paris-Charles de Gaulle airports.

Section 4: Includes all of the results of the Safety Assessment study and summarises the safety analyses performed for the six-noise abatement procedures defined in [S II D3.1-2].

Section 5: Includes the information obtained from the report on the Noise and Emissions Evaluation.

Section 6: Includes the information about the Cost Benefit Analysis (CBA).

Appendices: Provides all of the appendices associated with this report including reference documents, definitions, and methodologies used for each study.

### **1.3. General Assumptions and Hypothesis**

As the main scope of the Sourdine II project was to assess the design and promote new noise abatement procedures to decrease the impact of noise on the population surrounding the airport and to assess the impact on capacity and safety by inserting new procedures into the different airports analysed within the project (specifically in SII project Madrid-Barajas, Paris Charles de Gaulle, Amsterdam Schiphol and Naples Capodichino) all of the components of the system not directly related with the analysed procedures were modelled in such a way so that the noise and emissions and capacity results were clear and were not biased. Thus, the possible noise and emissions, capacity and safety benefits were strictly due to the implementation of the new procedures designed specifically for the Sourdine II project.

The sections on capacity and noise and emissions also include assumptions and hypothesis that were very specific to those areas. The general assumptions and hypothesis used by the noise and emissions, capacity and safety assessments included the following:

#### **I. Airport modelling**

The airport system had been modelled in such a way that no element apart from the procedures could influence the envisioned benefits of the noise procedures.

#### **II. Wind and weather modelling**

The simulation had been carried out with nominal weather condition. No wind had been taken into account.

#### **III. Aircraft equipment**

All aircraft were supposed to be RNAV equipped. Simulations had been carried out under Vector and P-RNAV environment.

In 2015 Madrid-Barajas, Schiphol, Charles de Gaulle and Naples expect to operate within a full RNAV environment. Vectoring based approaches within the baseline scenario would be closer to current practises, but in order to maintain consistency among the simulations all simulations were carried out under P-RNAV conditions. This resulted in less lateral track deviation as well.

#### **IV. Parallel runways, same CDA in both arrival RWYs**

The CDA approaches selected by Sourdine II had been adapted for each airport environment. The design of the procedures could not be segregated from the control technique that they intended to use. In this aspect SII meant a huge conceptual change, since the operational concept eliminated the possibility of issuing control instructions – speed control and vectoring-after the point of initiation of the CDA manoeuvre.

Currently, simultaneous approaches to parallel runways should maintain at least 1000ft of vertical separation before entry to the Non-Transgression Zone (NTZ). During the simulations, the same CDAs were inserted in both parallel runways, even though this meant that the vertical separation was not maintained at the entrance of the NTZ. This was applied to all FTS scenarios with at least two arrival parallel runways: Madrid, Amsterdam, and Paris.

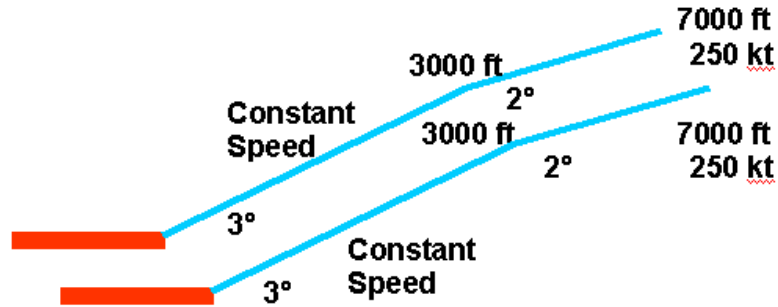


Figure 1-1: CDA Approaches for parallel runways

**V. Vertical profile**

All the aircraft inside each of the previously described groups flew the same vertical profile for each single procedure.

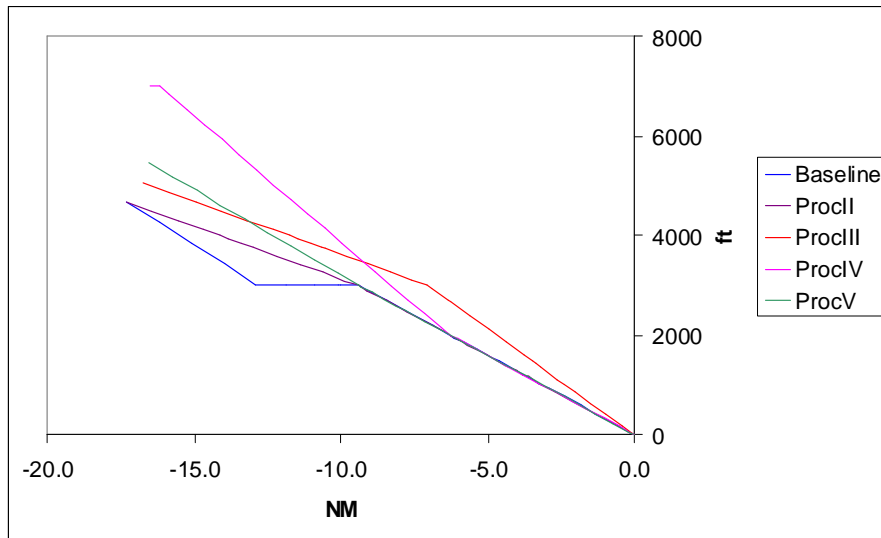


Figure 1-2: Souridine II procedures vertical profiles

## 2. Project Scopes

### 2.1. Geographical Scope

In the Sourdine II (SII) Project, one of the most important points was the application of the set of NAAPs to four different airports.

The four airports selected were: Madrid-Barajas, Naples-Capodichino, Amsterdam-Schiphol and Paris-Charles de Gaulle airports. The different environments and dimensions of the selected airports demonstrated the validity of the new NAAPs for different airport types and validated the SII concept for the ECAC area. In the simulation scenarios not only the airport had been taken into account but also the TMA structure expected in 2015. Basically, a series of scenarios consisted of noise abatement procedures for arrivals were analysed and compared with a conventional 3000ft arrival procedure defined within the baseline scenario. Each of the Sourdine II procedures was provided as a speed and vertical profile versus the distance with respect to the runway threshold. These speed and vertical profile were adapted to the horizontal paths in each airport and TMA expected for the year 2015.

The specific airports described in Sourdine II were classified into three categories: large (Paris-Charles de Gaulle), medium (Amsterdam Schiphol and Madrid Barajas) and small (Naples Capodichino). Table 2-1 describes each of the airports analysed in Sourdine II Project. Table 2-2 shows the projected airport configurations for the year 2015.

	Small airports	Medium airports	Large airports
<b>Layout</b>	Only one concrete	Usually, only one concrete	Usually, more than one concrete runway
<b>Traffic</b>	90% VFR - 10% IFR	80% IFR - 20% VFR	In principle, only IFR
	No capacity problems	Distribution not even along day	Operated with declared capacity
	Usually domestic flights	Domestic and international flights	Domestic and international flights
	Cat A, B and C aircraft	Cat A, B and C aircraft. D possible	Any category of aircraft
	Accessible to IFR flights	Accessible to VFR flights	
<b>Procedures /Airspace</b>	Generally IFR approach procedures based on NPA	Usually, ILS available only on one QFU	Normally, NPA and PA available on several QFU's
	Basic airspace	NPA procedures on other QFU	Usually CAT-III procedures implemented on several QFU's
	Class D CTR	Usually, a CTR and a TMA	Runway schemes to balance environmental impact
	Usually quite high minima		Complex airspace structure
			A TMA with one or more CTRs
		Associated airports	
<b>Air traffic control</b>	Very limited ATC services	Limited ATC services	Full radar service available
	No ATC aiding tools	Generally radar services available	Controller tools available

**Table 2-1: Airport Classification**

Airport	Runways	2015 Operations	Procedures
<b>Madrid-Barajas</b>	2 set of parallel runways: 33L & 33R FOR ARRIVAL 36L & 36R FOR DEPARTURES	885 Arrivals Traffic load slightly unbalance 10% Turboprops	RNAV Speed Control, Holding, No Vectoring
<b>Paris-Charles de Gaulle</b>	4 parallel independent runways: External for ARR (26L & 27R) Internal for DEP (26R & 27L)	1108 Arrivals 589 North (27R) / 519 South (26L) 3% Turboprops	RNAV
<b>Amsterdam-Schiphol</b>	4 runways: Inbound for ARR (18R & 18C) Outbound for DEP (18L & 24)	910 Arrivals 10% Turboprops	RNAV
<b>Naples-Capodichino</b>	1 runway (24-06): 100% of ARR RWY24 74% of DEP RWY24 / 26% RWY06	304 TOTAL 152 Arrivals 22% Turboprops	Conventional

**Table 2-2: Sourdine II Configurations of Airports**

As will be shown in this document, the percentage of turboprops (slow aircraft) has an important influence on the capacity impact for each airport.

Figure 2-1 shows the Sourdine II Airport Scenarios for Madrid-Barajas and Paris-CDG.

Figure 2-2 shows the Sourdine II Airport Scenarios for Schiphol and Naples.

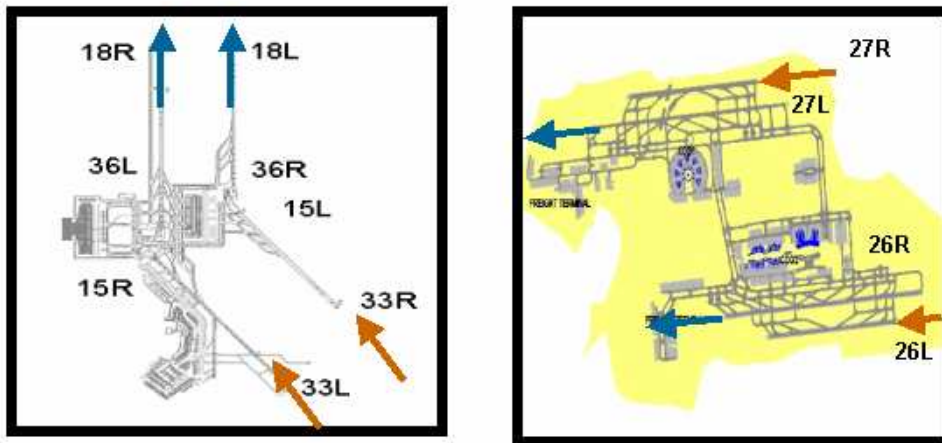


Figure 2-1: Sourdine II Airport Scenarios Madrid-Barajas & Paris-CDG

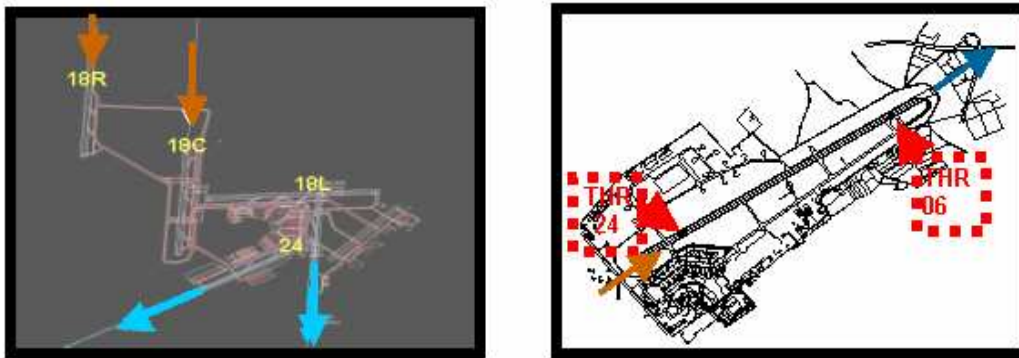


Figure 2-2: Sourdine II Airport Scenarios Schiphol & Naples

## 2.2. Time Scope

### 2.2.1. Time Scope

The year 2015 was used as the timeframe for all of the scenarios including the baseline scenario.

The flown traffic database provided a set of six months of the most recent traffic data available (year 2001 or 2002) in order to select a representative day of traffic. From this traffic data, a representative day was chosen, together with the current airspace rules, to calibrate the simulation model to ensure that simulation results were sensible and that the model represented a realistic situation.

In order to obtain a realistic traffic sample, a set of criteria had been established to exclude days from the analysed period that would distort the traffic sample due to the following causes: Industrial actions, staff shortages, technical problems, runway accident or work on runways, security threats, humanitarian/military actions, temporary reductions in some approach capacity, bad weather, etc.

The methodology for acquiring the representative 2001 day depended on the airport traffic pattern and on the kind of traffic involved in each TMA. Table 2-3 shows some of the points considered when selecting the reference day.

<b>Airport Regular Traffic</b>	Assess the relevant TMA / APP sector type of traffic.
	Select the most regular months.
	Eliminate extraordinary days.
	Evaluate the daily average hourly distribution.
	Select the most similar day, the best-correlated day.

**Table 2-3: Airport Regular Traffic**

This representative day (year 2001 or 2002) was then used as a basis to extrapolate a final baseline and SII concept traffic sample for the simulations (year 2015)

Changes in fleet mix and aircraft motorization foreseen for 2015 had been taken into account to obtain the final traffic samples. High predictions STATFOR forecasts from EUROCONTROL had been used to generate 2015 traffic samples. For each airport the traffic (operations/day) was increased progressively in order to obtain enough data to perform a realistic capacity assessment.



## 3. Capacity Results

### 3.1. Introduction of Capacity Results

The goal of this sub-section is, on one hand, to summarise the different results derived from the capacity assessment carried out within Sourdine II activities that include a series of new noise abatement arrival procedures performed at Madrid-Barajas, Naples-Capodichino, Amsterdam-Schiphol and Paris-Charles de Gaulle airports. On the other hand, this section tries to provide general conclusions about the impact on the airport capacity of the procedures designed within Sourdine II activities.

This assessment carried out through three main phases of fast time simulation (FTS) trials (a detailed description of each phase is included in this section):

- Pre-calibration
- Calibration
- Baseline vs. Sourdine II procedures
  - Preliminary data obtained for A320 and A340
  - Refined data for A319, A320, A321, A330 and A340

This section is exclusively focused on the final capacity assessment results obtained for the baseline scenario and Sourdine II scenarios with the final set of data. The rest of the phases are extensively described in the individual simulation report of each FTS site.

The capacity assessment has been focused exclusively on the arrival noise abatement procedures designed by Sourdine II Project. This choice can be justified taken into account that the approach procedures, due to their aircraft dependant speed and/or vertical profile, are much more critical regarding capacity than the departure procedures. Two departure procedures were also produced but they are similar to the ICAO-A procedure for departures. Preliminary analysis showed that no capacity problems are foreseen due to the implementation of these procedures in the airport.

Basically, four Noise Advanced Abatement Procedures (NAAPs) for arrivals were analysed and compared with a conventional 3000ft arrival procedure defined within the baseline scenario:

- **Baseline FMS approach procedure:** This procedure has a standard vertical flight path, with a level segment at 3000ft, during this last part of the flight path deceleration is performed, making this procedure quite competitive and better than standard approach procedures.

The Sourdine II procedures were based on data provided by Airbus and the procedures were simulated in each airport for the situation for the year 2015 based on R-NAV trajectories.

A brief description of the four arrival procedures considered:

- Procedure II: **Basic CDA with 2 degrees initial FPA with a 3 degrees ILS path and a variable speed profile.** This procedure follows a fixed 2-degrees path angle from 7000ft up to ILS intercept at 3000ft. The aircraft decelerates at idle thrust in clean configuration during this part of the flight, deploying the cleanest possible landing configuration.
- Procedure III: **CDA with 2° initial FPA and increased final glide slope (4°).** The difference between procedure II and procedure III is the steeper flight path angle on the ILS (3°proc. II vs. 4° proc III).
- Procedure IV: **CDA with constant speed, variable FPA segment at landing configuration.** The procedure is largely flown, from 7000ft to ILS intercept, with idle thrust and in landing configuration.

- Procedure V: **CDA with constant speed, variable FPA segment at intermediate configuration.** The procedure is similar to procedure n° IV, with the difference that the variable FP is the result of an idle thrust descent from 7000ft to ILS intercept on an intermediate landing configuration.

Validation activities have been carried-out here through fast time simulations in order to get a first valuation of the expected results in terms of airport capacity.

Two platforms were used to validate the new set of procedures from the capacity point of view: TAAM from Preston Aviation Solution and SIMMOD from ATAC Corporation. These have been used as the fast time simulation tools for the different phases of the Sourdine II project. Amsterdam-Schiphol, Paris-Charles de Gaulle and Madrid-Barajas airports validation activities used TAAM for simulation purposes. TAAM is a fast time simulation tool, based on a gate-to-gate concept. It is a continuous simulator that stores information every time step defined by the user. It simulates the gate-to-gate concept including a very realistic model of the airport, TMA and en-route environment. It works building 4D flight plans and contains a very powerful rule base that can be developed by the user depending on their specific needs. Using TAAM it is possible to run multiple iterations of the same scenario, with certain model parameters and characteristics randomised to reflect the spread of such characteristics in real-life operations.

Naples Capodichino airport selected SIMMOD as the FTS platform to validate the new procedures. SIMMOD is a discrete-event simulation model; it represents a system evolving over time by means of a mathematical model, the state of which changes at discrete points in time. These points are those at which an event occurs, where an event is an instantaneous occurrence that changes the state variables. SIMMOD is a stochastic model, meaning that it uses random variables to represent day-to-day variations in air traffic phenomena. Because SIMMOD is designed to produce realistic results from any iteration of a defined application dataset, it is usually necessary to run several iterations with a single dataset in order to account for iteration-to-iteration variability.

The Fast Time Simulation expresses the behaviour of the real world element that is being validated in a mathematical model that defines the relationships between the input and output variables. Fast time techniques are especially suitable for a preliminary assessment of a new ATM operational concept. Since fast-time techniques can never completely represent the actions of a human operator their application lies mainly in the earlier stages of the validation life cycle.

### 3.2. Specific Assumptions and Hypothesis of Capacity Results

As the main aim of the Sourdine II project was to assess the impact on capacity by inserting new procedures into the different airports analyzed within the project all of the components of the system that were not directly related to the analysed procedures should be modelled in such a way so that they would not cause a bottleneck for the airport capacity. Thus, the possible loss or gain in capacity was strictly due to the implementation of the new procedures designed within the Sourdine II project.

In addition to the general assumptions and hypothesis presented previously in Section 4 of this report, the specific assumptions and hypothesis made during the capacity assessments for the Madrid-Barajas, Paris Charles de Gaulle, Amsterdam Schiphol and Naples Capodichino airports included the following:

#### I. Airport Modelling

The airport system had been modelled in such a way that no element apart from the procedures could mean a bottleneck from the capacity point of view.

TAAM simulations, FTS partners decided not to take into account any limitation regarding taxi system, aprons and gates, ATC workload, sector capacity, etc. In order to reach this objective, the airport has been modelled as a runway system with no taxi centrelines or gates.

SIMMOD required the modelling of these elements (taxi system and gates). Taxi system and gates will be modelled in a way that they will not mean the least efficient component of the system and then limit the capacity figures of the system.

## II. Iterations per Scenario

In order to achieve a high statistical confidence on the simulation results, each partner involved in FTS exercise had to run a specific number of iterations per scenario. Both for TAAM and SIMMOD, running **10 iterations** per scenario was sufficient to obtain significant results.

## III. Aircraft groups based on FAS and Wake turbulence criteria

The timetable used in the final fast time simulation trials contained 7 aircraft types: A319, A320, A321, A330, A340, F50 and MD11. The rest of the fleet mix foreseen in 2015 was adapted to these groups based on Final Approach values (FAS) and wake turbulence criteria. The speed profiles used for the F50 and the MD11 were deduced from the A320 and the A340 respectively.

The Sourdine II procedures showed significant speed differences between the speed profiles. These differences implied extended separation between successive aircraft to comply with the separation criteria within the TMA. The extended separation was calculated during the pre-processing of the simulation. The results showed a consistent increase in arrival delay for proposed procedures. The more speed differences between aircraft types during the approach segment, the higher the arrival delay due to the extended separation used. For those aircraft with different motorization available, the most common ones for the year 2015 were selected.

## 3.3. Scenarios and Traffic for Capacity Results

### 3.3.1. Type of Experiment Performed for Capacity Results

The capacity assessment of the new NAAPs designed within Sourdine II activities was developed based on relative and quantitative experiments. Basically, a series of capacity metrics and indicators were obtained from Sourdine II scenarios (with noise abatement procedures for arrivals implemented) and compared against results obtained by a baseline scenario (with a conventional arrival procedure with a level band at 3000ft). This method provided information about the possible gain or loss in terms of airport capacity if the Sourdine II procedures were implemented in each of the four airports.

### 3.3.2. Level of Detail for Capacity Results

Determining the performance of a new ATM concept was only of value when modelling was performed with a great level of detail. The emphasis of this study was put on the difference between the Sourdine II scenarios and a Baseline scenario with respect to delay, performance and capacity. In order to ensure reliable results, constraints were kept to a minimum, and unnecessary elements were discarded. The main reason to discard elements was to ensure transparency among the results and minimise any negative influences on the procedures. Due to the assumptions and hypothesis described above, modelling was in line with an intermediate level of detail.

## 3.4. Metrics and Methodology Used for Capacity Results

Some outputs of the capacity assessment are the indicators and metrics established in the SII Validation Methodology. The main metrics and indicators calculated in the SII project for the capacity assessment are:

- Airport throughput:

Measurements of the airport throughput (divided in landings and take-offs to/from SII airport) for a given time interval.

- Total delay for each aircraft.

Specification of the total delay for each aircraft (divided in arrivals and departures to/from SII airport): departure delay and arrival delay. Also, calculation of the average arrival delay per operation.

- Percentage of delayed aircraft.

Specification of the percentage of delayed aircraft (divided in arrivals and departures) within a defined delay range for a given time interval (hourly and daily).

- Arrival Airport capacity

Specification of the arrival capacity as the maximum number of arrival operations that each airport can manage per hour with a maximum tolerable delay value.

### **3.4.1. Methodology to Assess Airport Capacity**

The following points briefly explain the methodology agreed upon by the consortium to assess the capacity impact of inserting the new procedures designed within the Sourdine II project for each FTS site.

- Establish the maximum tolerable delay value
- Increase the traffic sample
- Calculation of the average delay per hour
- Report the average delay per hour vs. Number of movements per hour
- Choose the best tendency curve
- Intersection between the curve and the selected maximum tolerable delay value

For further details on the methodology for calculations refer to Appendix A2.

## **3.5. Simulation Results for Capacity Results**

A brief summary of results obtained during the capacity assessment was presented in this section. The emphasis of the capacity assessment was to analyse the effects of the Sourdine II arrival procedures in the airport capacity, hence, the results were focused exclusively on arrivals.

The issues described were as follows:

- Airport arrival throughput
- Cumulative & average arrival delay
- Average arrival capacity
- Number of delayed arrivals

These metrics and indicators were obtained for Sourdine II scenarios and compared against those obtained from the baseline scenario described before. Not all of the sites analysed the whole set of arrival procedures designed within the Sourdine II activities and, consequently, results for certain procedures were not available.

Some of the graphs included in the following section intend to be an example of the type of simulation results obtained from the four airports involved in the Sourdine II Project. A detailed simulation report produced for Madrid-Barajas, Amsterdam-Schiphol, Naples-Capodichino and Paris-Charles de Gaulle included the whole set of results for each airport.

### 3.5.1. Airport Arrival Throughput

The following table indicates the average arrival throughput as movements/hour for each Sourdine II procedure. In order to give an idea of the sustainability, the maximum throughput values and average values during peak hours were mentioned (max / avg). The average numbers were calculated taking into account different peak hours.

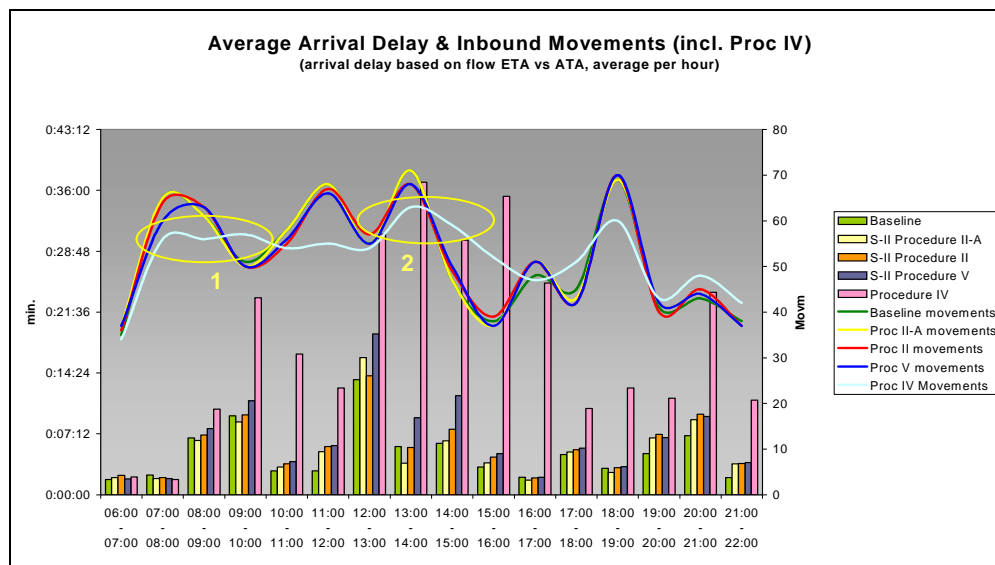
MAXIMUM / AVERAGE ARRIVAL THROUGHPUT (Movements/hour)					
Airport	Baseline	NAP II	NAP III	NAP IV	NAP V
Madrid	36 / 35	35 / 33	35 / 33	34 / 32	35 / 32
Paris-CDG	40 / 38	38 / 38	38 / 38	x	39 / 38
Amsterdam	36 / 32	35 / 31	x	34 / 29	34 / 30
Naples	16	16	x	15	15

**Table 3-1: Maximum/ Average Arrival Throughputs**

The first conclusion made was that although during peak periods the Sourdine II scenarios seem to have had problems accommodating the same traffic demands as in the baseline scenario. These problems were solved in the following hours without causing a big amount of average delay (see Figure 3-1). Procedure IV seemed to have a more negative effect on airport arrival throughput than the rest of the procedures.

So, the simulations do not envision a dramatic loss of arrival capacity for any of the airports considered in the year 2015.

As an example, Figure 3-1 shows the inbound movements and the arrival delay for Amsterdam-Schiphol airport. The period was distributed over one hour. Within this chart it was important to compare these results with the baseline scenario. The baseline movements were considered as the “planned” movements, during comparison.



**Figure 3-1: Inbound Movements and Arrival Delay ( Schiphol )**

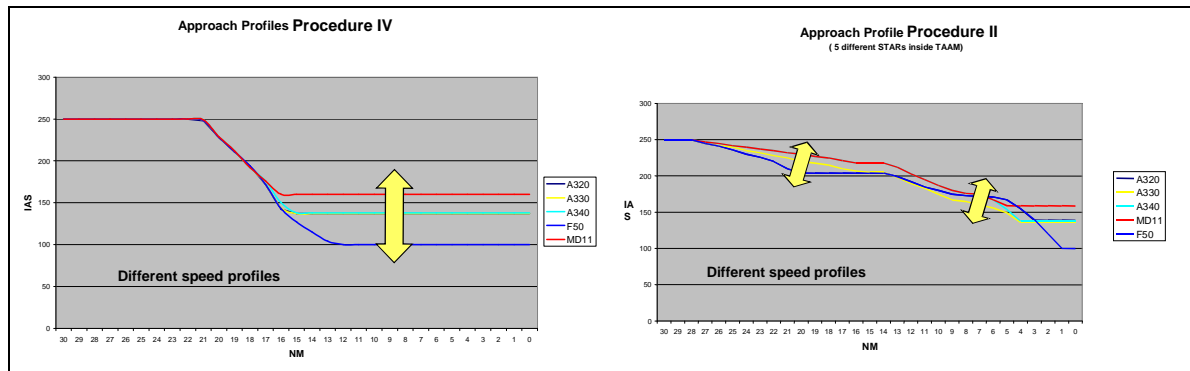
Procedure II, III and V seemed able to cope with the traffic demand, and show more-or-less a similar behaviour as the baseline. Procedure IV showed a deviated pattern: due to the bigger speed differences between aircraft types flying Procedure IV. Additional separation was needed between successive aircraft at the beginning of the CDA.

In the Baseline scenario, there was a homogeneous distribution of speed profiles between the different aircraft models. Controllers applied speed constraints to the aircraft at certain points during the approach (for example ILS interception, beginning of the level segment, etc.) to smooth separations between the aircraft on final approach. The controller actions to provide and optimise separation between aircraft from the TMA entry to the RWY included:

- Speed control.
- RNAV diversions (No vectoring is applied).
- Holding.

There was also an extensive use of speed control to adjust separation between successive aircraft and comply with the wake turbulence separation criteria. This was especially significant in the level segment before the ILS interception.

On the contrary, in the Sourdine II scenarios, and due to the definition of the CDAs, there were bigger differences between speed profiles for the different aircraft models considered. For example, in the Procedure IV, where the aircraft had to fly the FAS over the last 15 NM, the differences in flight time over the same distance between F50 and A340 were very important. The more differences in speed between different aircraft types, the more separation was required between them.



**Figure 3-2: Different speed profiles Procedure IV vs. Procedure II.**

In the Sourdine II scenario were the same as in the Baseline scenario. However, once the aircraft began to fly the CDA to the runway, they could not apply either speed control or holding or vectoring. That meant that if the separation based on the wake turbulence had to be secured, the separation between different aircraft at different stages on the approach would be spoiled with respect to the baseline scenario.

Figure 3-3, below, shows a slower aircraft (for example a F50) trailing a faster aircraft (for example a A340) flying one of the Sourdine II arrival procedures. When the A340 was beginning the CDA, the F50 had to be separated by at least 5 NM due to wake turbulence safe separations. Since during the CDA the speed profile was fixed, the initial separation grew along the time and at the end instead of 5 NM there is 7,45 NM.

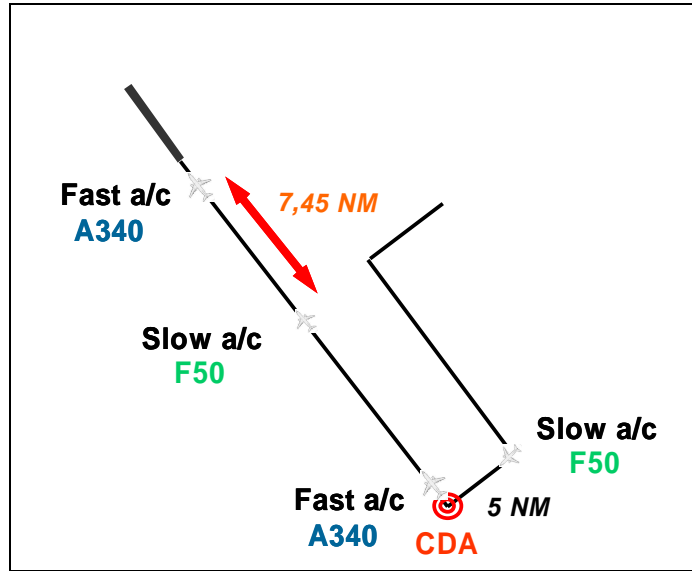


Figure 3-3: Slow aircraft trailing a fast aircraft

Figure 3-4, below, shows a faster aircraft (for example a A340) trailing a slower aircraft (for example a F50) flying the same procedure as that in Figure 3-3. On the runway threshold they should have maintained at least 3 NM. That means that the separation between aircraft at the beginning of the CDA should have been increased to avoid over takings or violation of separation during the approach.

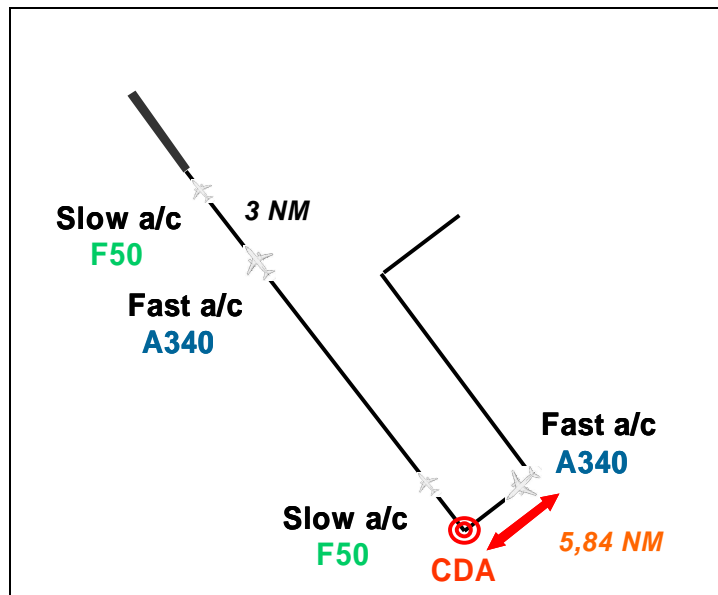


Figure 3-4: Fast aircraft trailing a slow aircraft

### 3.5.2. Cumulative & Average Arrival Delay

The Average Arrival Delay provided the sum of the recorded delay per each hourly time band divided into the number of arrival operations registered during that time band, while the Cumulative Arrival Delay provided, hour per hour, delay cumulated until that moment of the day. Both metrics were calculated for the NAAPs designed in the Sourdine II Project and compared against those obtained in the Baseline scenario.

The following table indicates the average arrival delay (minutes) for each Sourdine II procedure and the Baseline scenario:

AVERAGE ARRIVAL DELAY (Minutes)					
Airport	Baseline	NAP II	NAP III	NAP IV	NAP V
Madrid	1,8	3,9	3,6	4,6	3,8
Paris-CDG	3,0	3,2	3,3	x	3,3
Amsterdam	3,9	4,9	x	8,6	5,6
Naples	2,7	2,9	x	4,4	3,7

**Table 3-2: Average Arrival Delay**

The Sourdine II NAAPs generated delays greater than those generated in the Baseline scenario in the four airports considered in the Project.

As explained in the previous section, this happened because the new NAAPs required an increase in the separation distance between successive arrival aircraft with respect to the same situation in the Baseline scenario since safe separation distances (i.e. wake turbulence criteria) had to be maintained along the approach, from the beginning of the CDA to the runway threshold. As a general rule, the more speed differences between aircraft types flying the same arrival procedure, the more separation was needed.

This was especially significant for the NAAP IV, since in that case the aircraft reached the FAS very early (around 15 NM to the runway threshold) and, from that point, it flew at a low speed to the runway, forcing the trailing aircraft to increase its separation distance before starting the CDA. This explains why the NAAP IV provided the biggest delay value of all of the sets of NAAPs for all of the airports considered within the Project (regardless their size or layout).

The rest of the NAAPs provided bigger delays than the Baseline scenario, but not as significant as in Procedure IV.

The fleet mix also caused the amount of arrival delay. The fleet mix determined the performance of the ATM system by reducing disturbances within the traffic flow. The more the consistency of aircraft types within a traffic flow, the less extra separation was required due to the speed differences. Therefore, it was clear that changes with respect to the fleet mix would also have implications in the results. It was therefore worth mentioning that results would be interpreted in context with the assumptions made, especially those related to aircraft groups created in order to run the simulation exercises. These assumptions are described in chapters 1.3 and 3.4 of this document, and more detailed description is found within the individual report simulation for each airport (Madrid-Barajas, Amsterdam-Schiphol, Naples-Capodichino and Paris-Charles de Gaulle).

Figures 3-5 and 3-6 show the average and cumulative delays obtained for Naples-Capodichino airport during fast time simulation exercises.

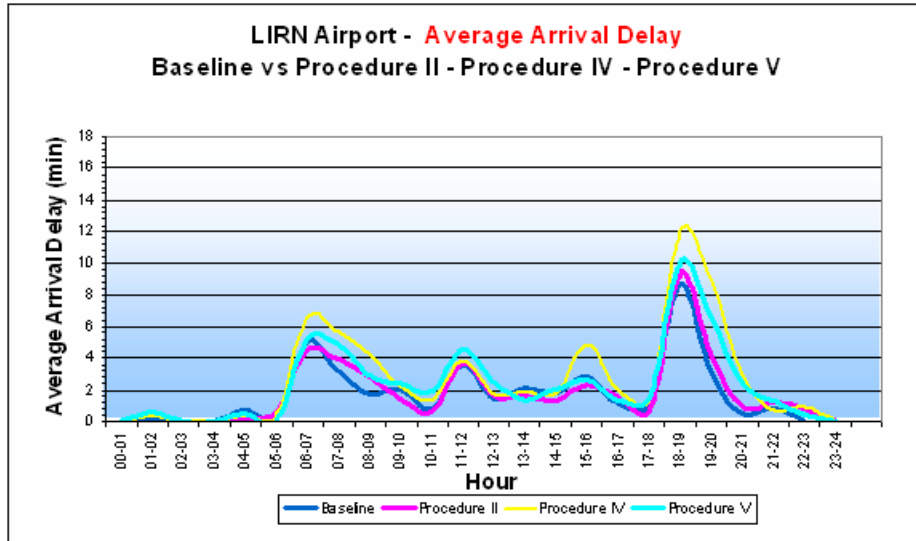


Figure 3-5: Average Arrival Delay (Naples)

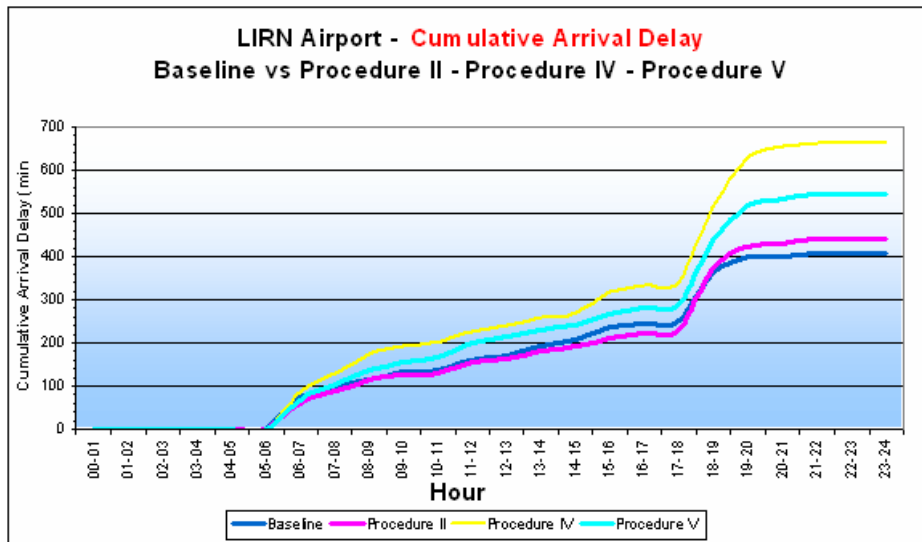


Figure 3-6: Cumulative Arrival Delay (Naples)

Figures 3-5 and 3-6 confirm a negative effect of NAAPs on arrival delay, in particular Procedure IV that generated the worst cumulative and average delays of all the set.

**3.5.3. Average Arrival Capacity**

The obtained capacity figures were based on the methodology for capacity calculation, agreed upon within the consortium (see Appendix 2). The capacity calculation stated by Sourdine-II provided an exponential trend line based on the average delay per hour (dividing the total amount of delay generated during each hour between the number of operations) and the number of movements. From the baseline scenario the tolerable delay value per hour for arrivals was calculated for each airport.

This value was based on 10±1 minutes. In order to have had a good estimation of the capacity impact of the new procedures, the traffic sample was progressively increased.

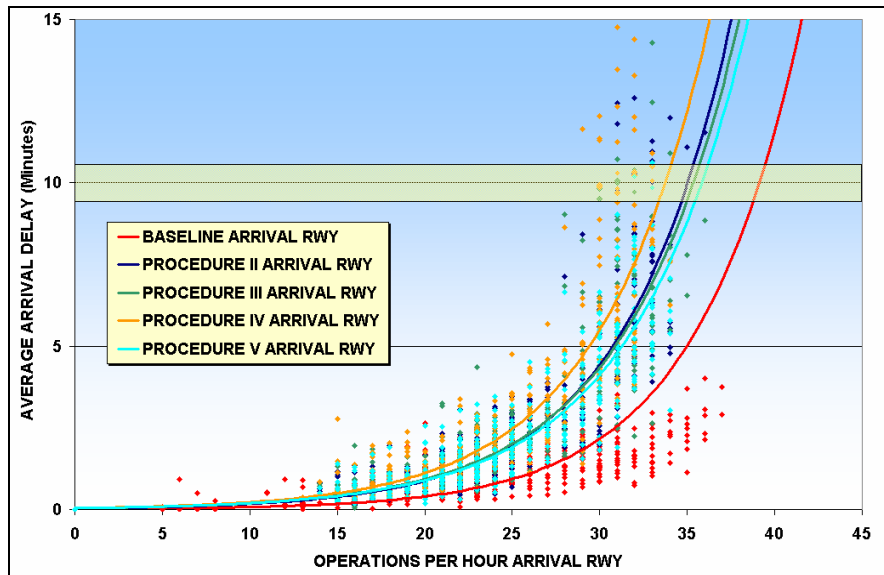
The following table provides the arrival capacity figures obtained for each airport and scenario applying the methodology described in Appendix 2.

ARRIVAL CAPACITY					
Airport	Baseline	NAP II	NAP III	NAP IV	NAP V
Madrid	78-80	70-72	70-72	68-70	72-74
Paris-CDG	81-83	80-82	80-82	x	80-81
Amsterdam	72-74	69-71	x	59-61	66-68
Naples	31-33	30-32	x	28-30	30-32

**Table 3-3: Arrival Capacity**

All the arrival procedures designed in the Sourdine II Project meant a loss of arrival airport capacity. This was especially significant for Procedure IV, where aircraft flew at the Final Approach Speed (FAS) at a very early stage during the approach. The same reasons that explained the increment in the arrival average delay and in the airport throughput also explained this reduction on airport capacity.

Figure 3-7 shows the way these capacity figures were obtained. e.g. Madrid-Barajas.



**Figure 3-7: Arrival Capacity (Madrid-Barajas)**

### 3.5.4. Number of Delayed Arrivals More Than 10 Minutes

The following table indicates the percentage of arrival operations delayed more than 10 minutes over their expected time of arrival for each airport and each scenario. Naples-Capodichino results were not available since the simulation tool used in that case (SIMMOD) did not provide that information.

NUMBER OF ARRIVALS DELAYED MORE THAN 10 MINUTES (%)					
Airport	Baseline	NAP II	NAP III	NAP IV	NAP V
Madrid	2%	11%	10%	14%	12%
Paris-CDG	2%	3%	3%	x	2%
Amsterdam	11%	17%	x	36%	20%

Table 3-4: Average Arrival Delay

The histogram showed in Figure 3-8 provides the percentage of arrival operations delayed within one-minute periods for all the NAAPs considered and the Baseline scenario, e.g. Madrid-Barajas airport.

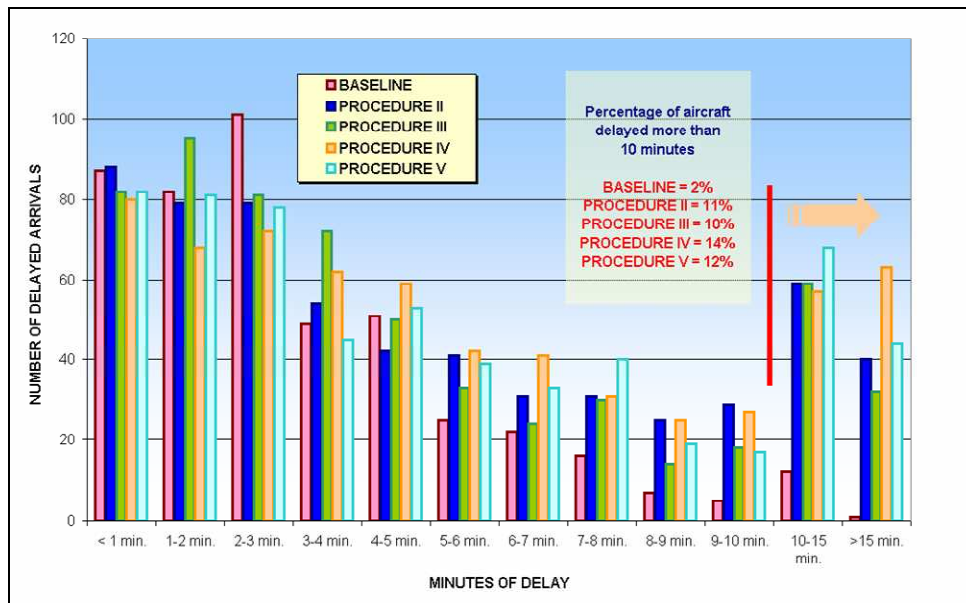


Figure 3-8: Number of Delayed Arrivals (Madrid-Barajas)

In the baseline scenario, most aircraft were affected by an arrival delay of between 0-5 minutes. The more the delay distribution was built up, the less the number of affected aircraft. However, for the Sourdine II procedures, especially in case of Procedure IV, the percentage of delayed aircraft seemed to increase as the delay distribution increased. All of the Sourdine II procedures required an additional separation between successive aircraft since once the aircraft began the CDA the speed control should not have been applied to tune the in trail separations. That means that if the minimum separation could not be fulfilled by means of speed control before the beginning of the CDA or applying RNAV diversion, the controllers could only send the aircraft into a holding state. Therefore, the number of holdings increased and a holding meant usually an extra delay per aircraft.

### 3.6. Conclusions

These conclusions describe the capacity and delay results obtained during Fast Time Simulation exercises over a set of four SII Arrival procedures compared against the results obtained by a baseline scenario (a “do-nothing” scenario in 2015).

There is a decrease of the arrival airport capacity when NAAPs designed within Sourdine II are implemented in the airport. However, for the traffic foreseen for the year 2015 in the four airports considered in this analysis, there exists no sustained capacity problem: airports seem to have problems to accommodate the same traffic demand as in the baseline scenario, but these problems are solved in the following hours without causing a big amount of average delay.

In Sourdine II procedures, speed control may not be used between the beginning of the CDA and the runway, therefore:

- Spacing between successive arrivals is less refined than in the baseline scenario.

#### 3.6.1. Departure Procedures

The two departure procedures produced by Sourdine II have different aims: one to reduce noise close to the airport and one further away. Both of them are similar to the ICAO-A procedure for departures. Preliminary analysis showed that no capacity problems are foreseen due to the implementation of these procedures in the airport. Wake turbulence separation criteria and the location of the divergence point between departure routes for each runway/airport are far more critical from the capacity point of view than the differences in the speed and/or vertical profile between those departure procedures.

### 3.7.

#### 3.7.1. Arrival procedure II, III and V

The Sourdine II procedures II, III and V are affected by an increased arrival delay respect to the baseline scenario<sup>1</sup>.

This increasing of arrival delay is caused by the extended separation required to compensate the speed differences between aircraft. The more speed differences between aircraft types, the more separation was needed in order to maintain minimum safe separation between successive aircraft (e.g. wake turbulence). This increase of separation affects arrival delay negatively and therefore arrival capacity decreases.

- A variant of Procedure II, called Procedure II-A, has been analysed in Amsterdam-Schiphol airport. Procedure II-A is basically procedure II with some speed constraints that increase the homogeneity between speed profiles during approach. Because of the minor speed differences between the speed profiles of the different aircraft types, the performance of this procedure is more in line with the baseline scenario. The speed constraints were selected in such away that all aircraft were able to fly the profile (deduced from a generic CDA).

#### 3.7.2. Arrival procedure IV

Procedure IV obtained the worst results in terms of delay and capacity of all the set of arrival procedures considered in SII Project.

Procedure IV has significant speed differences, especially FAS values, between the slower aircraft (e.g. F50 FAS 100kts) and the faster aircraft (e.g. A340 FAS 139kts) and, in this procedure, aircraft have to fly the FAS over the last 15NM before the runway threshold. Flying at the Final Approach Speed at a very early stage has a negative impact on spacing and therefore on capacity.

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<sup>1</sup> It should be emphasized that the increased flying time in SII procedures is not part of the calculated delay.

The arrival separation is increased at 30NM from the runway threshold to achieve wake turbulence separation at the runway:

- Differences between speed profiles are bigger than in the rest of scenarios, specially in the baseline scenario, where controllers usually apply speed constraints.
- At the end, more separation means less capacity.

### **3.7.3. Final Conclusion**

There is a decrease of the arrival capacity for the presented Sourdine II scenarios. However, for the traffic foreseen for 2015 there exists no sustained capacity problem. Arrival procedure V appears to be the most promising procedure in terms of capacity.

The results in terms of capacity and delay of the implementation of the four SII arrival procedures in the four airports have been obtained with a realistic fleet mix. Besides all the Airbus models whose data were available, MD11s and F50s were also included within the simulation scenarios in order to take into account the importance of the effect of fleet mix and the speed differences between different aircraft types flying the same procedure.

Afterwards, and looking at the results obtained, it can be stated that including a more realistic fleet mix was of great importance in this study. The main results obtained in this study have shown that the composition of the fleet mix may influence the performance of the ATM system significantly when implementing these CDAs. The speed differences between aircraft types can be considered as a major problem when introducing CDAs within a high traffic dense environment: The more speed differences between aircraft types, the more separation needed in order to maintain minimum safe separation between successive aircraft (e.g. wake turbulence). This increase of separation affects arrival delay negatively and therefore arrival capacity decreases.

A consistent fleet mix does provide positive performance effects of the ATM system: the more the consistency of aircraft types occurs within a traffic flow, the less extra separation is required due to the speed differences. For example, taking into account two similar airports like Charles de Gaulle and Schiphol (both 4 runways), the different percentage in turboprops (slow aircraft) in their fleet mix (3% for Charles de Gaulle and 10% for Schiphol) explains the differences in capacity reduction obtained: the less the aircraft type consistency (and therefore speed profile consistency as well), the more capacity problems will occur.

When standard approach procedures are being flown, ATC guides the aircraft with speed control and radar vectoring to the ILS-localiser in such a way that the separation criteria during approach and on final are met. It is not important for the expected time of arrival to a runway threshold to be equal to the actual time of arrival, as long as the separation is guaranteed. The planning system takes care of the fact that not too many aircraft enter the TMA and the landing interval is based on the separation criteria on final applied at that time. During a CDA, the situation is different; here the air traffic controller is expected not to intervene. Therefore, the landing time is in this situation in the hands of the pilot, who is unaware of the preceding and trailing aircraft.

It is expected that tools like Controller Pilot Data-link Communications (CPDLC), Arrival Manager (AMAN), Departure Manager (DMAN), Area Navigation (RNAV), Adapted Flight Management System (FMS) and/or engine control systems, etc.. will be necessary in order to enable ATC / ATFM to ensure separation, integrate arriving traffic flows, separate departing from arriving traffic and achieve an optimal sequence without 'spoiling' the noise abatement procedure.

During Fast Time Simulations, It has been found that the director sector does not have enough space to sequence the aircraft at the beginning of the CDA. Thus, an AMAN would be required, as well as a device to calculate the suitable speed for each aircraft to optimise separations. Other requirements would be to begin sequencing and speed control actions at a higher altitude (FL240) or to change the TMA structure (extended TMA).

The lack of speed control between the beginning of the CDA and the runway leads to less refined spacing between successive arrivals. An increased arrival separation at 30NM from the runway threshold is required to achieve the necessary wake turbulence separation at the runway. Including

some speed constraints along the procedure (variant II-A) could cause less capacity reduction, increasing the homogeneity between speed profiles of the different aircraft types during approach.

The lateral location of the inbound trajectories might be interesting as well for further analysis. For each aircraft speed segment, a separate STAR could be used, which ensures a consistent speed profile that results in no extra separation. For example a STAR for the turboprops, a second STAR for average speed segment aircraft types, and a third STAR for high-speed aircraft types. The Slow trajectory “compensates” the Fast trajectory due to the short amount of track miles. In this way the overall time required to fly each STAR will remain the same for each trajectory.

The three inbound STARs should be merged at the ILS if possible. It should be clear that the complexity of inbound STARs inside the TMA increases considerably.

Airborne Separation Assurance System (ASAS) spacing functionality (also called Station Keeping) could also be a potential enabler to maintain capacity, but this needs further investigation and is outside the scope of this study. The same counts for the downlink of aircraft performance data (e.g. 4D constraint points like EAT and ETA) using data link applications.

If the straight segment before the runway threshold can be reduced to a minimum (during a departure as well as during an approach), the procedure designer has more freedom of avoiding potentially noise sensitive areas.

Previous research concerning the introduction of MLS showed that, within certain constraints, i.e. adequate approach minima, guidance, turn radius and glide path interception position, curved path procedures are flyable with appropriately equipped wide-body aircraft. During the simulator trials of this MLS research, it was shown that, for all of the tested pilots (40 pilots), the minimum operationally acceptable straight-in segment for a wide-body curved path instrument approach is 3.0NM under Cat I and below weather conditions. For higher weather minima, shorter straight-in segments may be acceptable. This indicates the need for future research into this issue.

Some aspects not taken into account in the Fast Time Simulations, as wind speed and direction and pilot response uncertainties, could affect arrival capacity. For example, wind can affect an aircraft track significantly. Many RNAV / FMS systems take account of the calculated, or forecast, wind when computing a turn. A strong tail wind will cause the turn to start early, with a larger than normal turn radius, while a strong head wind will result in a late turn and a smaller than normal radius. Some RNAV / FMS systems calculate the turn beforehand and only re-assess the situation as the turn is nearing completion when the following subsequent track is ‘captured’ - the turn itself is considered to be frozen - while others make continual reassessments and adjustments during the turn.



## 4. Safety Assessment

### 4.1. Introduction to safety assessment results

Because complete detailed safety analysis would have been a very elaborate and demanding effort, only part of the four approach and two departure procedures were identified to fall within the scope of detailed evaluation. Therefore, a further selection of these procedures was made. To accomplish such a selection, an initial high-level safety evaluation of all six procedures was first done. It was noted that these procedure definitions did not include any embedding of the procedure in an operation.

Based on the initial high-level safety evaluation and on inputs not related to safety the Sourdine II management made a selection of three procedures for safety assessment. For each of these three procedures an operation was defined on a specific airport including specific human roles and technical systems. For each of these operations, a safety assessment was performed, documented in [S II D4.2-2] and [S II D4.2-3] and summarised in the current document.

The initial high-level safety evaluation identified the following main safety issues for the four approach procedures:

- II. Basic CDA with 2° initial Flight Path Angle;
  - A possible excess speed at glide slope intercept possibly leading to an unstabilised approach.
  
- III. Basic CDA with 2° initial FPA and increased final glide slope;
  - A possible excess speed at glide slope intercept possibly leading to unstabilised approach; more severe than for procedure 2 due to the fact that the excess speed is more difficult to control on a steep final segment;
  - The steep final glide slope is a non-standard operation and potentially leads to higher workload. This operation requires special analysis in relation to acceptance and to obstacle clearance surfaces.
  
- IV. CDA with constant speed, variable FPA segment at landing configuration;
  - A possible steep intermediate approach segment resulting to glide slope interception from above, with the potential consequences of a glide slope undershoot and an unstabilised approach;
  - Potential flight path control problems, which could lead to an increased workload and an unstabilised approach in case the path is too shallow;
  
- V. CDA with constant speed, variable FPA segment at intermediate configuration;
  - The same issues as for procedure IV, though both less severe.

The main safety issues related to each of the two departure procedures are as follows:

- 2. Sourdine optimised close-in procedure;
  - Speed control problems at low power-setting at OEI climb thrust
  
- 3. Sourdine optimised distant procedure;
  - The same issue as for procedure 2, but less severe.

Because Procedure II was expected to cause a limited capacity decrease, a variant of Procedure II was defined by the Sourdine II operational designers, called Procedure II-A. In Procedure II-A, speed constraints were imposed on the 2-degree flight path angle segment. The procedures selected for safety assessment were: approach Procedure II-A, approach Procedure V, and departure Procedure 2.

#### **4.1.1. Safety Assessment of Approach Procedure II-A on Schiphol Airport**

A safety assessment was performed for an operation considering Sourdine II approach Procedure II-A in the context of Schiphol airport. The risk had been assessed with respect to risk criteria that combined the [ESARR 4] severity classification with the well-known frequency classification of JAA; the risk was classified per conflict scenario to be NEGLIGIBLE, TOLERABLE, or UNACCEPTABLE.

Five conflict scenarios were identified that described in which way an accident or incident could occur:

1. Conflict between two aircraft merging onto one route
2. Conflict between two aircraft on the same route
3. Conflict between two aircraft established on their respective localizers
4. Conflict between two aircraft (one for 18R and one for 18C) of which at least one was turning to intercept its localizer, the other aircraft may also be turning in or already be established on its own localizer.
5. An approaching aircraft encounters the wake vortex of another aircraft in approach.

The risks of conflict scenarios 1 and 3 were classified as TOLERABLE, and the risks of conflict scenarios 2, 4 and 5 were classified as being either TOLERABLE or UNACCEPTABLE.

The uncertainty in the latter results was related to the use of data retrieved from experts, who assess a future operation by extrapolating their experiences with the current operation; to details of the operational description that remain to be specified; and to the scarceness of statistical data on model parameter values.

When considering to what extent the identified (possibly) UNACCEPTABLE risks were generic for the vertical flight profile considered, irrespective of the Schiphol implementation considered, the following conclusions hold:

- The possibly UNACCEPTABLE risk for conflict scenarios 2 and 5, related to longitudinal separation problems caused by an insufficient initial separation at the IAF and by a reduced ability to provide separation in case of 34 aircraft per hour, may be generic for the vertical flight profile considered.
- The possibly UNACCEPTABLE risk for conflict scenario 4, caused by aircraft overshooting the ILS while turning in for parallel approach, while vertical separation of 1000ft has not been guaranteed, is not generic for the vertical profile. However, when considering a generic implementation of this profile on parallel runways, it is very well possible that the risk is possibly UNACCEPTABLE, depending of course on the distance between the runways, the staggering between the runways, and the exact implementation of the procedure.

Since the operation had risks that were classified as (possibly) UNACCEPTABLE, the operation needed to be improved before implementation. Safety bottlenecks were identified that could serve as was considered most logical to do a new cycle of the safety assessment once the operation had been improved. Also for conflict scenarios 2 and 5 a simulation-based approach could have been used.

#### **4.1.2. Safety Assessment of Approach Procedure V on Barajas Airport**

The outcome of the safety assessment for approach Procedure V at Barajas airport revealed a series of safety significant issues, which were recommended for further analysis. A distinction was made

between those related to the inherent characteristics of the Sourdine II approach Procedure V and those for which the particular parallel runway set-up was the determining factor when performing simultaneous and independent CDAs to both runways.

1. *Sourdine II approach Procedure V issues:*

- Non-adherences to Continuous Descent Approach (CDA) speed descent profiles may cause aircraft to breach longitudinal separation (e.g. catch up aircraft ahead or be caught up by trailing aircraft). As a potential result, the probability of wake vortex encounters was likely to also increase. The risk of wake vortex encounter had been classified as possibly unacceptable without further mitigation.

2. *Parallel runway CDA safety issues*

- Non-adherences to vertical CDA profiles may breach the 1000ft vertical separation that by design, should be maintained at all times between aircraft established on the parallel localisers prior to reaching the area parallel to the NTZ.
- Separation between aircraft established on the parallel localisers was based on 1000ft vertical separation at all times prior to reaching the area parallel to the NTZ. As a consequence, small-excursion overshoots followed by rapid localiser interceptions would only be associated with an erosion of safety margins whereas wide-excursion overshooting developing into wrong localiser interception or adjacent sector non-authorized incursion would pose a safety critical issue.

The qualitative safety assessment has shown that the Sourdine II approach Procedure V adapted to the future Barajas Airport parallel runway configuration exhibited some safety significant issues that are in need of a more detailed and quantitative analysis. It is recommended that decision support tools such as an Arrival Manager (AMAN) and safety-net additional functionality to monitor potential longitudinal breaches of separation for localiser-established consecutive aircraft be considered in future safety assessments.

**4.1.3. Safety Assessment of Departure Procedure 2 on Barajas Airport**

The Sourdine II departure Procedure 2 aimed at reducing the noise impact around the SID footprint closest to the runway, causing the aircraft to operate at reduced performance with One Engine Inoperable (OEI) power settings. Hence, the main procedure risks were associated with airport obstacle limiting surface infringements that may lead to loss of separation with obstacles and/or ground. The main emphasis of the high level assessment was placed on whether the procedure-induced departure from the aircraft optimal climbing performance could erode safety margins.

The safety assessment had shown that the most significant risks associated with the Sourdine II departure Procedure 2 were due to either engine loss or sudden adverse meteorological conditions that could impair the aircraft airworthiness. However, it was deemed that aircraft could recover from these situations despite flying at reduced power settings and therefore, the procedure does not degrade safety margins. The conducted high-level assessment was concluded with all identified risks associated with the departure procedure having been preliminarily classified as acceptable.

**4.2. Organization of the Safety Assessment**

In work package 3 of the Sourdine II project, many new noise abatement procedures were defined, as reported in [S II D3.1-1]. In work package 5, all of these procedures were assessed with respect to their noise impact by executing very accurate single event simulations for the A320 and the A340 aircraft [S II D5.3]. Based on these simulations, apart from a baseline approach procedure and a baseline departure procedure, four approach procedures and two departure procedures were selected to assess them with respect to:

- Capacity;
- Safety;
- Emissions;

- Airport noise (assessment of noise footprints/contours for realistic fleet mixes for the following airports: Paris (Charles de Gaulle) / Madrid (Barajas) / Naples (Capodichino) / Amsterdam (Schiphol);
- Cost-benefit analysis; and
- Acceptance of end-users (pilots and air-traffic controllers).

Because the complete detailed safety analysis and detailed assessment of the “acceptance to end-users” by Real Time Simulations in a cockpit simulator and ATC simulator, would be a very elaborate and demanding effort, only part of the four approach and two departure procedures were identified to fall within the scope of a detailed evaluation. Therefore, a further selection of these procedures had to be made for the detailed assessment with respect to the two parameters of safety and acceptance to end-users.

The safety methodology described in Section 4.4 was used for the safety assessments. Section 6.4.10 provides a description for each of the safety assessments and to what extent the general methodology description was followed.

To support the selection process, an initial high-level safety evaluation of all six procedures had to be defined first. This was documented in Section 4.4 for the procedures as they have been defined in [SII D3.1-2]. For a short summary of the procedures, the reader should refer to the beginning of Sections 6.5.1 (approach) and 6.5.2 (departure). It should be noted that these procedure definitions do not include any embedding of the procedure in an operation, including a description of the technical systems, humans, and exact procedures and their interactions, and the specific operational context of such an operation. It was decided that for the initial high-level safety evaluation of these procedures no operational context was needed.

Section 6.6 describes the further selection for the scope based on all information then available: the initial high-level safety evaluation, single event noise simulations, some draft results of capacity assessments, prototyping sessions on a cockpit simulator and an ATC simulator, and information gathered in meetings with the expert panel. The following aspects were taken into account in the further selection: safety, capacity impact, cost-benefit, acceptability for pilot and air-traffic controller, availability of new avionics functions, etc. As these criteria did not only involve safety, the Sourdine II management had made this further selection. The aim was to select those procedures that look, with the limited information available, as the most promising procedures for implementation.

For the ‘most promising’ procedures selected for the scope of the safety assessments this way, an operation was defined for either Schiphol airport (Amsterdam) or Barajas airport (Madrid) by operational concept developers. This meant that the human roles, technical systems, and procedures of the operation were described, as was the operational context, and the interactions between these elements. Next, for each of those operations a safety assessment was performed. These were described in Sections 4.6 and 6.9.

It is noted that previously the first idea was to assess all procedures qualitatively (as part of WP4) and next to assess one of these procedures quantitatively (as part of WP6). However, it was decided to assess each of the selected operations only once. Within such an assessment it was necessary to consider which parts of the operation were assessed using an argumentation-based way and which used a simulation-based way of working. Here, ‘simulation-based’ referred to the usage of Monte Carlo simulations; often using these simulations for more detailed risk assessment. This was a quantitative approach. ‘Argumentation-based’ referred to safety assessment in which argumentations were built to support why the risk was of a certain class. This provided too much of a qualitative approach. However, quantitative frequency classes could be used, and the argumentations could have a quantitative character. In Section 6.4 more details about the simulation-based and argumentation-based way of working have been provided.

### 4.3. Safety Assessment Methodology

The safety methodology assessment is described in Appendix 3. Appendix 3 provides a description of the TOPAZ safety assessment methodology used.

The safety evaluation documented in Section 4.5 and the selection of procedures for further research documented in Section 4.6 can be seen as part of the scope definition for the three safety assessments. In Sections 4.6, 4.8 and 4.9 of this document these safety assessments are described.

The following describes the extent to which the general methodology description was followed in the assessments of Sections 4.6, 4.8 and 4.9:

- The safety assessment described in Section 4.7 did not deviate from the methodology as described.
- For the safety assessment described in Section 4.8 and Section 4.9 some differences were:
  - Steps 2 and 3: no clustering of individual hazards into conflict scenarios has been applied; instead ‘scenario-like’ hazards were identified.
  - Steps 4, 5 and 6: the frequency assessment was not performed for every possible severity outcome. Instead, the worst-case credible severity of the outcome of the hazard was selected and assessed on frequency.
  - Step 5: the frequency assessment was done purely qualitatively.

#### 4.4. Initial High-Level Safety Evaluation of Six Procedures

In this section an initial high-level safety evaluation is done for the four approach procedures and two take-off procedures. These procedures are described in Section 1, the Introduction.

The procedures are compared with a baseline approach or take-off procedure that is currently in standard use. In this safety evaluation the potential safety impacts of conducting these procedures are described as compared to the current standard operating procedures. The six procedures and two baseline (approach and take-off) procedures are briefly summarised; for a more complete description of these procedures one is referred to [S II D3.1]. Subsequently the main safety issues that are related to conducting these procedures are addressed.

##### 4.4.1. Initial High-Level Safety Evaluation of the Approach Procedures

The following approach procedures are considered:

- I. Baseline approach procedure; descend to 3000 ft with constant speed, and at this altitude fly a level segment while changing to the intermediate configuration, until the glide slope is intercepted. At glide slope intercept the gear is extended and the aircraft is configured for the final approach configuration.
- II. Basic CDA with 2° initial Flight Path Angle (FPA); characteristic for this procedure is that from 7000 ft to the glide path interception point a constant 2° flight path angle is flown while the aircraft decelerates (with idle power) to the intermediate configuration.
- III. Basic CDA with 2° initial FPA and increased final glide slope; this procedure is similar to the previous, except that the final approach path is steeper (4° instead of 3°).
- IV. CDA with constant speed, variable FPA segment at landing configuration; characteristic for this procedure is that the FPA during the descent from 7000 ft to 2000 ft is not constant. Before 7000 ft the aircraft decelerates with idle thrust while configuring to the landing configuration and subsequently the aircraft descends further to 2000 ft, where the glide slope is intercepted.
- V. CDA with constant speed, variable FPA segment at intermediate configuration; this procedure is similar to the previous procedure (IV), except that the aircraft is first configured to the intermediate configuration, then intercepts the glide slope at 3000 ft, where the aircraft is further configured to the final approach configuration.

### **Main operational differences**

A principal difference between the baseline and the introduced CDA procedures is that all CDA procedures try to avoid the level segment before the glide slope intercept as a way to reduce the noise burden on the ground. The inevitable consequence is that the glide slope is not intercepted from a level segment but from a descending segment. For procedures II and III this descending segment will have a fixed descend angle of 2°, and therefore there will be a rather shallow intercept angle with the glide slope. Although non-standard, most autopilot and flight director systems will be able to accommodate such an intercept.

The shallow intercept may lead to an increase in pilot workload because some additional thrust corrections may be required to compensate for gear extension (for some aircraft types the additional drag of gear extension is approximately equivalent to a change in flight path angle of 3° without significant thrust changes).

For procedures IV and V the difference with the baseline may be somewhat more noticeable, because the intercept with the glide slope may occur from a steeper (than 2°) descend path. It may even be possible that the glide slope is intercepted with a significant intercept angle from above.

The safety concerns are considered in the following.

### **Flight path or speed control on the intermediate approach segment**

When comparing the procedures II & III with IV & V, an essential difference is that in the first two procedures the flight path angle is the controlled variable (path on elevator), while in the latter two procedures the airspeed is the controlled variable (speed on elevator).

#### Path on elevator (procedures II and III)

The consequence of having the flight path angle, as the controlled variable in the first two procedures is that there is only limited control over airspeed. This means that airspeed will change according to a pre-planned schedule, depending on aircraft performance characteristics. The only way to control airspeed is by adjusting (i.e., advancing or delaying) the required configuration changes. In real circumstances, resulting from the fact that the planned conditions may (or will) deviate from the planned conditions, the speed schedule cannot be expected to develop as planned. The final consequence from this is that the aircraft will be not delivered at the glide slope intercept point at the planned airspeed. In case that speed bleed-off will be higher than anticipated this will require early application of engine thrust, in order to prevent under-speed conditions. It is noted that this will reduce the anticipated reductions in noise production; significant safety implications are not expected.

In case the speed bleed-off will be less than anticipated, the aircraft will arrive at glide slope intercept with excess speed that has to be reduced while the aircraft is configuring for the final approach configuration. This may lead to an increased workload and potentially to situations of unstabilised approaches. It should however be noted that the proposed CDA procedures all have a final approach segment extending to 3000 ft. This means that there is a relatively long (about 9 NM) final approach segment length, which in general will provide sufficient time for the pilot to stabilise the aircraft.

#### Speed on elevator (procedures IV and V)

For the last two procedures (IV and V), airspeed instead of flight path is the controlled variable. Therefore the resulting (vertical) flight path will depend on the pre-planned schedule and the associated aircraft performance characteristics. Here also it has to be assumed that planning will not be perfect and therefore the actual flight path will deviate from the planned flight path. This means that the vertical flight path will either be too steep or too shallow. In the first case the minimum descent altitude will be reached before the glide slope is intercepted. This will result into a level flight segment before intercepting the glide slope, requiring associated power changes, and thus partly negating the anticipated noise reduction, but not having any significant implications on safety.

In case the resulting flight path angle is too shallow, this may result in late (i.e. low altitude) intercept of the glide slope. This may lead to an unstabilised approach and it may significantly add to the pilot's workload.

#### Glideslope intercept

As already discussed, the shallow glide slope intercept angle in procedures II and III is non-standard and may lead to some increase in pilot workload. A more significant issue exists however for procedures IV and V, namely that the resulting flight path angle before intercepting the glide slope may become steeper than the glide path angle itself (i.e. steeper than  $3^\circ$ ). Especially for procedure IV, in which the aircraft is configured for the final approach configuration before intercepting the glide slope, this 'interception from above' can be expected.

It should be emphasised here that intercepting the glide slope from above is a non-standard procedure that may increase pilot workload significantly. Moreover, it is known that current technology autopilot and flight director control laws are not optimized for glide path intercept from above. This may lead to situations of significantly undershooting the glide path, or in worst case not capturing the glide path at all. The safety implications of this behaviour are obvious; serious reductions in the margins to the obstacle clearance surfaces may be caused. It is noted that possible solutions to this potential problem that imply introducing a level segment before intercepting the glide path would again reduce the noise benefits of the proposed procedure.

#### **Steep approach**

An additional safety concern for procedure III is that the final approach path is steeper than the standard  $3^\circ$  (i.e.  $4^\circ$ ). In itself, this constitutes not a major safety concern from an aircraft handling point of view. In general, aircraft are certified up to an approach angle of  $4.5^\circ$  without requiring further proof or demonstration (above  $4.5^\circ$  special steep approach certification is required). Nevertheless it is a deviation from standard operating practices, and therefore would require special pilot training in order to get familiarised with the non-standard visual reference and flare characteristics.

In addition, it is stated in the ICAO PANS-OPS document [PANS-OPS V1]: *"Glide path angles above  $3.5^\circ$  should be used in approach procedure design only for obstacle clearance purposes and must not be used as a means to introduce noise abatement procedures. Such procedures are non-standard and require a special approval"*.

This means that any approach procedure using a glide slope in excess of  $3.5^\circ$  for noise abatement purposes would require a special safety case, addressing (also from [PANS-OPS V1]):

- a) An appropriate adjustment of the obstacle assessment surfaces; and
- b) An appropriate increase in the height loss/altimeter margin.

The height loss/ altimeter margin should be verified by certification or flight trials. The effects of the following issues should then be covered: a minimum drag configuration, wind shear, control laws, handling characteristics, a minimum power setting for anti-icing, modification of GPWS, the use of flight director/autopilot, the engine spin-up time and an increase of the landing speed  $V_{at}$  for handling considerations.

#### **Summary**

In the following the main safety issues concerning the defined CDA procedures are summarised:

- II. Basic CDA with  $2^\circ$  initial Flight Path Angle;
  - A possible excess speed at glide slope intercept possibly leading to an unstabilised approach.
- III. Basic CDA with  $2^\circ$  initial FPA and increased final glide slope;
  - A possible excess speed at glide slope intercept possibly leading to an unstabilised approach; more severe than for procedure 2 due to the fact that the excess speed is more difficult to control on a steep final segment;

- The steep final glide slope is a non-standard operation and potentially leads to higher workload. This operation requires special analysis in relation to acceptance and to obstacle clearance surfaces.
- IV. CDA with constant speed, variable FPA segment at landing configuration;
- A possible steep intermediate approach segment resulting to glide slope interception from above, with the potential consequences of a glide slope undershoot and an unstabilised approach;
  - Potential flight path control problems, which could lead to an increased workload and an unstabilised approach in case the path is too shallow;
- V. CDA with constant speed, variable FPA segment at intermediate configuration;
- The same issues as for procedure IV, though both less severe.

#### **4.4.2. Initial High-Level Safety Analysis of the Departure Procedures**

The following departure procedures are considered:

1. Baseline take-off procedure; this procedure concerns the standard (ICAO-A) take-off procedure, comprising a climb out at  $V_2 + 10$  with take-off power until 1500 ft, then reduce to climb thrust, and at 3000 ft retract flaps and accelerate to 250 kts while climbing further to 15000 ft.
2. Sourdine optimised close-in procedure; this procedure is almost similar to the close-in take-off climb procedure described as NADP 1 in [PANS-OPS, Vol. 2]: Climb out at  $V_2 + (10 \text{ to } 20)$  kts with take-off power, and reduce at 800ft. From 800ft the prescribed power setting is used that provides the minimum one engine inoperative (OEI) climb gradient in case an engine failure occurs, and from 3000 ft to 5000 ft a steeper climb gradient is flown by selecting climb power, while maintaining speed. Finally when passing 5000 ft the aircraft is cleaned up and accelerated to 250 kts.
3. Sourdine optimised distant procedure; this procedure is almost similar to the distant take-off climb procedure described as NADP 2 in [PANS-OPS, Vol. 2]. When comparing this procedure to Procedure 2, the main difference is that after reaching 800 ft first the aircraft is cleaned up and accelerated to the zero-flap speed  $V_{zf}$ . After reaching that speed thrust is reduced to the prescribed power setting providing the minimum one engine inoperative climb gradient in case an engine failure occurs.

#### **Main operational differences**

As indicated the defined departure procedures do not differ significantly from the noise abatement procedures as provided by ICAO [PANS-OPS, Vol. 2]; they can be considered as 'optimised' versions of those. The optimised procedures however extend to 5000 ft, whereas the ICAO procedures prescribe a smooth transition to en-route climb speed above 3000 ft. A second difference is that [PANS-OPS, Vol. 2] only mentions "reduced power, while maintaining positive climb" during the second climb segment, while the optimised procedures prescribe a reduction to the OEI climb gradient thrust. This means that if, after the thrust-cut-back, an engine failure occurs, the required climb performance is obtained without changing the engine setting.

Directly after the thrust cutback, the procedures 2 and 3 prescribe the thrust setting and the speed (at fixed configuration). As a consequence, the flight path angle will be the resulting parameter.

#### **Effect of the number of engines**

For the Sourdine departures, the thrust cutback of 2-engined aircraft will be very close to the ICAO-A procedure. For 4-engined aircraft, the thrust cutback will be large as compared to ICAO-A procedure.

However, in case an engine failure occurs, the prescribed minimum climb performance is still not violated during “standard” weather operations. However, due to severe atmospheric disturbances (turbulence, windshear) an undershoot in the flight path angle may occur, which would infringe on the margins to the obstacle clearance surfaces.

### **Engine failure during climbing at the OEI climb thrust**

When engine failure occurs, the minimum required climb performance is still met. However, due to the low power setting after thrust cutback, it may take additional time, especially for today’s high by-pass ratio engines, to increase climb performance.

### **Speed control during climb out**

In particular, departure procedure 2 envisions to keep airspeed constant at  $V_2 + (10 \text{ to } 20)$  kts at a low power setting until 3000 ft is reached. This procedure will leave the aircraft relatively vulnerable to speed disturbances for a significant period of time. In case the airspeed would drop below lower values, speed control will be hampered by relatively sluggish engine response at low power setting. In addition, due to flying with a low climb gradient, it is not preferred to accelerate speed recovery by using the speed on elevator technique (i.e. trading altitude for speed). For that reason speed control may prove difficult for departure procedure 2.

For procedure 3 this problem seems less severe because after reaching 800 ft the aircraft is first accelerated to  $V_{z1}$  and flaps and slats are retracted before the OEI climb gradient is maintained. This leaves the aircraft less vulnerable to speed disturbances closely to the ground.

### **Summary**

Optimised departure procedures (involving deep thrust cutback and gradual thrust increase) can be realised only with aircraft equipped with dedicated FADEC/FMS functionalities, in case of which there are no safety issues. These procedures can not be realised manually, without appropriate systems.

In the following the main safety issues concerning the defined departure procedures are summarised:

2. Sourdine optimised close-in procedure;
  - Speed control problems at low power setting at OEI climb thrust
3. Sourdine optimised distant procedure;
  - The same issue as for procedure 2, but less severe.

## **4.5. Selection of Procedures for Safety Assessment**

As previously discussed, the selection of the four approach and two departure procedures was introduced and made for the detailed safety assessment and also for detailed assessment with respect to acceptance by the end-users. The initial high-level safety evaluation of all these four plus two other procedures serves as input to this selection process, as does the high-level assessment of acceptance to controllers and pilots of references [S II D6.1] and [S II D6.2]. Furthermore, all other information currently available is used as input: single event noise simulations, some draft results of capacity assessments, prototyping sessions on a cockpit simulator and an ATC simulator, and information gathered in meetings with the expert panel.

The following aspects were taken into account in the further selection: safety, capacity impact, cost-benefit, acceptability for pilot and air-traffic controller, availability of new avionics functions, etc. The aim was to select those procedures that look, with the limited information available, the most promising procedures for implementation. This was the way the scope of the safety assessments was determined.

#### **4.5.1. Selection of Approach Procedures**

For the approach procedures, the following observations apply:

PROCEDURE I: BASELINE APPROACH PROCEDURE: This was the baseline arrival procedure.

Procedure II: Basic CDA with 2° initial FPA: In this procedure a fixed 2-degree flight path angle from 7000ft up to the ILS intercept at 3000ft was applied. This was a very realistic and probably operationally feasible procedure, both from the perspective of the pilot and ATC. All civil aircraft types were able to decelerate in a clean configuration during this 2-degree flight path. However, when the fixed flight path angle was combined with idle thrust, different aircraft types showed different speed profiles. This caused a capacity decrease at the airport.

It should be noted that speed constraints could have been added to the procedure definition, and to allow for (low) non-idle thrust settings. Then the speed profiles of the different aircraft types could be harmonised (to a large extent) and the capacity restrictions might be very limited.

The main safety issue identified for procedure II was that a possible excess speed at glide slope intercept might lead to an unstabilised approach.

Procedure III: Basic CDA with 2° initial FPA and increased final glideslope: The difference between arrival Procedure II and III was the steeper flight path angle on the ILS (3° for Procedure II, 4° for Procedure III). This had a major impact on aircraft operations since this increased flight path angle required a new certification process for the auto-land system. This was not foreseen for the existing fleet of aircraft from a cost-benefit point of view. Therefore the introduction of an increased glide slope as the standard operating procedure would require a renewal of the fleet or its avionics and would take at least 20 years.

This procedure had the same main safety issue as Procedure II, though more severe. Another safety issue is the 4° glide slope angle, which required special analysis. At least it could increase the workload in the cockpit.

Also for this procedure one could introduce speed constraints. The effect of these constraints would be about the same as indicated for Procedure II.

Procedure IV: CDA with constant speed, variable FPA segment at landing configuration: In this procedure a large part, between 7000 ft up to ILS intercept, was flown with idle thrust in landing configuration. During the RTS prototyping sessions in both the flight simulator (see reference [S II D6.2]) and the ATC simulator (see reference [S II D6.1]) several issues were raised concerning the fly ability and controllability:

There was no control available once the descent from 7000ft was initiated: engines were on idle, in numerous aircraft types and no speed brakes were available in the landing configuration.

- From the moment of glide slope intercept, high thrust settings were required to maintain the 3 degrees path. Normally the landing configuration was reached significantly later.
- Aircraft were not designed to fly for these long times with the required flaps settings: aircraft structure fatigue might lead to higher maintenance costs, auto-pilot control laws might reach their limit.
- The steep descent would be uncomfortable for passengers.
- The steep decent towards the glide slope might trigger the ground proximity warning system (for field surrounded by terrain, but possibly also for flat areas due to the high sink rate), especially in lower visibility conditions pilot might cancel the approach.

An important aspect for ATC was the unpredictability of the CDA Initiation Point (CIP); when would the pilot start the descent along this variable flight path? Although the speed profile was fixed the early speed reduction and the speed variations (Final Approach Speed was aircraft specific and can

easily vary 30kts over different aircraft types) hence could result in a substantial loss of runway capacity.

Main safety issues that were identified related to a possible glide slope intercept from above and to potential flight path control problems.

Procedure V: CDA with constant speed, variable FPA segment at landing configuration: This was the same type of procedure as Procedure IV. Procedure V also uses a variable flight path, which was now the resultant of a thrust idle descent in an intermediate flap configuration from 7000 ft up to ILS intercept. This configuration directly solved many of the above raised issues of Procedure IV. The fly ability was improved considerably:

- Pilots had control over the aircraft in case of ending up too high (speed brakes are available, earlier adding drag by earlier flap selections on the glide slope etc.

For this procedure the same ATC aspects as mentioned for Procedure IV were of interest (unpredictability of CIP, early speed reduction and speed variations). Although variations in intermediate flap speed occurred between the different aircraft types, the speed levels were much higher in a long range of the approach procedure, yielding less capacity reduction than for Procedure IV.

Main safety issues identified for this procedure were the same as for Procedure IV, however less severe.

## Conclusion

Procedure II and III both were procedures with a fixed, prescribed flight path angle (at idle thrust), resulting in different speeds for different types of aircraft. Procedure IV and V were defined with a fixed speed at idle thrust, resulting in a different flight path angle for different types of aircraft. For completeness at least one procedure of each type of procedures was evaluated.

As Procedure II looked much more promising with respect to the fly ability aspects, Procedure II was preferred over Procedure III. Because Procedure II was expected to cause a limited capacity decrease, a variant of Procedure II was defined (called procedure II-A). In procedure II-A, speed constraints were imposed on the 2-degree flight path angle segment.

The impact of these speed constraints, i.e., the difference between procedure II and II-A, would be analysed in the FTS for the Schiphol situation, as well as during the RTS in the flight deck simulator and the ATC simulator. The detailed safety analysis would be limited to the II-A variant.

From the other two sets of arrival Procedures (IV and V), Procedure V was advantageous on all main aspects (fly ability, safety, aircraft loads, passenger comfort, and capacity). Therefore Procedure V was preferred over Procedure IV.

Based on the considerations above, for safety assessment the following Sourdine II approach procedures were selected: Procedures II-A and V.

The safety assessment for approach Procedure II-A on Schiphol airport was documented in [S II D4.2-2a], and the safety assessment for Procedure V on Barajas airport was documented in [S II D4.2-3]. The safety assessments have been summarised in Sections 4.7 and 4.8.

#### 4.5.2. Selection of Departure Procedures

For the departure procedures, the following observations applied:

Procedure 1: Baseline take-off procedure: This was the baseline departure procedure.

Procedure 2: Sourdine optimised close-in procedure: This was the close-in departure procedure, for which the noise relief was located relatively close to the runway. This procedure resembles the well known ICAO-A and NADP1 procedures.

- Main safety issues identified for this procedure were that speed control problems can occur at the low power setting at OEI climb thrust.

Procedure 3: Sourdine optimised distant procedure: This was a distant procedure, for which the noise relief was located further away from the runway. This procedure was more in line with the ICAO-B and NADP2 procedures. While noise relief close to the runway could only be realised by changing the vertical path, noise relief further away from the runway could often be realised by changing the lateral path.

The main safety issue identified for this procedure was the same as for procedure 2, though less severe.

#### Conclusion

Both departure procedures (Procedures 2 and 3) used low energy profiles (aircraft stay relatively low) and required gradual thrust restoration (probably automatic). While noise relief closely to the runway could only be realised by choosing a low energy profile, noise relief further away from the runway could often be realised by changing the lateral path. Therefore Procedure 3 was considered to be of less interest than Procedure 2. Procedure 3 may be somewhat more promising from a safety point of view, but in the end Procedure 2 was judged to be more promising.

Based on the considerations above, for safety assessment the following Sourdine II procedure had been selected: Departure Procedure 2. The safety assessment for departure Procedure 2 on Barajas airport is documented in [S II D4.2-3], and is summarised in Section 4.8.

### 4.6. Safety Assessment of Approach Procedure II-A on Schiphol Airport

#### 4.6.1. Introduction

In Section 4.6.1 approach Procedure II was introduced. The characteristic for this procedure was that from 7000 ft to the glide path interception point a constant 2° flight path angle was flown while the aircraft decelerated (with idle power) to the intermediate configuration. A variant of this approach Procedure II was defined called approach Procedure II-A. In this Procedure II-A the speed constraints were imposed on the 2° flight path angle segment.

This safety assessment was performed for a specific operation featuring Procedure II-A applied to Schiphol airport, including the people, further procedures and systems playing a role in it. The safety assessment was described in the following documents:

Safety assessment of approach procedure II-A on Schiphol airport	
[S II D4.2-2a]	Main document
[S II D4.2-2b]	Argumentation-based analysis
[S II D4.2-2c]	Simulation-based analysis
[S II D4.2-2d]	Collection of expert interviews

Document [S II D4.2-2a] was the main document of this safety assessment. Documents [S II D4.2-2b] and [S II D4.2-2c] contained the more detailed safety analysis. In [S II D4.2-2d] all the supporting expert interviews were collected. Below, is a summary of the safety assessment.

The risks associated with the operation have been assessed using the safety assessment methodology TOPAZ. This methodology combined an argumentation-based approach with a simulation-based approach. The assessment performed was an absolute assessment of all the risks of the operation as described in this document, but restricted to the scope adopted in [S II D4.2-2a].

### 4.6.2. The Operation

Approach Procedure II-A was considered as a Continuous Descent Approach (CDA) procedure, as it features a fixed three-dimensional flight path that did not include a horizontal segment before the glide path intercept. It was however not a classical CDA with idle thrust; some speed constraints were in force, and thrust had to be applied when required. This way it was aimed to reduce noise hindrance, while maintaining capacity. The procedure was flown using P-RNAV (Precision Area Navigation).

In [S II D6.6] a concept of operation had been developed for approach Procedure II-A on Schiphol airport Amsterdam. Apart from the procedure the operation consisted of people, technical systems, more procedures, the operational context, and the interactions between these elements. The route structure associated with the considered approach procedure, applied to the situation of Schiphol airport, is provided in the figure below.

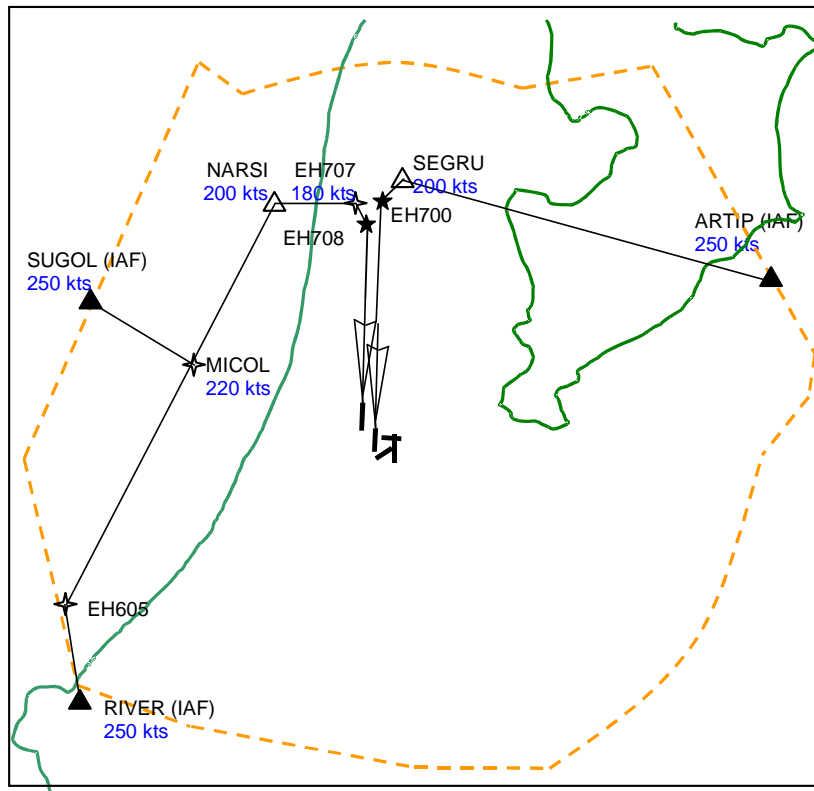


Figure 4-2: Arrival route structure on Schiphol airport considered, with speed constraints indicated.

#### **4.6.3. Conflict Scenarios**

In various brainstorming sessions with operational experts, hazards were identified that could occur in the considered operation. These hazards were structured into five conflict scenarios that describe the ways in which the hazards could lead to or worsen a conflict situation, and some sub scenarios:

- 1 Conflict between two aircraft merging onto one route
  - a At MICOL
  - b At NARSI (after a direct-to from SUGOL)
  - c At EH708 (after an extended downwind)
- 2 Conflict between two aircraft on the same route
  - a Two aircraft on the same route before the CDA (from ARTIP, SUGOL or RIVER)
  - b Two aircraft on the same CDA (from ARTIP or the one from RIVER/SUGOL)
  - c Two aircraft on the extended downwind
  - d Two aircraft on the same ILS
- 3 Conflict between two aircraft established on their respective localizers (one for 18R and one for 18C)
- 4 Conflict between two aircraft (one for 18R and one for 18C) of which at least one was turning to intercept its localiser, the other aircraft may also be turning in or already had been established on its own localiser. Here several situations can be taken into account: One or both aircraft could make a turn towards the wrong ILS or to a wrong waypoint, or may make an overshoot. In addition, one or both aircraft may have had to come from the extended downwind or not.
- 5 An approaching aircraft encounters the wake vortex of another aircraft in approach.
  - a An aircraft flies into the wake vortex of an aircraft of the traffic flow that it was to be merged with
  - b An aircraft flies into the wake vortex of the preceding aircraft in the same approach flow
  - c On the parallel approach an aircraft flew into the wake vortex of the aircraft flying on the parallel lane
  - d While turning in for parallel approaches an aircraft flew into the wake vortex of the aircraft turning in on the parallel lane

#### **4.6.4. Risk Assessment Results**

The risks have been assessed using risk criteria that combined the [ESARR 4] severity classification with the well-known frequency classification of JAA. This was done since a suitable approach for applying the overall ESARR 4 maximum allowed frequency to a conflict scenario was not (yet) available. The risk of each conflict scenario was classified as either UNACCEPTABLE (above a maximum tolerable probability), TOLERABLE or NEGLIGIBLE.

Conflict scenarios 1, 2, 3, and 5 have been analysed using an argumentation-based approach. In this approach for each of these conflict scenarios the severity and the frequency have been assessed using argumentations built on inputs retrieved mainly from operational experts' judgement, information from the real-time experiments [S II D6.3], and knowledge from other studies. Based on the severity and frequency assessments, and the adopted risk criteria, an evaluation of the acceptability of the risk of each conflict scenario was given.

The risk of conflict scenario 4 has been assessed using a simulation-based approach. Here, only accident risk has been considered, thus no incident risk. This approach relies to a large extent on Monte Carlo simulations using an advanced stochastic model. The approach uses four steps:

1. Development of a mathematical model
2. Model-based accident risk assessment
3. Bias and uncertainty assessment
4. Combination of the results from step 2 and 3.

The bias and uncertainty assessment (step 3) judged all model assumptions adopted during the model-based accident risk assessment (steps 1 and 2), and assessed the factor by which model-based accident risk should be multiplied to compensate for the effect of these model assumptions. The result of step 4 was an expected accident risk value and a 95% uncertainty area for realistic accident risk.

The results of the risk assessment WERE that the risks of conflict scenarios 1 and 3 WERE assessed to be TOLERABLE, and that the risks of conflict scenarios 2, 4 and 5 WERE either TOLERABLE or UNACCEPTABLE. For the risk of conflict scenario 4, the expected accident risk value WAS in the TOLERABLE region, and large part of the 95% uncertainty area WAS in the TOLERABLE region with a small part in the UNACCEPTABLE region. It could be decided to qualify this as tolerable; however, more important WAS that the current detailed risk assessment would require better founded risk criteria.

#### **Uncertainty in the assessment results**

For all conflict scenarios, some uncertainty ranges in the risk assessment results were found. In particular, for some conflict scenarios it could not be ruled out that the risk was in more than one acceptability region (UNACCEPTABLE, TOLERABLE, and NEGLIGIBLE). The reason for this was the uncertainty in the risk assessment, which was related to the following issues:

- A certain level of uncertainty was inherent to the method chosen, which depends on the structured use of operational experts' judgements, who would assess a future operation extrapolating their experiences with the current operation;
- The details of the operational description remain to be specified; and
- Statistical data on model parameter values was scarce.

#### **4.6.5. Potential Safety Bottlenecks**

The possibility of UNACCEPTABLE risk could not be ruled out in the conflict scenarios 2, 4 and 5. Potential safety bottlenecks for these conflict scenarios are discussed next.

For conflict scenario 2 the following conclusions hold:

- The risk was possibly UNACCEPTABLE for both the approach procedure to runway 18C and the one to runway 18R. The reason for the risk being possibly UNACCEPTABLE was that longitudinal separation problems could occur caused by an insufficient initial separation at the IAF and by a reduced ability to provide separation in case of 34 aircraft per hour, may be generic for the vertical flight profile considered; this could ultimately lead to danger of collision.
- The possibly UNACCEPTABLE risk for conflict scenarios 2 and 5, related also.
- The reduced ability of the controllers to maintain separation when assuming 34 aircraft per hour was related to:
  - The aircraft had trouble flying both a vertical profile and prescribed speed, also because changing circumstances (e.g., wind predictions change differ from actual wind) were not taken into account;
  - The controllers become more reactive, and should not vector anymore, and speed instructions had only limited efficacy, also because controllers did not know the exact performance and reaction of the aircraft;

- The declared capacity of 34 aircraft per hour (a lower capacity would provide more space);
- The non-optimal timing of the traffic entering the TMA.

For conflict scenario 4 the following conclusions hold:

- The biggest contributor to accident risk was the situation in which an aircraft for runway 18R did not turn in for ILS, while an aircraft for runway 18C turned in for ILS 18C.
- Main reason why an aircraft would not turn in for an ILS localiser course was that an incorrect ILS localiser frequency is selected and that this remained undetected. Hence, this issue could be regarded as a safety bottleneck. Both the crew and the system could make the selection error. In the latter case a wrong input of the runway or ILS identifier or a database error could be the cause.
- A related safety bottleneck was that, as it was assumed, the autopilot automatically drops LNAV once the localizer interception mode was engaged. This means that in case the correct localiser frequency has not been selected the aircraft did not follow the defined route but crossed the extended centreline.
- Finally, an important safety bottleneck was that in this concept of operation (in contrast with current Schiphol operations), there was not a 1000ft vertical separation between two aircraft turning in for their respective ILSs for runways 18R and 18C. Indeed, if there would be a 1000ft vertical separation between the two flows of traffic, the situation in which one aircraft did not intercept its ILS (i.e. the safety bottleneck mentioned above) would not necessarily lead to loss of separation anymore, hence the weight of the biggest contributor to risk as identified above would be reduced.

It was noted that these latter safety bottlenecks were not directly related to flying a CDA. The choice taken by the operation designers to implement two CDAs with completely identical vertical paths on the parallel runways however did result in the fact that the aircraft could not turn in for the final approach with 1000ft vertical separation. Furthermore an important assumption made was that the NTZ stretches from the runway to beyond the ILS interception points; this was not in accordance with current ICAO regulations.

For conflict scenario 5 the following conclusions hold:

- As for conflict scenario 2, the risk was possibly UNACCEPTABLE for both the approach procedure to runway 18C and the one to runway 18R, and this was related to a reduced ability to provide separation further on the route; causes for this have already been mentioned. Here however this could ultimately lead to danger of a wake vortex encounter.
- Conflict scenario 5 considered wake vortex encounters and thus also more directly wake vortex related hazards could be seen as safety bottlenecks. However, it was judged that the relevant safety bottlenecks were the common causes that cause the high risk of both conflict scenarios 2 and 5. Accordingly, no more direct wake vortex related safety bottlenecks have been identified.

#### **4.6.6. Concluding Remarks on Schiphol**

The Sourdine II operation for approach procedure II-A on Schiphol airport had risks that were classified as (possibly) UNACCEPTABLE. Therefore, the operation should be improved before implementation. The identified safety bottlenecks could serve as a starting point for the operational concept designers for the identification of risk mitigating measures. It was considered most logical to do a new cycle of the safety assessment once the operation had been improved; then also for conflict scenarios 2 and 5 a simulation-based approach may be used. A study was recommended to determine to better define the risk criteria that could be derived for the type of detailed risk assessments performed in this document.

When considering to which extent the identified (possibly) UNACCEPTABLE risks were generic for the vertical flight profile considered, irrespective of the Schiphol implementation considered, the following conclusions hold:

- The possibly UNACCEPTABLE risk for conflict scenarios 2 and 5, related to longitudinal separation problems caused by an insufficient initial separation at the IAF and by a reduced ability to provide separation in case of 34 aircraft per hour, may be generic for the vertical flight profile considered.
- The possibly UNACCEPTABLE risk for conflict scenario 4, caused by aircraft overshooting the ILS while turning in for parallel approach, while vertical separation of 1000ft has not been guaranteed, WAS not generic for the vertical profile. However, when considering a generic implementation of this profile on parallel runways, it WAS very well possible that the risk WAS possibly UNACCEPTABLE, depending of course on the distance between the runways, the staggering between the runways, and the exact implementation of the procedure.

When comparing the risk of the operation studied with the risk of the resembling operation on Schiphol airport considered in the Approve study, no conclusive statement could be made on which of the two operations was safer. Both operations showed some (possibly) UNACCEPTABLE risks.

- The causes of the (possibly) Unacceptable risk in the Approve study WERE related to aspects of the operation not part of the Sourdine II operation: In Approve only part of the traffic is P-RNAV equipped and follows the RNAV route, the rest of the traffic WAS radar vectored along the routes; in Approve there WAS a turn in the route just for a merging point, and in Approve aircraft WERE expected to fly straight ahead, off-route, in case no timely approach clearance WAS derived.

The causes of the (possibly) UNACCEPTABLE risk in the Sourdine II study were related to some aspects of the operation not part of the Approve operation and some aspects out of scope in the Approve study. Turning in for final approach without vertical separation was not part of the Approve operation, and longitudinal problems along the route were hardly considered in Approve operation.

## 4.7. Safety Assessment of Approach Procedure V on Barajas Airport

### 4.7.1. Introduction

This section describes the safety assessment carried out by AENA (Aeropuertos Españoles y Navegación Aérea) considering the extrapolation of the Sourdine II procedure V, CDA with constant speed, variable FPA segment at intermediate configuration) to Barajas airport, considering the most probable parallel runway scenario in 2015. The full safety assessment can be found in [S II D4.2-3].

From a pure operational point of view, some hypotheses have been considered when performing the assessment, before considering the safety perspective. Prior to the safety assessment, a modification to approach procedure V was required to overcome a significant constraint when extrapolating the vertical profiles described in Sourdine II to the future Barajas scenario. The Barajas parallel runways approach operations will be based on vertical separation and a clear incompatibility would arise if “pure” CDA to both approaches was to be applied as the runway heads are not sufficiently staggered in distance to ensure a 1000ft vertical separation while performing independent continuous descent approaches. The adopted solution following extensive consultations with operational experts has been to modify, prior to carrying out the safety assessment, the Sourdine II procedure:

- Apply a pure Sourdine II procedure V for approaches to runway 33L, starting at 8000 feet.
- Apply Sourdine II procedure V with a horizontal level flight leg in the intermediate approach for the approaches to runway 33R.

The hazard identification has been carried out through brainstorming sessions with operational personnel and further analysis with safety experts. The information captured during the sessions was processed and as a result, twenty-two identified hazards were grouped into categories based on the phase of flight within the approach stage: TMA transition, approach intermediate – localiser intercept, approach intermediate – localiser establish, approach final and TMA overall.

The main purpose for the argumentation-based safety assessment has been to evaluate the Sourdine II noise abatement approach procedure V safety implications when introduced into a real airport approach scenario. Only hazards directly related to the Sourdine II noise abatement approach procedure or whose consequences would be made worse by its implementation have been considered. Thus, the present safety assessment needs to be considered within its intended scope and cannot be understood to cover, either partially or totally, any safety aspect of the future Barajas Airport operations.

#### **4.7.2. Safety Assessment Methodology and Criteria Considerations for Barajas Airport**

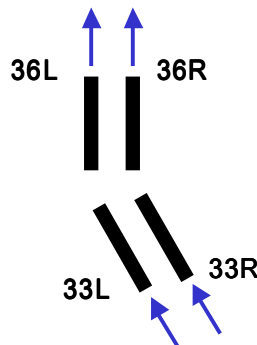
The argumentation-based safety assessments for Sourdine II procedures adapted for Barajas Airport (circa 2015) have been carried out following a methodology consistent with ESARR 4 [ESARR 4] requirements. Expert sessions with the participation of pilots, ATC officers and safety personnel familiar with the Barajas Airport future parallel runway planned operations have been held to introduce the concept of operations and to identify the hazards that the Sourdine II procedure would pose to ATM operations. Subsequently, the identified hazards have been assigned a severity and an estimated occurrence frequency in order to determine their risk tolerability. No attempt had been made to numerically quantify the frequency occurrence.

With regards to severity classification, the ESARR 4 scheme had been employed to classify the identified hazards. Unfortunately, the risk classification scheme (or matrix) provided by ESARR 4 was still under development and an alternative scheme must have been selected to complete the risk analysis. The risk classification scheme selected corresponded to ED-78A “Guidelines For Approval Of The Provision And Use Of Air Traffic Services Supported By Data Communications” [ED-78A].

There were some assumptions made for the safety assessment methodology employed using ESARR 4 and ED-78A. The ED-78A guideline hazard classification was somewhat different to ESARR 4 severity classification scheme, as identified in SRCs Assessment of EUROCAE ED78A as a means of compliance with ESARR 4 [SRC Doc 20]. A comparison between both schemes could be found in [S II D4.2-3]. However, with regards to ESARR 4 hazard identification, risk assessment and mitigation processes, ED-78A was found in agreement with ESARR 4 in terms of an assessment of the effects they may have had on the safety of aircraft, as well as an assessment of the severity of those effects. For the purposes of this safety assessment, the differences between severity classification schemes were not deemed significant in order to obtain a preliminary assessment of risk tolerability regardless of their acceptability. Should a more in-depth noise abatement procedure safety analysis be developed based on the present assessment, it would be recommendable to analyse the classification scheme differences in detail before reaching any judgements on risk tolerability.

#### **4.7.3. The Operation**

The operation under study corresponded to the Sourdine II approach procedure V (CDA with idle thrust) extrapolated to Barajas in an anticipated 2015 scenario, with two sets of parallel runways. The study focused on the most commonly used North Configuration at Barajas, 33L and 33R for approaches and 36L and 36R for departures as displayed in Figure 4-3.



**Figure 4-3: Barajas Airport parallel runway north configuration**

The scenario under consideration presents the following characteristics:

- Two sets of parallel runways.
- The arrivals and the departures were segregated.
- The distance between the runways enabled independent departures as well as independent arrivals procedures. There were some dependencies between arrivals to runway 33R and departures from 36L due to the missed approach procedures from the 33R (in North configuration).

During the description of the operation for the Sourdine II approach Procedure V applied to Barajas, the following hypotheses have been considered:

- The runways used for arrivals in North Configuration were 33R and 33L.
- It has been considered only from the IAFs to the missed approach fix, of both runways.
- From a technological point of view:
  - Communications: Mainly voice communication. Probably for 2015 there will be more data link applications but this study was focused on the CDA for Barajas rather than on technological improvements.
  - Navigation: RNP1 in TMA and RNP0.3 in final approach (ILS segment). All the aircraft following the procedure will be equipped.
  - Surveillance: Mode S. There was an NTZ (No Transgression Zone) with additional equipment (high resolution radar screen).
- Aircraft equipped with new generation FMS, followed the procedure as it is described in [S II D3-1].
- Fleets: A320 and A340. The rationale for choosing this fleet was data availability.
- Roles:
  - Ground:
    - Directors controllers (one per runway): West for 33L and East for 33R. Only for arrival traffic to each of the runways.
    - Final approach (one per runway): West for 33L and East for 33R; they were in charge of NTZ surveillance. Only for arrival traffic to each of the runways.
  - Air:
    - Pilot flying.
    - Pilot not flying.

When extrapolating the Soudine II Procedure V vertical profile to the future Barajas scenarios, there was a pure operational constraint: the current description of the future Barajas operations for approaches to parallel runways were based in vertical separation, so there was a clear incompatibility with applying a pure CDA to both approaches. This constraint was identified before undertaking the safety analysis.

The solution adopted following operational expert consultation had been to:

- Apply a pure Sourdine II procedure V for approaches to runway 33L, starting at 8000 feet
- Apply Sourdine II procedure V with a horizontal level flight leg in the intermediate approach for the approaches to runway 33R

There was a larger population close to the approach area of runway 33L rather than runway 33R; for this reason it was decided to apply a pure CDA to runway 33L in order to reduce the noise level where it was more necessary.

The following figure shows the application of this CDA V to Barajas future scenario (horizontal profiles), starting with the baseline and then showing the different possibilities depending on the approach route.

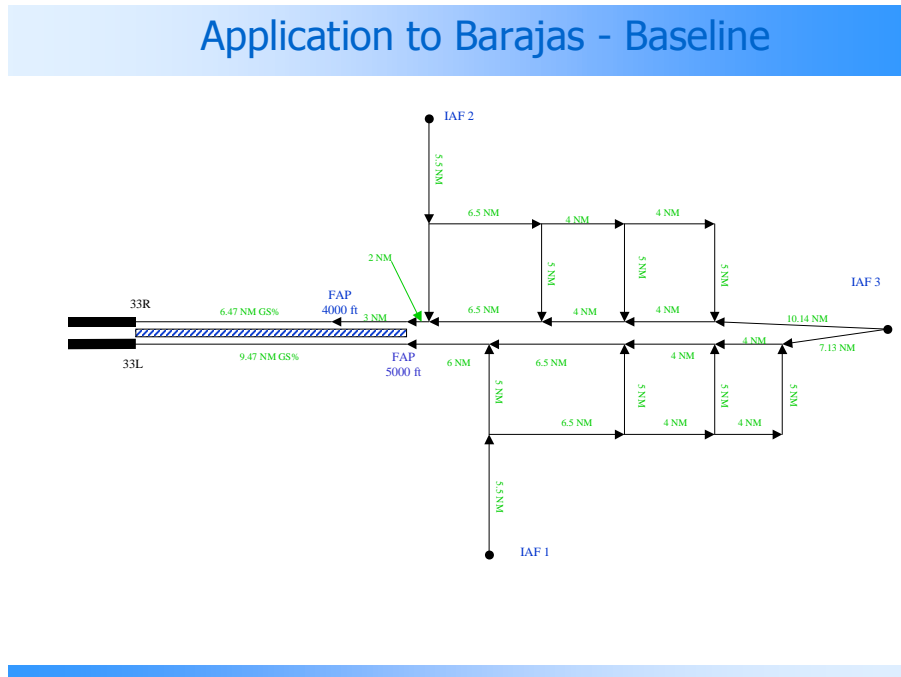


Figure 4-4: Baseline.

The baseline provided the complete set of procedures that were proposed to be used in the future Barajas airport, considering only the horizontal layout. The baselines showed an arrays approach that took advantage of the capacity of the runway having possibilities for high and low number of arrivals, depending on the length of the approach. It was used as the starting point to apply the vertical profiles defined in Sourdine II Procedure V.

There were three IAFs: the IAF1 for aircraft approaching from the south-west area, the IAF2 used by aircraft approaching form the south-east area and the IAF3, used to balance East and West traffic when necessary.

All the aircraft had to be aligned with the ILS localiser before reaching the area parallel to the NTZ. When the aircraft reached the area parallel to the NTZ, there was at least 1000 ft of vertical separation between the two parallel approaches. From the Final Approach Point, in both approaches, the aircraft descended according to the glide slope (3°).

**4.7.4. Safety Assessment Outcome**

When trying to extrapolate the vertical profiles described in Sourdine II to the future Barajas scenarios, a significant constraint was found. The future Barajas operations under current consideration for approaches to parallel runways are based in vertical separation. Therefore, a clear incompatibility arose when applying “pure” CDA to both approaches as the runway heads were not sufficiently staggered in distance to ensure a 1000ft vertical separation while performing independent continuous descent approaches for both runways. The adopted solution following extensive consultations with operational experts was to modify the Sourdine II procedure with a level flight leg in the intermediate approach for approach to runway 33R due to the lower population density in the

runway vicinity. In runway 33L a pure Sourdine II approach Procedure V was applied. This procedure modification was carried out prior to undertaking the safety assessment.

Identified hazards have been grouped as a function of the phase of flight within the approach stage into the following categories (the number of derived risks appear between brackets):

- TMA Transition (4)
- Approach Intermediate – Localiser Intercept (3)
- Approach Intermediate – Localiser Established (11)
- Approach Final (3)
- TMA Overall (1)

The outcome of the safety assessment revealed a series of safety significant issues, which were recommended for further analysis. A distinction was made between those related to the inherent characteristics was the determining factor when performing simultaneous and independent CDAs for both runways.

***Sourdine II approach Procedure V issues:***

1. The fact that final approach controllers will only monitor separation rather than issue vectors to implement separation (except in conflict situations) makes that non-adherences to CDA speed descent profiles may cause aircraft to breach longitudinal separation (e.g. catch up aircraft ahead or be caught up by trailing aircraft). As a potential result, the probability of wake vortex encounters was likely to also increase. A simulation exercise for final approach standard separations for different traffic mixes at peak times will be required to determine whether CDAs could be sustained without being detrimental to airport capacity. Mitigation emergency procedures will also be required to manage breaches of separation during the final approach stage prior to the NTZ and the impact of any aborted approaches on departures analysed. The risk of wake vortex encounter has been classified as possibly unacceptable (Risk ID 18) without further mitigation. Additionally while some of the procedure deviation risks have been assessed as acceptable (Risks ID 8 & 9), it must be noted that this tolerability is based on the minimum safety requirement established by ED78-A. The construction of a simulation model was recommended to evaluate the frequency of occurrence in more detail.

***Parallel runway CDA safety issues***

2. Within the final approach stage once established in the localiser, separation was ensured vertically. Thus, non-adherences to vertical CDA profiles may breach the 1000ft vertical separation that by design, should be maintained at all times between aircraft established on the parallel localisers prior to reaching the area parallel to the NTZ. While the associated risk of such occurrences would be low, it would constitute a significant erosion of safety margins according to current safety standards and any subsequent non-adherence to the horizontal flight profile could rapidly develop into a serious incident with very little reaction time available.
3. Independent CDA-based approaches to parallel runway airport configurations exhibit a safety significant issue related to failed localiser intercepts, commonly known as localiser “overshoots”. In the future Barajas airport configuration, separation between aircraft established on the parallel localisers was based on 1000ft vertical separation at all times prior to reaching the area parallel to the NTZ. As a consequence, small-excursion overshoots followed by rapid localiser interceptions would only be associated with an erosion of safety margins as vertical separation would be maintained with opposing traffic. However, wide-excursion overshooting developing into wrong localiser interception or adjacent sector non-authorized incursion would pose a safety critical issue as while continuously descending vertical separation with other aircraft in the vicinity would rapidly be eroded. The outcome of the safety assessment has shown that there may be UNACCEPTABLE risks associated with localiser-failed interceptions. It was also recommended that a simulation model be constructed in order to obtain a more detailed risk quantification and established the most severe incidents likelihood of occurrence.

#### **4.7.5. Concluding Remarks on Barajas Procedure V**

The qualitative safety assessment has shown that the Sourdine II approach Procedure V adapted to the future Barajas Airport parallel runway configuration exhibited some safety significant issues that were in need of a more detailed and quantitative analysis. It was recommended that the analysis took into consideration the inclusion of decision support tools such as an Arrival Manager (AMAN) to manage the arrival sequences on both runways. It was also suggested that a safety-net additional functionality was considered in order to monitor potential longitudinal breaches of separation for localiser-established consecutive aircraft.

### **4.8. Safety Assessment of Departure Procedure 2 on Barajas Airport**

#### **4.8.1. Introduction**

This section describes the safety assessment carried out by AENA (Aeropuertos Españoles y Navegación Aérea) considering the extrapolation of the Sourdine II departure procedure, take off power up to 800ft, OEI setting up to 3000ft with steeper climb gradient flown up to 5000ft, cleaning up and accelerating until 250kts) to Barajas airport, considering the most probable parallel runway scenario in 2015. The full safety assessment can be found in [S II D4.2-3].

The hazard identification has been carried out through a brainstorming session with operational personnel and further analysis with safety experts. The information captured during the session was processed and as a result, ten hazards were identified. It must be noted that resource constraints limited the number of operational experts involved in the analysis. For this reason the assessment has been termed as a high-level safety assessment. Subsequently and subject to this caveat, all derived risks have been preliminarily considered to be acceptable.

The main purpose for the argumentation-based safety assessment has been to evaluate the Sourdine II departure procedure 2 safety implications when introduced into a real airport approach scenario. Only hazards directly related to the Sourdine II departure procedure or whose consequences would be made worse by its implementation have been considered. Thus, the present safety assessment needs to be considered within its intended scope and cannot be understood to cover, either partially or totally, any safety aspect of the future Barajas Airport operations.

#### **4.8.2. Safety Assessment Methodology and Criteria Considerations**

The argumentation-based safety assessments for Sourdine II procedures adapted for Barajas Airport (circa 2015) have been carried out following a methodology consistent with ESARR 4 [ESARR 4] requirements. Expert sessions with the participation of pilots, ATC officers and safety personnel familiar with the Barajas Airport future parallel runway planned operations have been held to introduce the concept of operations and to identify the hazards that the Sourdine II procedure would pose to ATM operations. Subsequently, the identified hazards have been assigned a severity and an estimated occurrence frequency in order to determine their risk tolerability. No attempt has been made to numerically quantify the frequency occurrence.

With regards to severity classification, the ESARR 4 scheme has been employed to classify the identified hazards. Unfortunately, the risk classification scheme (or matrix) provided by ESARR 4 is still under development and an alternative scheme must have been selected to complete the risk analysis. The risk classification scheme selected corresponds to ED-78A "Guidelines For Approval Of The Provision And Use Of Air Traffic Services Supported By Data Communications" [ED-78A].

#### **4.8.3. The Operation**

The operation under study corresponds to the Sourdine II departure Procedure 2 (Optimised Close-In) extrapolated to Barajas in an anticipated 2015 scenario, with two sets of parallel runways. The study focuses on the most commonly used North Configuration at Barajas, 33L and 33R for approaches and 36L and 36R for departures (as shown in Figure 4-3).

The scenario under consideration presented the following characteristics:

- Two sets of parallel runways.
- The arrivals and the departures were segregated.
- The distance between runways enabled independent departures as well as independent arrivals procedures. There were some dependencies between arrivals to runway 33R and departures from 36L due to the missed approach procedures from the 33R (in North configuration).

During the description of the operation for the Sourdine II departure Procedure 2 applied to Barajas, the following hypotheses have been considered:

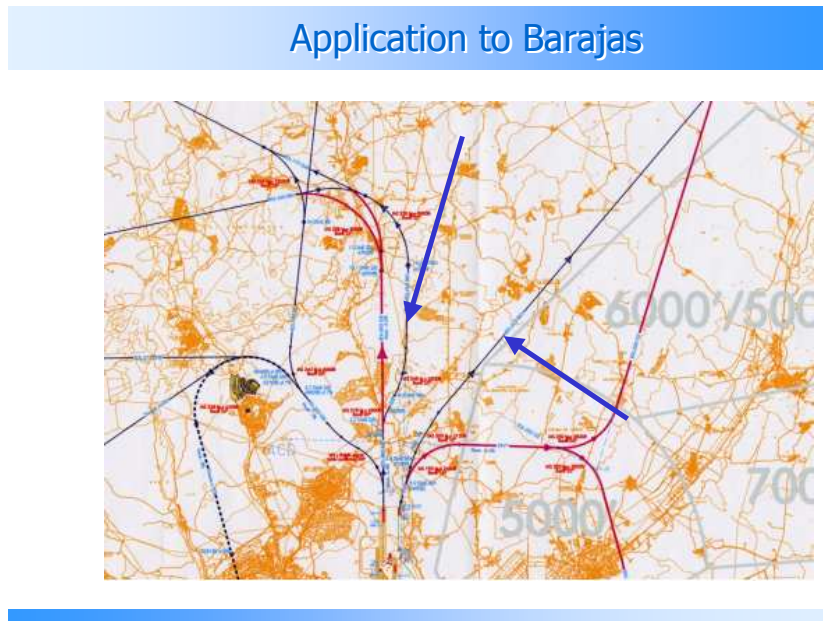
- The runways used for departures in North Configuration were 36R and 36L.
- It had been considered only from the threshold to approximately 48 MN since lift-off.
- From a technological point of view:
  - Communications: Mainly voice communication. Probably for 2015 there will be more data link applications but this study was focused on the CDA for Barajas rather than on technological improvements.
  - Navigation: RNP1 in TMA. All the aircraft following the procedure would be equipped.
  - Surveillance: Radar separation for departure.
- Aircraft equipped with new generation FMS that followed the procedure as it was described in [S II D3-1].
- Fleets: A340. The rationale for choosing this fleet was data availability.
- Roles:
  - Ground:
    - Departure controllers (one per runway): West for 36L and East for 36R.
  - Air:
    - Pilot flying.
    - Pilot not flying.

The departure Procedure 2 (Optimised Close-In), considering the vertical profile, was described in the following table, from the data provided in the project:

Condition	Parameter values
0 ft	<ul style="list-style-type: none"> <li>- TOGA (Take-off Go Around) thrust</li> <li>- Brake release and acceleration to rotation speed. Rotation and lift-off</li> </ul>
	<ul style="list-style-type: none"> <li>- Retraction of undercarriage</li> <li>- Climb out at speed of V2 + 10-20 kts IAS</li> </ul>
1000 ft	<ul style="list-style-type: none"> <li>- Reduce thrust to OEI climb gradient or max climb (the lowest)</li> <li>- Maintain V2 + 10-20 kts IAS</li> </ul>
3000 ft	<ul style="list-style-type: none"> <li>- If OEI climb gradient thrust was selected, gradually change to thrust to climb thrust</li> <li>- Maintain V2 + 10-20 kts IAS</li> </ul>
5000 ft	<ul style="list-style-type: none"> <li>- Accelerate and retract flaps/slats on schedule to clean configuration</li> <li>- Continue acceleration to 250 kts</li> <li>- Climb to 15000 ft</li> </ul>

**Table 4-2: Description of Sourdine II departure procedure 2**

The following Figure 4-5 shows the set of departure procedures that have been planned to be used in the future Barajas airport, North configuration.



**Figure 4-5: Future departure procedures in Barajas Airport.**

#### **4.8.4. Safety Assessment Outcome**

Ten hazards were identified during the expert session for the Sourdine II departure Procedure 2, adapted to the future Barajas airport layout. Given the number of hazards and the characteristics of the procedure, the hazards were not classified into any particular categories. Five of the identified hazards were inherently characteristic of the departure procedure and the remaining five were of a more general nature and were also applicable to departures as well as to arrivals procedures.

The Sourdine II departure Procedure 2 aimed at reducing the noise impact around the SID footprint at ranges closest to the runway, causing the aircraft to operate at reduced performance with One Engine Inoperable (OEI) power settings. This fact necessarily imposed that the main procedure risks would be associated with the airport obstacle limiting surface infringements that might lead to the loss of separation with the obstacles and/or ground. The main emphasis of the assessment was placed on whether the procedure-induced departure from the aircraft optimal climbing performance could erode safety margins. In particular, the assessment had taken into account whether aircraft flying the Sourdine II departure Procedure 2 could easily recover from other failures even though flying at OEI power settings.

The safety assessment concludes that the most significant risks associated with the Sourdine II departure Procedure 2 were due to either engine loss (such as a catastrophic malfunction or malfunction caused by a bird strike) or sudden adverse meteorological conditions (such as wind shear or thunderstorm turbulence) that could impair the aircrafts' airworthiness. However, it was deemed that aircraft could recover from these situations despite flying at reduced power settings and therefore, the procedure did not degrade safety margins. The combination of both hazards (engine loss and adverse meteorological conditions) could have a significant safety impact. However restricting the range of meteorological conditions in which the Sourdine II departure Procedure 2 might be flown could mitigate this.

#### **4.8.5. Concluding Remarks on Barajas Departure Procedure 2**

The qualitative high-level safety assessment has shown that the Sourdine II departure Procedure 2 adapted for the future Barajas Airport parallel runway configuration exhibits some safety issues. These issues were related to the fact that noise reduction was achieved by operating the aircraft at reduced power settings and associated with any failure that might cause airport obstacle limiting surface infringements that might lead to loss of separation with obstacles and/or ground. The conducted high-level assessment has been concluded with all of the identified risks having been preliminarily considered as acceptable. Given the high level nature of the assessment in terms of number of participating experts, it was recommended that further analysis be undertaken to increase the confidence in the resulting risk classification

### **4.9. Conclusions**

Safety analyses have been performed for the four approach and two departure noise abatement procedures (NAPs) defined in [S II D3.1-2]. Based on an initial high-level safety evaluation of these four approach and two departure procedures and on inputs not related to safety the Sourdine II management made a selection of three procedures for safety assessment. For each of these three procedures an operation was defined on a specific airport including also specific personnel roles and technical systems. The results of these safety assessments consisted of an overview of the risks associated with the operations and showed which parts of the operations were most safety critical, such that feedback could be given to the operational concept designers.

First the conclusions of the initial high-level safety evaluation of the four approach and two departure procedures were given. Next, the main conclusions of each of the three safety assessments were presented.

#### **4.9.1. Conclusions of the Initial High-Level Safety Evaluation**

The main safety issues related to each of the four approach procedures were:

- II. Basic CDA with 2° initial Flight Path Angle;
  - A possible excess speed at glide slope intercept possibly leading to an unstabilised approach.
- III. Basic CDA with 2° initial FPA and increased final glideslope;
  - A possible excess speed at glide slope intercept possibly leading to unstabilised approach; more severe than for procedure 2 due to the fact that the excess speed was more difficult to control on a steep final segment;
  - The steep final glideslope is a non-standard operation and potentially leads to higher workload. This operation required special analysis in relation to acceptance and to obstacle clearance surfaces.
- IV. CDA with constant speed, variable FPA segment at landing configuration;
  - A possible steep intermediate approach segment resulting to glideslope interception from above, with the potential consequences of a glideslope undershoot and an unstabilised approach;
  - Potential flight path control problems, which could lead to an increased workload and an unstabilised approach in case the path is too shallow;
- V. CDA with constant speed, variable FPA segment at intermediate configuration;
  - The same issues as for Procedure IV, though both less severe.

Because Procedure II was expected to cause a limited capacity decrease, a variant of Procedure II was defined by Sourdine II operational designers, called Procedure II-A. In Procedure II-A, speed constraints were imposed on the 2-degree flight path angle segment.

The main safety issues related to each of the two departure procedures are:

1. Sourdine optimised close-in procedure;
  - Speed control problems with a low power setting at OEI climb thrust
2. Sourdine optimised distant procedure;
  - The same issue as for Procedure 2, but less severe.

#### **4.9.2. Main Conclusions of the Safety Assessment of Approach Procedure II-A on Schiphol Airport**

The safety assessment has been performed for the operation described in D4.2-2a, in which Sourdine II approach Procedure II-A was considered in the context of Schiphol airport. The risk has been assessed with respect to risk criteria that combined the [ESARR 4] severity classification with the well-known frequency classification of JAA.

Five conflict scenarios have been identified that describe in which way an accident or incident could occur. The risks of conflict scenarios 1 and 3 were classified as TOLERABLE, and the risks of conflict scenarios 2, 4 and 5 were classified as being either TOLERABLE or UNACCEPTABLE.

The uncertainty in the latter results was related to the use of data retrieved from experts, who assessed a future operation by extrapolating their experiences with the current operation; to details of the operational description that remain to be specified; and to the scarceness of statistical data on model parameter values.

When considering to which extent the identified (possibly) UNACCEPTABLE risks were generic for the vertical flight profile considered, irrespective of the Schiphol implementation considered, the following conclusions hold:

- The possibly UNACCEPTABLE risk for conflict scenarios 2 and 5, related to longitudinal separation problems caused by an insufficient initial separation at the IAF and by a reduced ability to provide separation in case of 34 aircraft per hour, may be generic for the vertical flight profile considered.
- The possibly UNACCEPTABLE risk for conflict scenario 4, caused by aircraft overshooting the ILS while turning in for parallel approach, while vertical separation of 1000ft has not been guaranteed, WAS not generic for the vertical profile. However, when considering a generic implementation of this profile on parallel runways, it WAS very possible that the risk was possibly UNACCEPTABLE, depending of course on the distance between the runways, the staggering between the runways, and the exact implementation of the procedure.

Since the operation had risks that were classified as (possibly) UNACCEPTABLE, the operation should be improved before implementation. Safety bottlenecks have been identified that could serve as a starting point for the operational concept designers for the identification of risk mitigating measures. It is considered most logical to do a new cycle of the safety assessment once the operation has been improved; then also for conflict scenarios 2 and 5 a simulation-based approach may be used.

#### **4.9.3. Main Conclusions of the Safety Assessment of Approach Procedure V on Barajas Airport**

The outcome of the safety assessment for approach Procedure V on Barajas airport has revealed a series of safety significant issues, which were recommended for further analysis. A distinction was made between those related to the inherent characteristics of the Sourdine II approach Procedure V and those for which the particular parallel runway set-up was the determining factor when performing simultaneous and independent CDAs to both runways.

##### *1. Sourdine II approach procedure V issues:*

- The fact that final approach controllers would only monitor separation rather than issue vectors to implement separation (except in conflict situations) the non-adherences to CDA speed descent profiles might cause aircraft to breach longitudinal separation (e.g. catch up aircraft ahead or be caught up by trailing aircraft). As a potential result, the probability of wake vortex encounters was likely to also increase. The risk of wake vortex encounter has been classified as possibly unacceptable without further mitigation.

##### *2. Parallel runway CDA safety issues*

- Within the final approach stage once established in the localiser, separation was ensured vertically. Thus, non-adherences to vertical CDA profiles might breach the 1000ft vertical separation that by design, should be maintained at all times between aircraft established on the parallel localisers prior to reaching the area parallel to the NTZ.
- Independent CDA-based approaches to parallel runway airport configurations exhibited a safety significant issue related to failed localiser intercepts (i.e. “overshoots”). In the future Barajas airport configuration, separation between aircraft established on the parallel localisers was based on 1000ft vertical separation at all times prior to reaching the area parallel to the NTZ. As a consequence, small-exursion overshoots followed by rapid localiser interceptions would only be associated with an erosion of safety margins while wide-exursion overshooting developing into wrong localiser interception or adjacent sector non-authorized incursion would pose a safety critical issue.

The qualitative safety assessment has shown that the Sourdine II approach Procedure V adapted to the future Barajas Airport parallel runway configuration exhibited some safety significant issues that were in need of a more detailed and quantitative analysis. It was recommended that decision support tools such as an Arrival Manager (AMAN) and safety-net additional functionality to monitor potential

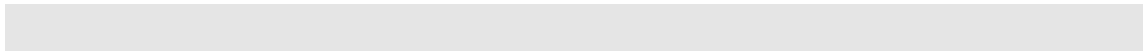
longitudinal breaches of separation for localiser-established consecutive aircraft were considered in relation to future safety assessments.

#### ***4.9.4. Main Conclusions of the Safety Assessment of Departure Procedure 2 on Barajas Airport***

It must be noted that resource constraints limited the number of operational experts involved in this particular departure procedure analysis. For this reason the assessment has been termed as a high-level safety assessment. The Sourdine II departure Procedure 2 aimed at reducing the noise impact around the SID footprint at ranges closest to the runway, causing the aircraft to operate at reduced performance with One Engine Inoperable (OEI) power settings. This fact necessarily imposed that the main procedure risks would be associated with the airport obstacle limiting surface infringements that might lead to the loss of separation with the obstacles and/or ground. The main emphasis of the assessment was placed on whether the procedure-induced departure from the aircraft optimal climbing performance could erode safety margins. In particular, the assessment has taken into account whether aircraft flying the SII departure Procedure 2 could easily recover from other failures, even though flying at OEI power settings.

The safety assessment has concluded that the most significant risks associated with the Sourdine II departure Procedure 2 were due to either engine loss (such as a catastrophic malfunction or malfunction caused by a bird strike) or sudden adverse meteorological conditions (such as windshear or thunderstorm turbulence) that could impair the aircrafts' airworthiness. It was deemed that the aircraft could recover from these situations despite flying at reduced power settings and therefore, the procedure did not degrade safety margins. The combination of both hazards (engine loss and adverse meteorological conditions) could have a significant safety impact. However, restricting the range of meteorological conditions in which the SII Sourdine departure Procedure 2 might be flown could mitigate this.

The conducted high-level assessment has concluded with all identified risks having been preliminarily considered as acceptable. Given the high level nature of the assessment in terms of number of participating experts, it has been recommended that further analysis be undertaken to increase the confidence in the resulting risk classification.



## 5. Noise Assessment and Emission Results

### 5.1. Introduction to Noise Results

The goal of this section is, on one hand, to summarise the different results derived from the noise assessment of the Sourdine II procedures carried out for Madrid-Barajas, Naples-Capodichino, Amsterdam-Schiphol and Paris-Charles de Gaulle airports. On the other hand, it describes the specific assumptions and methodology followed in determining the calculation of the population affected by noise (Madrid-Barajas only) and the fleet-mix substitution for INM7.0.

This document was exclusively focused on the final results obtained from the assessments, so only comparative bar charts were shown (SII procedures vs. Baseline), further details being available in the specific deliverables [S II D4-1-nb]. Further information on the methodology for the Noise assessment and the INM 7.0 package feature are available in [S II D5-2].

This deliverable summarises the results of Sourdine IIs' noise and emission assessment for the four chosen European Airports.

### 5.2. Noise Assumptions and Hypothesis

The general assumptions and hypothesis are found in Section 4 of this document. The specific assumption and hypothesis that pertains to noise assessment include the following:

**The aircraft substitution was based on eight aircrafts contained in updated INM7 database (new NPD curves [S II D5-2]).**

The timetable used in the final noise assessment contained real traffic data.

The traffic was increased based on 2015 forecast and aircraft model on airlines' future purchasing policy.

Aircrafts that were not included into the eleven aircraft of the INM7 database that included 6 Airbus and 4 Boeings were substituted accordingly, while Turboprops were not taken into account by the assessment (see Appendix 3 for further details).

### 5.3. Airport Traffic

Real traffic was used and adapted for the aircraft models presented in Sourdine II's INM7.0 software. In Table 5-1, the available aircraft and the substitutions made; turboprops were not included in the noise assessment, (for further details on the substitution process refer to Appendix 3).

MTOW Class [1000kg]	Aircraft	MTOW [1000kg]	SL Max EPNdb	Noise Assessment Substitution	
				substitution	optional
15 ≤ MTOW < 40	CRJ-100/200	21.5	86	none	
	EMB145	22-24	84.6	none	
	ATR42	16	80.7	none	
	Dornier 328	16	83.8	none	
	Embraer RJ145	22	84.2 – 84.6	none	
40 ≤ MTOW < 60	FOKKER70/100	45.18	91.7	B737-300	A319-111
	B737-300	62.8	90.4	B737-300	
	A319-111	64-75.5	92	A319-111	

MTOW Class [1000kg]	Aircraft	MTOW [1000kg]	SL Max EPNdb	Noise Assessment Substitution	
				substitution	optional
$60 \leq MTOW < 100$	B737-400	62.9-68.1	93.2	B737-300	
	B737-700	60-70	94.7	B737-800	
	MD-88	72.5	97.2	A321-232	
$60 \leq MTOW < 100$	MD-87	63.5	97.1	A321-232	
	MD 81(S80)	63.5	97.3	A321-232	
	MD82	67	96.3	A321-232	
	A320-211	73.5-77	94.4	A320-211	
	A320-214	73.5-77	94.4	A320-214	
	A320-232	73.5-77	94.4	A320-232	
	B737-800	78-79	93.1	B737-800	
	B737-900	78-79	94.3	B737-800	
	A321-211	83-93.5	94.3	A321-211	
A321-232	83-93.5	95.6	A321-232		
$100 \leq MTOW < 160$	B757-200	98.8-115.6	94.2-94.4	B757-200	
	B757-300	123.6	94.5	B757-200	
$160 \leq MTOW < 230$	B767-300	184.8-186.8	97	A330-301	B777-200
$230 \leq MTOW < 300$	A330-301	230-233	97.2	A330-301	
	A340-313	271-275	95.8	A340-313	
	MD11	275	96.1- 96.5	B777-200	
	B777-200	253-305.97	96.1	B777-200	
$300 \leq MTOW < 400$	747-400	363-396.6	103.8	A340-313	
	A340-600	368-380	98	A340-313	

Table 5-1: INM7.0 aircraft substitution

## 5.4. Metrics and Methodology

### 5.4.1. Metrics

The main metrics and indicators calculated in the SII project for the noise and emissions assessment were:

#### Lden [European Environmental Agency, INM6.0 manual]

Lden was a community noise equivalent Day-evening-night level. It provided a descriptor of noise level based on energy equivalent noise level (Leq) over a whole day with a penalty of 10 dB(A) for nighttime noise (22.00-7.00) and an additional penalty of 5 dB(A) for evening noise (i.e. 19.00-23.00).

#### Lnight [EEA, D2-1],

Lnight was the A-weighted long-term average sound level, as defined by ISO 1996-2 (1987), determined over all the night periods in a year. The definition of Lnight was the long-term LAeq over 8 hours outside at the most exposed facade. As Lnight was a relatively new definition and because the studies rarely cover such a long period, the research data was expressed in anything but Lnight..

### **LAMAX**

LAMax was the maximum A-weighted sound pressure level. It was often desired to measure the maximum level (LAMax) of individual noise events as those cases like noise coming from trains and aircraft (maximum noise level [STOCK]). LAMax values could be found inside the respective airport studies ([S II D4-1-2b] to [S II D4-1-5b]).

### **Range (db) of indicators**

Noise levels were given from 55 dB for Lden, 50 dB for Lnight, and incremented by 5dB. The highest noise level threshold to be accounted for in the results was determined by airport (and metric) specificities, and was determined by the surface of the corresponding contour. There was no point in presenting contour area variations (in percent) for very small areas but in any case, the highest threshold levels did not exceed 75 dB for Lden, and 70 dB for Lnight.

#### **5.4.2. Methodology to Assess Airport Noise**

In the following points have provided a brief explanation of the methodology agreed by the consortium to assess the noise impact of the new procedures designed within the Sourdine II project to each FTS site (for further details, refer to [S II D4-1-2b] to [S II D4-1-5b]).

- Establish fleet mix applying the agreed aircraft substitution (see Table 5-1).
- Superimpose the Sourdine II procedures vertical profile to the 2015 airport SID and STAR scenario.
- Use of INM7.0 to calculate the noise contours for the three metrics.
- Comparison of Sourdine II contours with Baseline and airport specific current approach procedures (Schiphol, Madrid).
- Further study has been made in Madrid Airport to calculate the impact of the Sourdine II procedures on the population affected by noise (see [S II D4-1-3b]).
- Analysis of the contours and summary of results.

#### **5.4.3. Methodology to Assess Population Affected by Noise**

Thanks to the information available at Madrid Barajas Airport on population distribution in the surrounding areas, a preliminary study on the number of people in the population affected by noise and the subsequent benefits of the SII was conducted.

The variation in population impacted by these procedures was studied for Madrid–Barajas using the following assumptions:

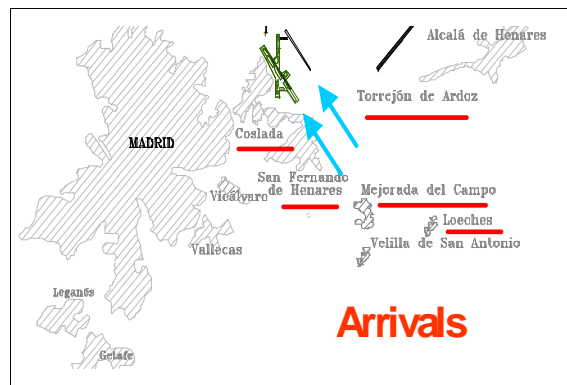
- Use of a homogeneous distribution of population in each of the populated area.
- Statistical data obtained from official sources: census 2001.
- Overlap Noise contours over the map of the surrounding populated areas
- Determination of the part of each populated area inside the different noise contours.
- Calculation of the population inside 50dB, 55dB, 60dB, 65dB, 70dB, 75dB, 80dB, 85dB and 90 dB.

Following the current methodology applied in Madrid-Barajas airport the following were also considered in Barajas' (expansion) including:

1. Isolation Acoustic Plan:
  - LAeq > 65dB day
  - LAeq > 55dB night
  - More than 50.000 received funding from the Plan
2. Adaptation to European Union legislation Plan
  - Lden and Lnight:
  - Lden > 55dB day
  - Lnight > 50dB night



**Figure 5-1 i.e affected population on Departures (areas, towns, etc..)**



**Figure 5-2 i.e affected population on Arrivals (areas, towns, etc..)**

## 5.5. Noise Assessment Results

A brief summary of results obtained during the noise assessment is presented in this section. The emphasis of the noise assessment was to analyse the effects of the Sourdine II arrival procedures compared to the baseline and the current standard procedures (see the Madrid and Schiphol assessment for further details).

The issues that were described included the following:

- Lden results
- Lnight results
- Noise affected population (Madrid Barajas case only)
- General conclusions

These metrics and assessments have been obtained for Sourdine II procedures and compared against those obtained from the current standard and baseline procedures described before. Not all the sites analysed the current standard procedure with the set of arrival procedures designed within Sourdine II activities and, consequently, more results for certain procedures were available.

The graphs included in the following section intend to give a high-level overview of the results obtained in the four airports involved in Sourdine II Project. A detailed simulation report has been produced for Madrid-Barajas, Amsterdam-Schiphol, Naples-Capodichino and Paris-Charles de Gaulle that included the whole set of results for each airport.

### 5.5.1. Sourdine II Approach Procedures Noise Results

#### 5.5.1.1. Lden

The following comparative bar charts summarise the results of the Lden indicator as calculated per procedure and scenario. In Schiphol and Madrid-Barajas a further comparison was made with the current standard arrival procedure; see Figure 5-7 for Madrid's case.

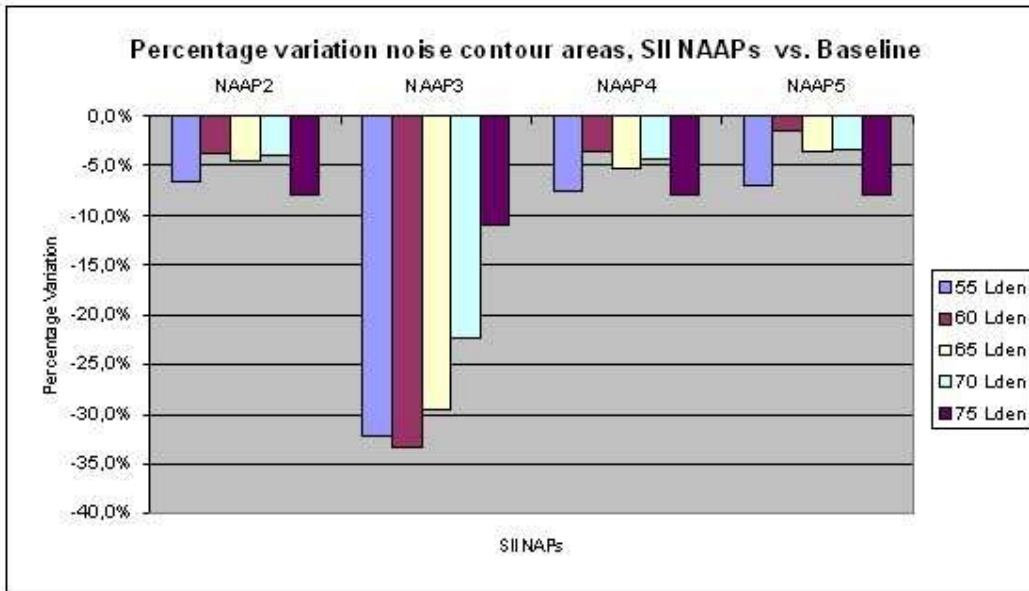


Figure 5-3: Footprint area of Sourdine II NAAPs Naples-Capodichino airport

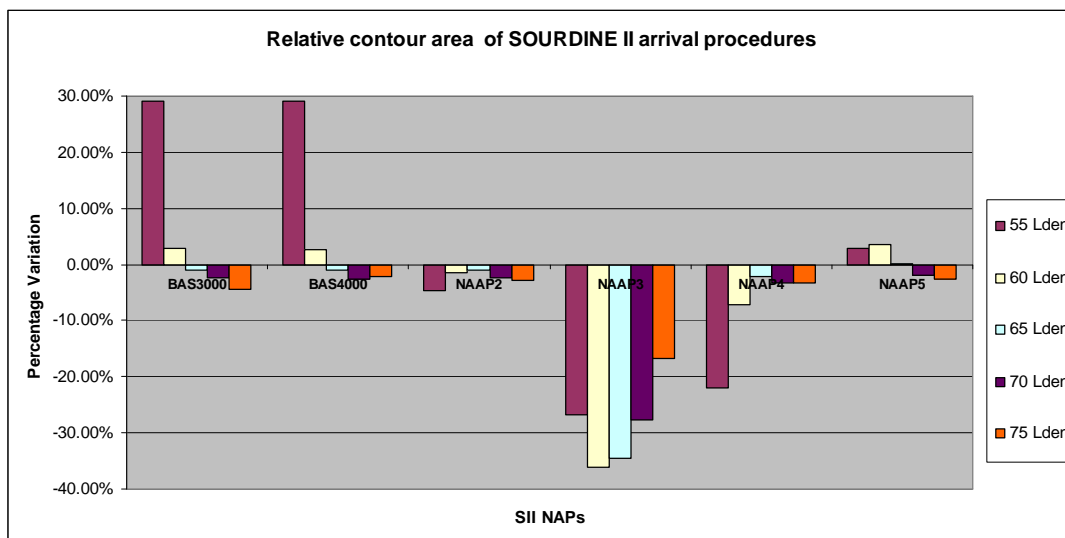
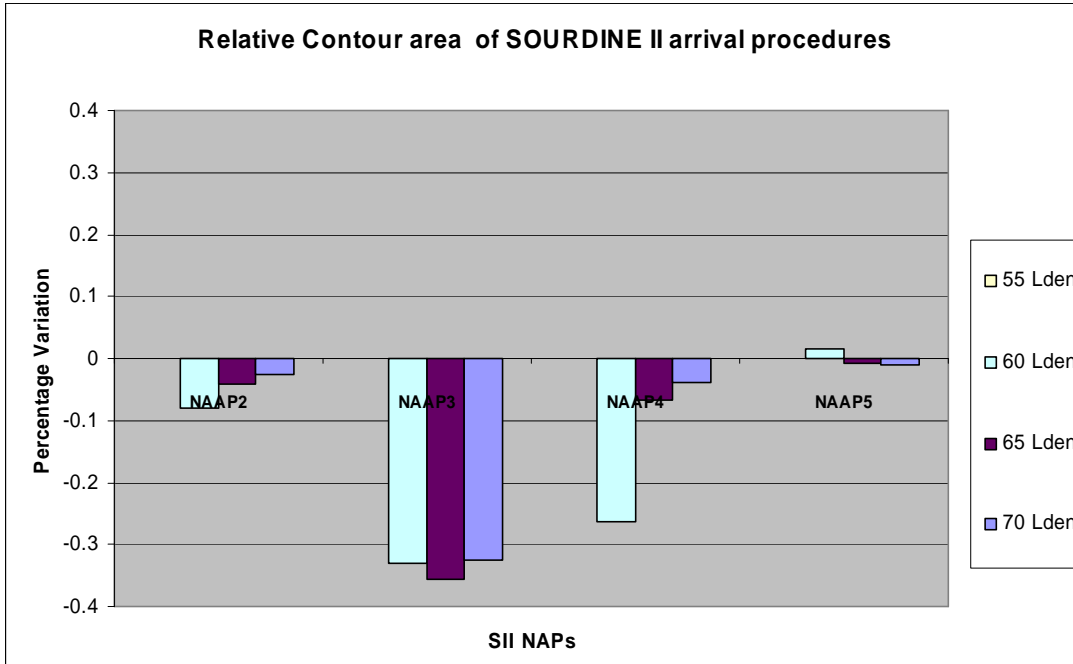
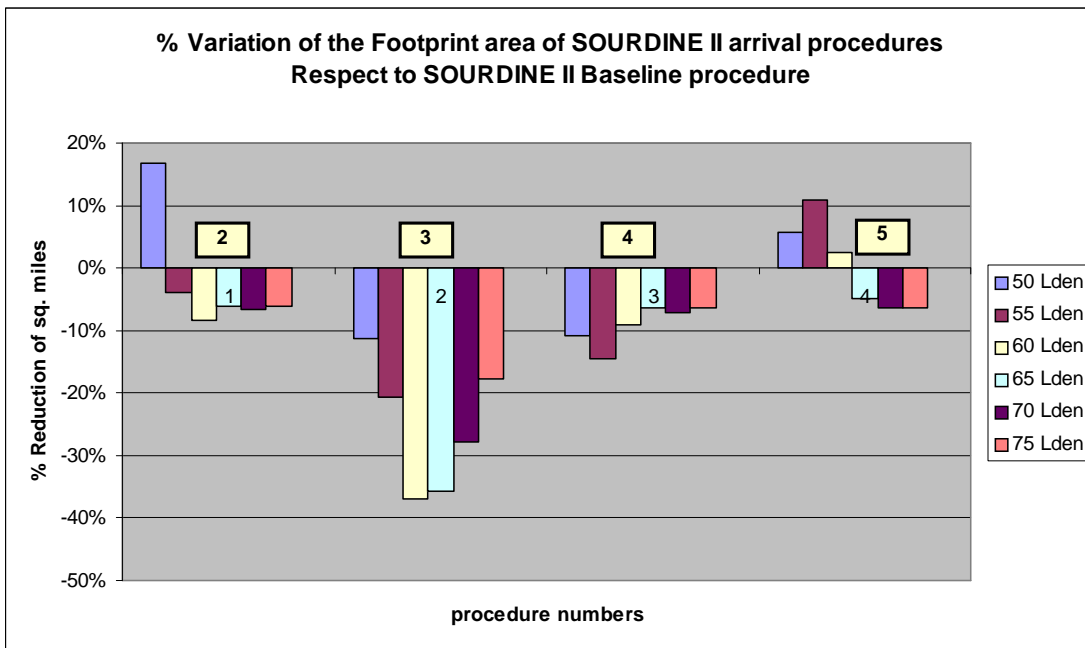


Figure 5-4: Footprint area of Sourdine II NAAPs Amsterdam Schiphol airport



**Figure 5-5: Footprint area of Sourdine II NAAPs CDG Airport**



**Figure 5-6: Footprint area of Sourdine II NAAPs Madrid Barajas airport**

The first conclusion that could be obtained and common to all the airports was that Procedure III was the most noise beneficial on all the range (db) followed by Procedures IV, II and V.

5.5.1.2. Comparison with Standard Procedures (Madrid-Barajas)

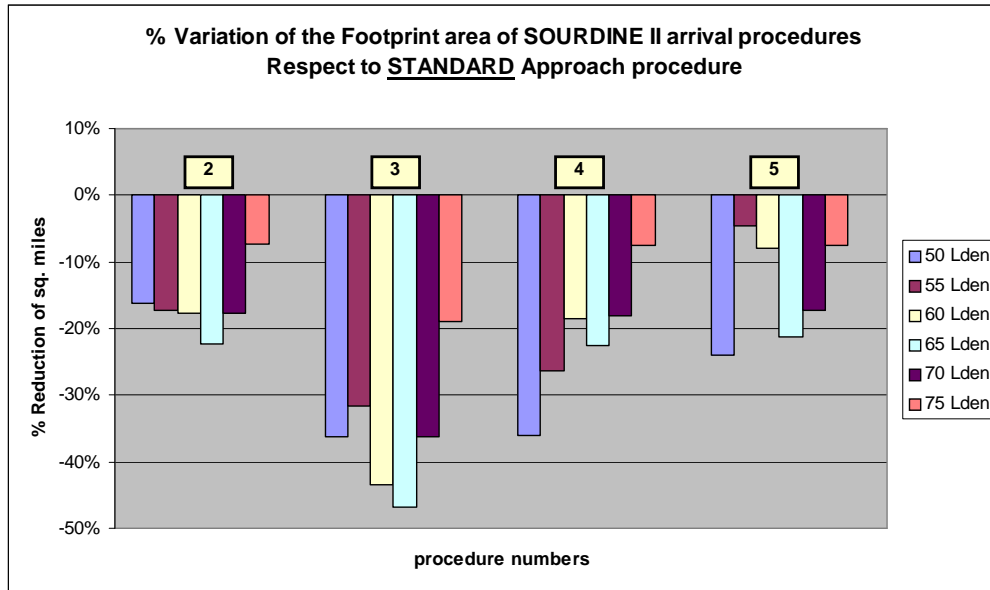


Figure 5-7: Arrivals Lden relative contour area bar charts (Standard Approach) Madrid Barajas airport

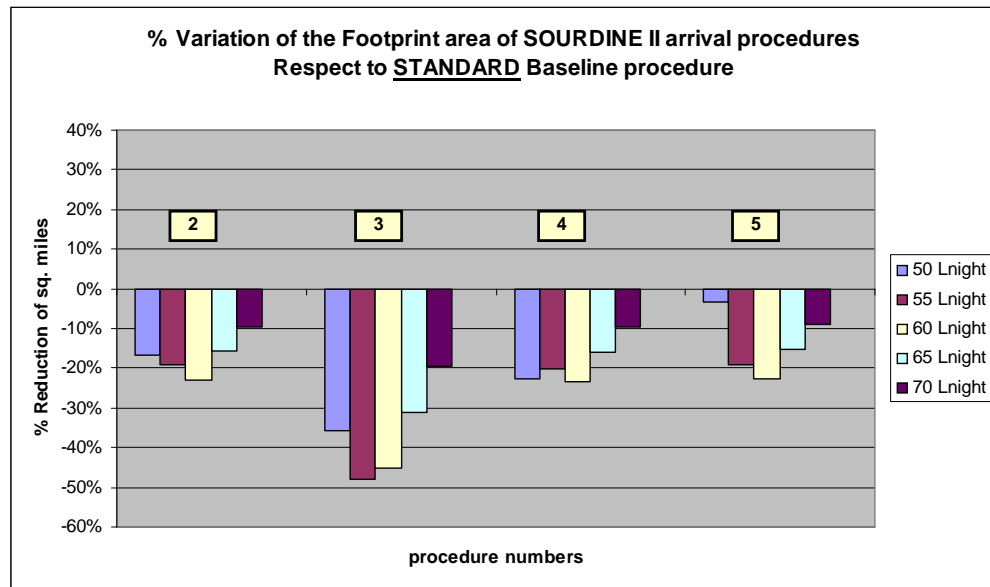


Figure 5-8: Arrivals Lnight relative contour area bar charts (Standard Approach) Madrid Barajas airport

5.5.1.3. Lnight

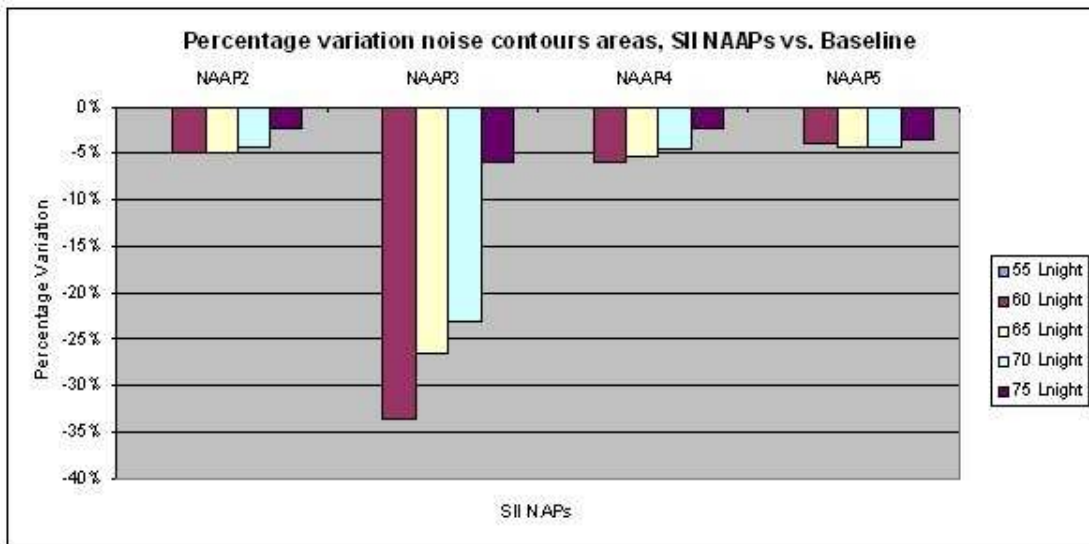


Figure 5-9: Relative contour area of Sourdine II NAAPs Naples-Capodichino airport

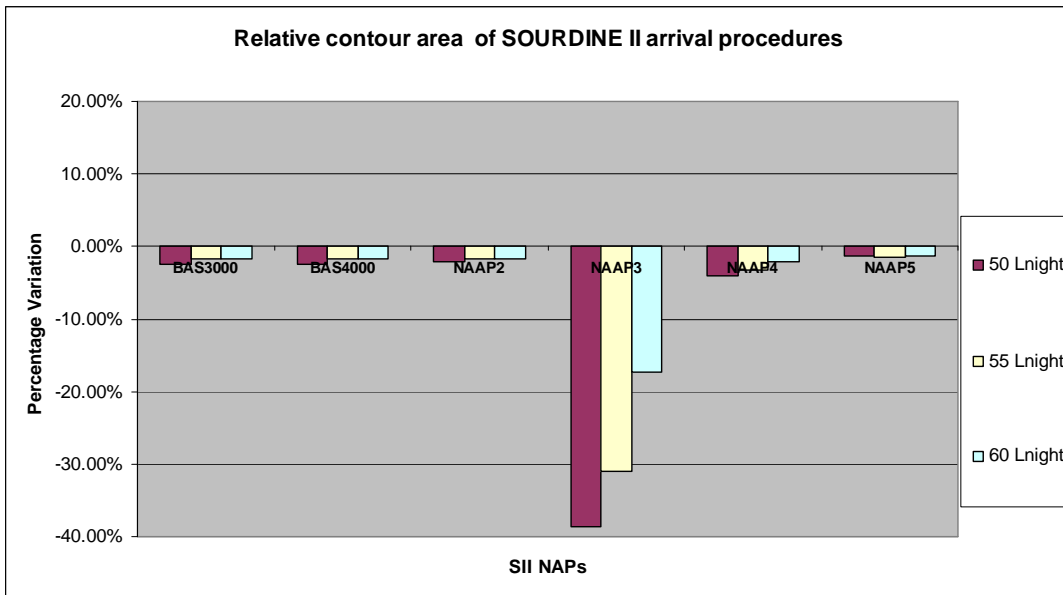


Figure 5-10: Relative contour area of Sourdine II NAAPs Amsterdam Schiphol airport

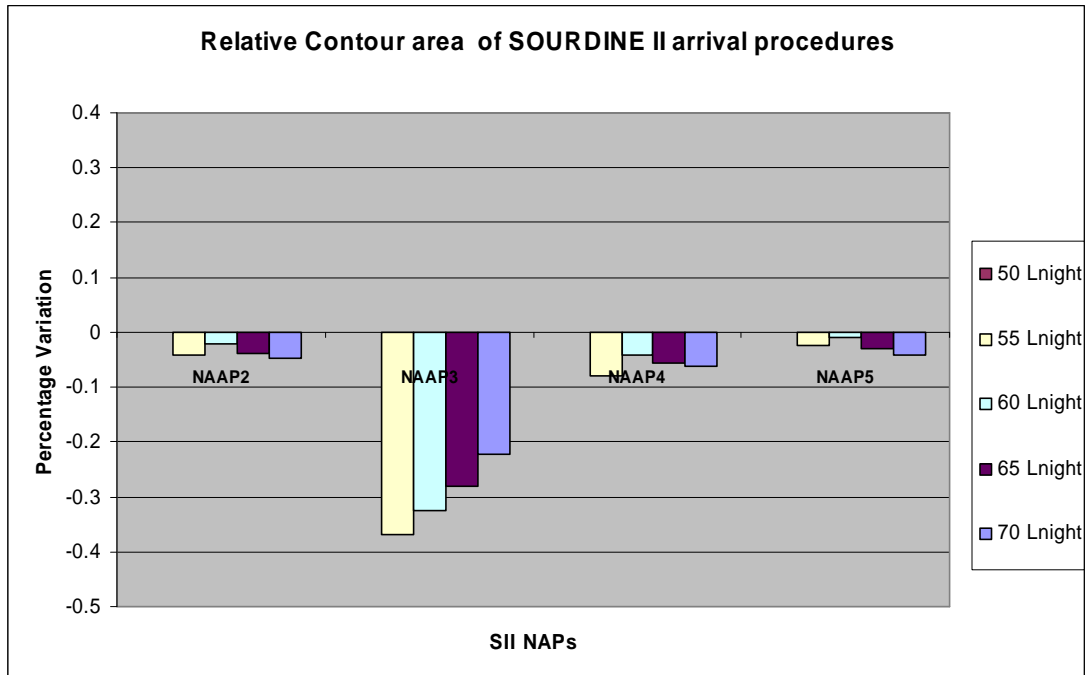


Figure 5-11: Relative contour area of Sourdine II NAAPs CDG Airport

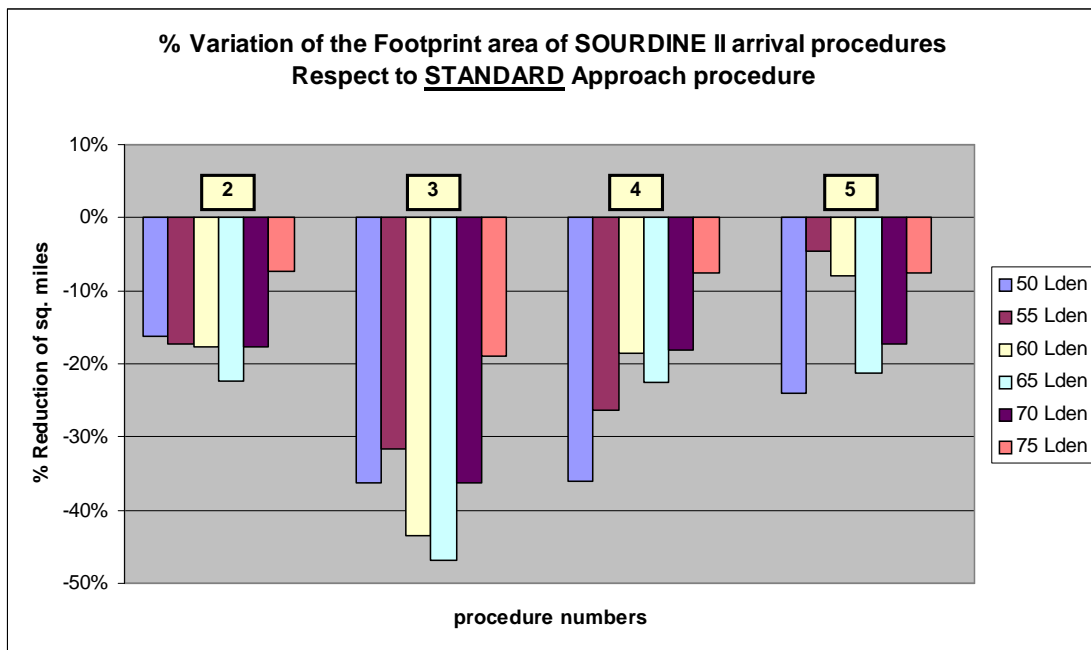


Figure 5-12: Relative contour area of Sourdine II NAAPs Madrid Barajas airport

The same happens for the Lnight indicator as in the Lden. The most noise beneficial procedure was the Sourdine II's Procedures III followed by IV, II and V.

#### 5.5.1.4. Lnight Analysis

The Lnight contours for Procedures II, IV and V showed very few differences as they were all in the area where the aircraft follow the same 3° vertical flight path. Slight variations were visible, especially in the 50dB contour due to differences in thrust and configuration, as well as the cumulative duration effect which changes with aircraft speed. In Procedure IV one can just appreciate the end of the height difference where the increased initial glide segment ends at the interception of the ILS glide slope at around 6.5NM. Procedure III, and is the case for the Lden index, showed a marked reduction in contour size. Again this was almost all due to the height difference between the two procedures.

### **5.5.2. Approach Procedures Analysis**

The analysis of the contours obtained from the four noise assessments has shown that the behaviour of the SourDine II procedures was similar or the same for all of the airports. Small differences could be appreciated for fleet-mix difference and/or the unbalanced use of the runways.

In general the same noise results were obtained for all the procedures thus the analysis below was valid for all the scenarios.

#### 5.5.2.1. Arrivals

##### Procedure II

Only the outer contour (55 dB) was slightly smaller. The other contours were virtually coinciding. This result was consistent with the altitude profiles: in Procedure II the altitude was higher at distances above ~ 9 NM, at smaller distances the profiles were the same. At approach, the altitude mainly determined the noise level; the thrust settings were also different at final approach (e.g. ~3000 vs. ~4400 pounds for the A319), but the NPD tables did not capture this difference.

##### Procedure III

Procedure III contours were significantly smaller than the baseline. This was a result of the final descent slope for Procedure III, 4°, whereas the baseline's was 3° and again, most of this difference was caused by the difference in height of the two profiles ( $\sin 4^\circ / \sin 3^\circ$ ) that gave a reduction of around 2.5 dB. This difference in noise energy was increased by the differences in thrust settings.

##### Procedure IV

As with procedure II, only the 55dB contour was affected by this procedure (with, again, a thinning of the 55dB and 60dB contours between 5.5 and 3.5 NM). The sharp initial approach angle increased the height of the aircraft before approx. 6.5NM and reduced the noise correspondingly.

##### Procedure V

The 55dB contour for Procedure V was approximately 2NM shorter and wider than that of the baseline, the contours melt into one, making no difference between the RWYs, whereas the 60dB contour was longer and thinner, showing the unbalanced traffic distribution effect encountered in all the previous procedures. The altitude profiles were the same after 10NM from the runway threshold that explained the shortening of the 55dB contour. So the rest of the changes probably resulted from the different aircraft thrusts and configurations necessary for maintaining speed over the continuous 3° decent in Procedure V.

In summary, the altitude profiles; the higher the aircraft, the lower the noise mainly determined the contours. The contour of the lowest noise level considered (55 dB) stretches out to a distance of ~ 12 NM, and it was the corresponding part of the profiles (i.e. < 12 NM) which determines the contours.

**5.5.3. Sourdine II Departure Procedures Noise Results**

The following bar charts show the comparative results for the Sourdine II NADPs.

5.5.3.1. Lden

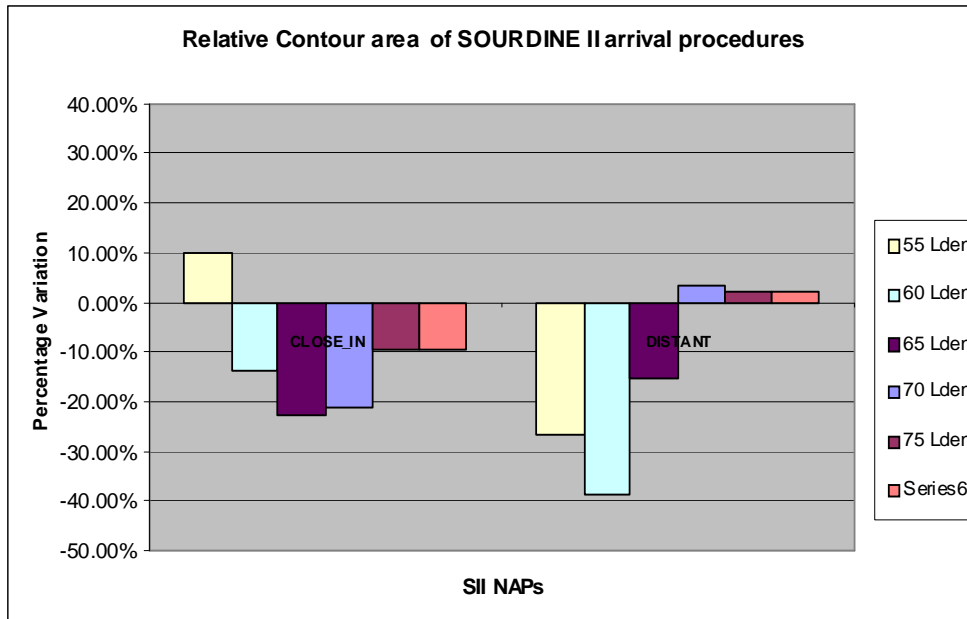


Figure 5-13: Footprint area of Sourdine II NADPs CDG Airport

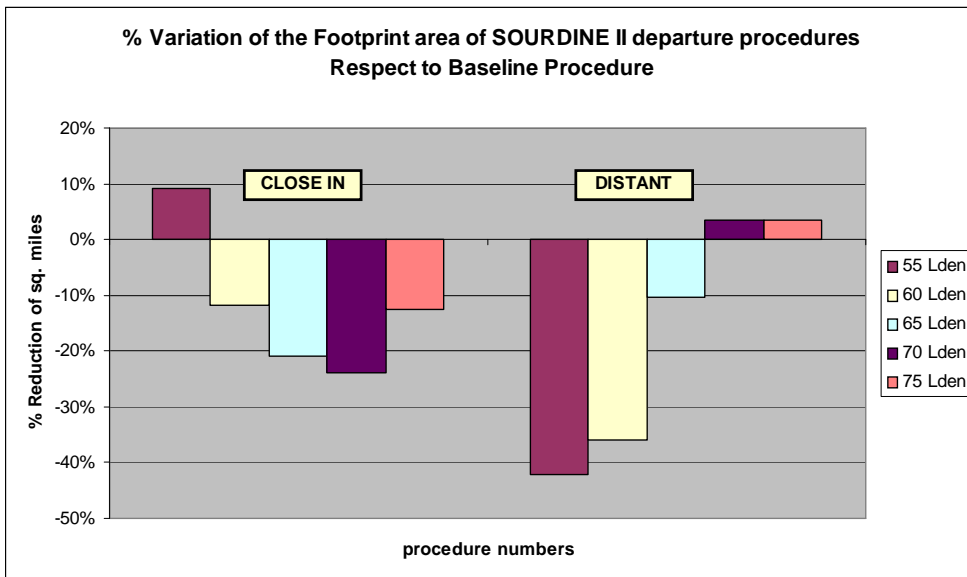


Figure 5-14: Footprint area of Sourdine II NADPs Madrid-Barajas airport

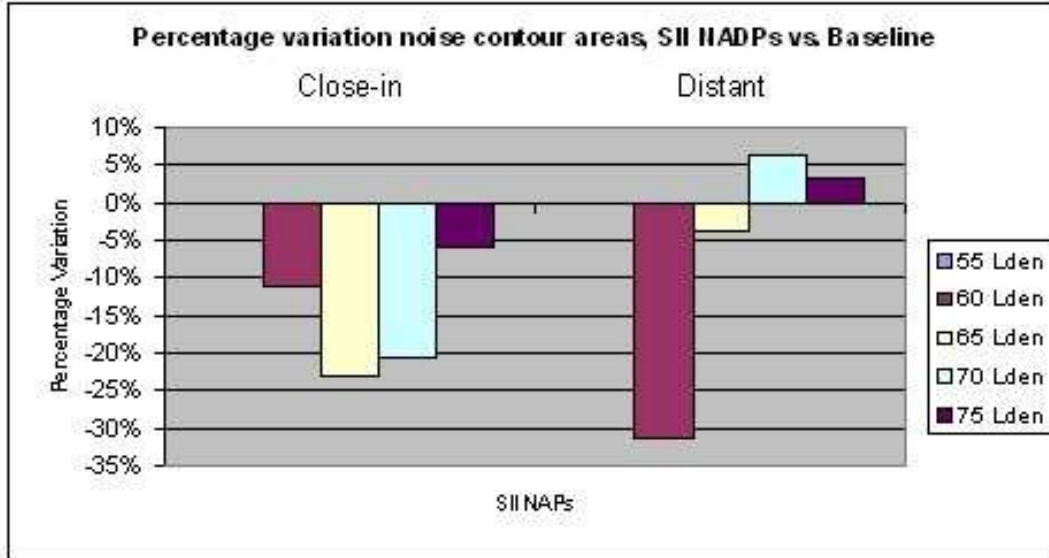


Figure 5-15: Footprint area of Sourdine II NADPs Naples-Capodichino airport

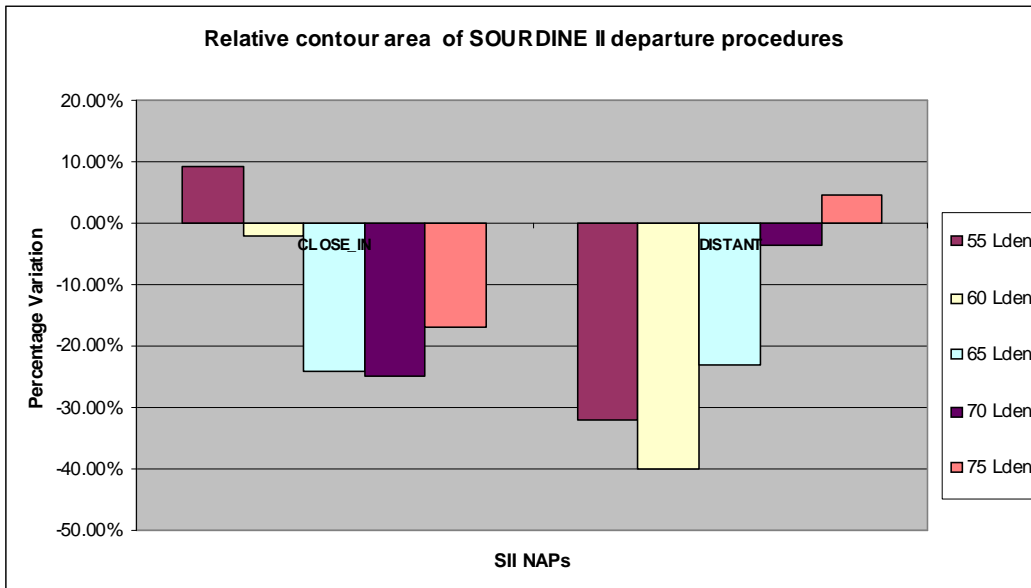


Figure 5-16: Footprint area of Sourdine II NADPs Amsterdam Schiphol airport

5.5.3.2. Knight

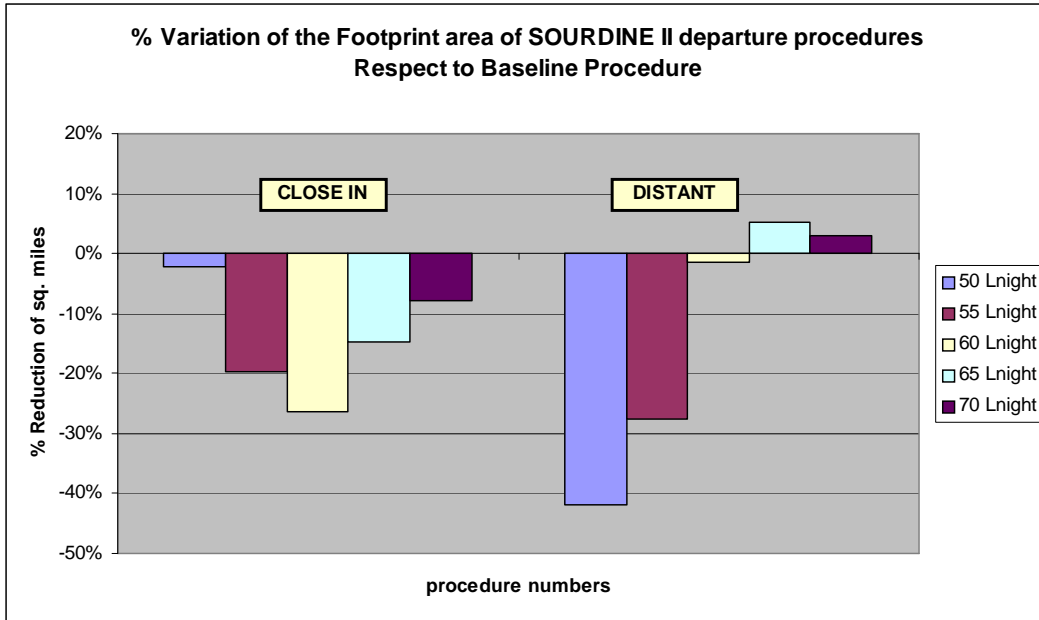


Figure 5-17: Relative contour area of Sourdine II NADPs Madrid-Barajas airport

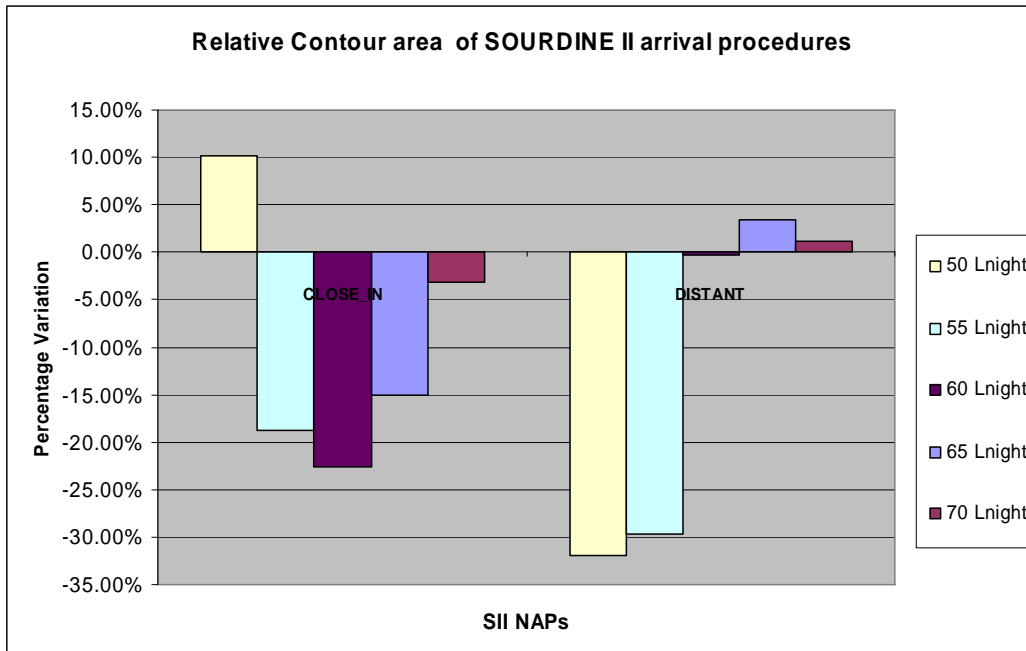


Figure 5-18: Relative contour area of Sourdine II NADPs CDG airport

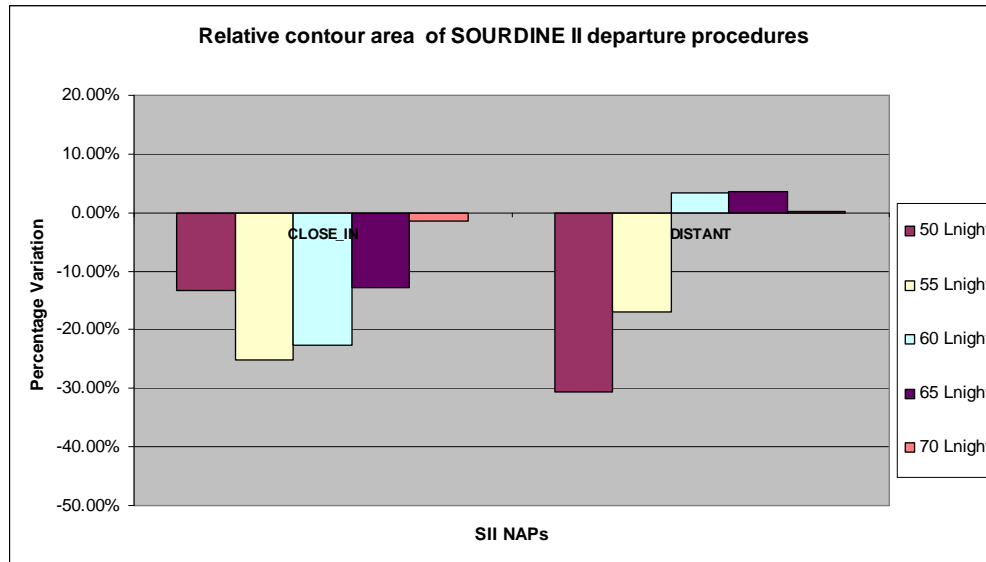


Figure 5-19: Relative contour area of Sourdine II NADPs Schiphol airport

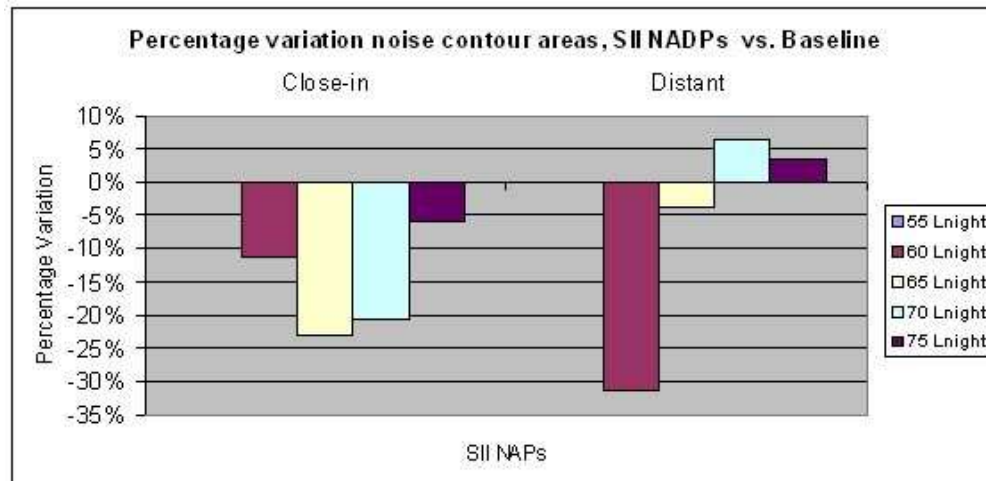


Figure 5-20: Relative contour area of Sourdine II NADPs Naples-Capodichino airport

#### 5.5.4. Departure Conclusions

As for the Approach procedures the results of the noise analysis were common for all the four scenarios with slight difference on fleet-mix and unbalanced use of the runways.

**Procedure 2:** The two largest contours (55dB and 60dB) of the close-in procedure were longer and thinner than those of the baseline, whereas the other, smaller contours were smaller all round. This was the desired result of the close-in procedure though, as could be seen, the reduction in noise occurs within 5NM of the runway. The differences close in were due to the reduced thrust values of the Sourdine II procedure, whereas the increased lengths of the larger contours for this procedure were due to the lower altitude attained by the aircraft at these points when thrust was restored.

**Procedure 3:** The Distant procedure was significantly quieter (fig. 29) in the larger part of the area of interest, despite the lower altitude. In this case the lower thrust at distances from 3 to 15 NM determined the difference. Only at larger distances (> 15 NM) was the lower altitude decisive. Also at positions very close to the runway the Distant procedure was somewhat noisier.

For the departures the noise level seemed to be determined mainly by the thrust settings, instead of by the altitudes, as was the case at arrivals.

### 5.5.5. Noise Affected Population Calculation Madrid-Barajas Airport

At Madrid Barajas Airport, a preliminary study of population affected by noise in the surrounding areas was conducted in order to analyse the influence of the proposed Sourdine II procedures in these areas. This study did not try to obtain realistic figures about the size of the population affected by airport operations. This should only be taken from a comparative point of view between a baseline scenario and several Sourdine II scenarios that shared the same hypothesis and assumptions. Obtaining a refined approximation of the size of the population affected by the future activity of Madrid-Barajas airport was not the goal of this study and all of the figures shown in this document shall not be used for any purpose that differs from this theoretical approach. With this objective in mind the statistical data of distribution of population from the census 2001 was used.

Noise contours previously obtained have been overlapped with the map of the surrounding populated areas, obtaining in this way numerical results.

#### General assumptions

For departures, a baseline had been compared with Close-in and Distant departures procedures for both Lden and Lnight metrics.

From tables containing general results for both metrics, it could be deduced that the reduction of noise-affected population was larger for the departures Distant procedure for all of the noise levels.

On the other hand, for arrivals the same metrics, Lden and Lnight, have been used. In this case there were two baselines, Standard Baseline and Baseline Procedure I. Taking whichever of these baselines as a reference, the noise contours of Procedure III were significantly smaller, and consequently the benefit for the population was higher. The reduction percentage of affected population was significant in all of the procedures for the noise contours >65dB and especially for Procedure III with a reduction higher than 80% for both baselines.

#### 5.5.5.1. Reduction in Affected People (55db)

> 55 Db	TORREJÓN	COSLADA	SAN FERNANDO DE HENARES	MEJORADA DEL CAMPO	LOECHES	TOTAL
STANDARD BASELINE	9901	19817	3945	13903	233	47799
BASELINE PROC I	8547	18824	2854	13914	64	44203
PROCEDURE II	8184	16926	2649	13602	0	41361
PROCEDURE III	8191	16117	2458	11346	0	38112
PROCEDURE IV	8250	17286	2754	13727	0	42017
PROCEDURE V	8287	17362	2554	13822	689	42714

Table 5-2: Reduction of affected population (>55dB):

#### Conclusions

- With Respect to Procedure I: 6%/14%/5%/4%.
- With Respect to the Standard Baseline: 13%/20%/12%/11%.

### 5.5.5.2. Reduction in Affected People (65db)

> 65 Db	TORREJÓN	COSLADA	SAN FERNANDO DE HENARES	MEJORADA DEL CAMPO	LOECHES	TOTAL
STANDARD BASELINE	2737	9550	740	0	0	13027
BASELINE PROC I	2272	8105	330	0	0	10707
PROCEDURE II	2110	6649	244	0	0	9003
PROCEDURE III	1441	457	0	0	0	1898
PROCEDURE IV	2232	6696	185	0	0	9113
PROCEDURE V	1999	6942	157	0	0	9098

**Table 5-3: Reduction of affected population (>65dB)**

#### Conclusions

- With Respect to Procedure I: 16%/82%/15%/15%.
- With Respect to the Standard Baseline: 31%/85%/30%/30%.

## 5.6. Conclusions

In conclusion, the sizes of the contours were generally a function of the altitude profiles, which was the most reflected mitigation by INM.

- Baseline Procedure I was very challenging from the noise impact point of view.
- All SII procedures reduced the Noise Contour Areas with respect to the Baseline scenario.
- Procedure III showed the greatest reduction of Noise contour area around Airports.
  - PROC III > PROC IV > PROC V » PROC II
- This reduction was especially significant during the night period.

For Madrid Barajas, where a study on population affected by noise was conducted, all procedures implied a significant reduction in the affected population, especially over 65 dB.

- PROC III > PROC II > PROC IV » PROC V

Departure procedures delivered noise benefits to well defined locations, following their definition of Close-in or Distant. In conclusion the choice was totally dependant on the density of population and its location around the airport. (Procedure 2 for Naples while Procedure 3 for Madrid-Barajas airport).

These conclusions were valid for all the airports (for further details refer to appropriate deliverable [S II D4-1-nb] where n = 2 Schiphol, n = 3 Barajas, n = 4 Charles De Gaulle and n = 5 Naples).

For Madrid **Barajas the different traffic volumes to the RWYs were such that differences could be appreciated between the approaches to the two runways.** The contour for the lowest noise level considered (55 dB) extends to approx. 10 NM from the runway threshold, and this contour's size was, therefore reduced accordingly at its extremity. If traffic volumes were less, this effect would not be noticeable.

## 6. Framework for Cost Benefit Analysis of NAPs

### 6.1. Introduction

Once the assessment of the SII NAPs on capacity, noise and emissions, safety and users acceptance point of view had been completed and evaluated the next step planned by the SII CBA methodology was to assess which stakeholders, investors or beneficiaries, might be impacted by the measured values. The previously noted evaluation, for example, might have been a change in the airport capacity, in the delay values, in the noise contours or in the other selected metrics.

### 6.2. Scope

The “Economic” aspect is one of the validation objectives considered within the SII project together with the aspects of safety, noise and emissions (environment) and capacity. Keeping safety as the first objective, the SII project focused on the environmental aspects by proposing new arrival and departure procedures on a long-term basis (beyond 2015) to prevent noise and emissions from becoming a constraint in the future with the increase of the airport capacity.

Performing a CBA is very difficult and above all when the evaluation covers a long period of time since more input parameters must be foreseen and these clearly impact the output results.

Once the procedures for the noise reduction have been efficiently demonstrated the success of their implementation depends on the price the involved, what the stakeholders are willing to pay and what they are willing to pay for by answering the following questions:

- “How convenient is it to apply a SII NAP?”
- “When is it more convenient to apply a NAP?”
- “Who is going to benefit from the SII NAP use?”
- “Who will have to pay to achieve the SII objective?”

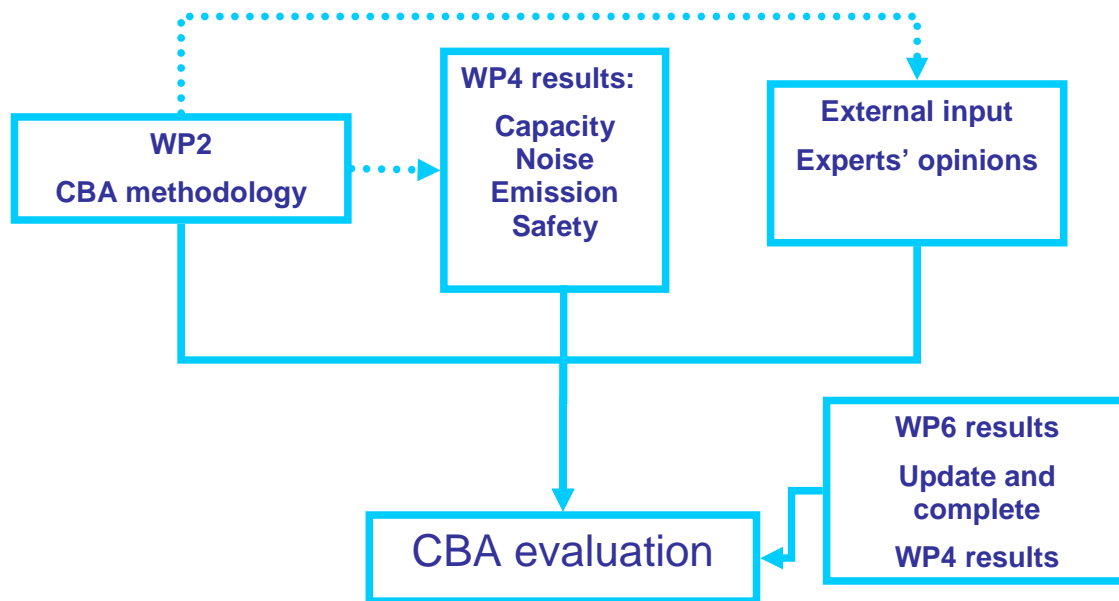
The answers to these and further questions require a clear understanding of the objectives of the SII project, to translate all Fast Time Simulations (FTS) and Real Time Simulations (RTS) into monetary terms (if possible) and compare costs and benefits identifying also who has to pay and who will benefit.

### 6.3. Input From Other WPs and External Input

Many inputs are necessary for the SII Cost Benefit Analysis. Some of those are expected to come from the Fast Time Simulations (FTS) while others come from Real Time Simulations (RTS) and others from literature studies and expert opinions.

Most input come from FTS [SII D4-1-na], providing many valuable parameters related to the effectiveness of the procedures planned within the SII project.

The scheme in the following picture summarises how the CBA has been performed and the links between WPs and external data.



**Figure 6-1: Cost Benefit Analysis Scheme**

Looking at the scheme in Figure 6-1, the CBA methodology was defined in WP2, identifying the parameters included in the CBA (both coming from the WP4 and from expert opinions) and the methods to calculate the costs and benefits.

Results coming from the WP6 have been used to update the preliminary economic results calculated with WP4 output.

## 6.4. Outline of the Study

As planned from the SII Validation Methodology [SII D2-1], the Cost Benefit Analysis had to be developed through a pre-defined sequence of steps:

- Cases identification: Do-nothing case and alternative case(s)
- Valuation types: Quantitative (€) or Qualitative (Improvement or Worsening of valuation parameters)
- Actors identification
- Cost categories identification and evaluation for each actor/stakeholder and for the identified cases
- Benefit categories identification and evaluation per each actor/stakeholder and for the identified cases
- Final assessment

### 6.4.1. Cases Identification

For evaluating the costs and the benefits coming from the SII NAPs implementation it was necessary, above all, to define the do-nothing case (if no change is planned to be applied at the selected timeframe) and the alternative cases.

The Base case is the scenario planned for 2015, with the future airport/airspace configuration, future A/D procedures, future air traffic data, future fleet mix and planned improvement/change in the ground and on-board technology.

The alternative cases were equal to the Base case, except for the A/D procedures (SII NAPs) and all the technological/operational changes necessary to their implementation.

#### **6.4.2. Valuation Types**

Two evaluation types have been identified, one is quantitative and the other one is qualitative. In both cases methods and guidelines the required input data for developing the CBA was supplied.

#### **6.4.3. Stakeholders Selected for the SII Project**

The identification of actors/stakeholders was a fundamental step towards the costs and the benefits calculation. The risk was, in fact, to exclude some of the actors from the list of those who have to pay or that can benefit from the SII NAPs implementation. The following stakeholders involved in the SII NAPs implementation have been listed below:

- Airlines
- Airport operator company
- APP/Arrival/Planning controller
- People living in the airport vicinity
- Passengers and cargo
- European Commission
- SII partners

#### **6.4.4. Identification of Costs/Benefits**

The identification of the costs was as important as the stakeholders' identification because excluding some of the costs/benefits could have lead investors/beneficiaries to the wrong conclusions.

- Investment costs
- Operational costs
- Social costs
- Noise charges
- Airport efficiency change (capacity/delay decrease)
- Decrease in noise levels benefits
- Decrease in emissions levels benefits
- Social costs (PM)

## 6.5. Air Navigation Service Provider

### 6.5.1. Investment Costs

#### Training Costs

The SII NAPs are long-term procedures and, as seen from the FTS and RTS results, they required the introduction of new tools supporting the technical ANSP staff for their implementation and application.

Conceptually speaking, the SII NAAPs kept one of the three aircraft performance parameters (speed, altitude and thrust) as a constant and played on the other two performance parameters. Once an aircraft started flying a NAAP only the configuration changes linked to the NAP were allowed. This meant that the inbound traffic had to be managed before the CDA started and this was done with the support of arrival management/monitoring tools developed for the SII NAPs, together with the Ghosting tool, that foresees the aircraft position when merging a/c flows in approach and sequences earlier inbound traffic, making the monitoring easier also. The introduction of new systems and procedures required the training of the operational staff because ATCO had to become confident and had to feel safe using them.

The introduction of the SII NADPs is easier because they imply fewer changes in the controllers operating way so there are fewer constraints to their application.

A preliminary assessment of the controllers' time training has been done through the RTS on Amsterdam Schiphol airport and, as a result, it has been found that three days training is the minimum requirement [SII D6-4] for the controllers training, having assumed that the controllers have to manage night air traffic. On the basis of the assumptions, three days are not sufficient for a full controllers training and in fact further RTS should be required for an estimation of ATCO training for managing the daily traffic. As for the first assessment, each airport had to take into account a minimum budget for the controllers training as described in the following paragraphs.

The hourly parameter of an ATCO depends from the State where the controller works. Indeed these costs depend on costs of living, which differ widely across the States in which the ANSPs are located. Due to unavailability of hourly ATCO parameter costs for each state it was decided to use an average hourly value. At the European system level, it had been estimated that the average employment costs per ATCO-hour were € 69 [ATM\_ACE]. This value had been chosen as the common value for the hourly controllers training in order to have a magnitude of the minimum effort required to ANSP for the controllers training. The following table shows a sample of ATCO training costs calculation for the application of SII NAAPs. The first column lists the number of controllers to be trained at three airports (Madrid, Naples and Schiphol), the second one lists the hourly ATCO costs updated for 2004 and the last one summarizes the calculated costs for the three days training:

	Number of controllers	Costs for one hour ATCo (€)	Training costs (€)
Madrid Barajas	70	70,60 €*	118.608,00 €
Naples Capodichino	35		59.304,00 €
Amsterdam Schiphol	75		127.080,00 €

**Table 6-3: ATCO training costs calculation for the application of SII NAAPs**

These costs have to be taken into account for the all the NAAPs because the SII arrival procedures introduced a new working way for the controllers who have had to manage the traffic before a CDA had been started and after that they were in charge of monitoring the landing aircraft. The departure

procedures do not require any particular training or support to be implemented so no investment costs were required by the ANSP for their implementation.

**New Equipment Costs**

The following table lists the new tools necessary for the implementation of the SII NAPS:

		<b>Costs in charges of ANSP</b>
<b>SII NAAPS</b>	NAAP II	Implementation of new tools: <ul style="list-style-type: none"> <li>- Monitoring/Management tools</li> <li>- Ghosting tool</li> </ul> Training of controllers on new tools and on new NADPs
	NAAP III	
	NAAP IV	
	NAAP V	
<b>SII NADPs</b>	NADP Close-in	None necessary
	NADP Distant	

**Table 6-4: New tools necessary for the implementation of the SII NAPS**

## 6.6. Airlines

The above table shows how much airlines are involved in the SII NAPs process implementation, how much they have to pay and how much they can benefit for the SII NAPs' use. The second column lists the identified cost/benefit/TBD categories and the third and fourth columns give details about the costs/benefits identified in the third column. In the following subsections the details on the single items have been explained.

### 6.6.1. Investment Costs

As expected, airlines are the main actors in the SII NAPs implementation process because pilots are in charge of applying the SII NAPs. The SII NAPs implementation will call for relevant investment costs for the airlines because new tools are required for both approach and departure procedures, such as flap deployment cue and vertical navigation display. This has been demonstrated to be very useful to a pilot because he has more information available on the NAP he is flying and he can act on the aircraft performances to reach the required noise abatement target.

Even for the airlines, as already seen for the ANSPs, the introduction of new systems and procedures requires the training of the operational staff because pilots have to become confident and have to feel safe in using them. In the pilots' case, this point is more emphasized because they are in charge of flying the NAP correctly and playing on the performance parameters to respect the conditions imposed by a continuous descent approach or from a noise departure procedure.

A preliminary assessment of the pilots training has been done through the RTS and as result it has been found that two days training is the minimum requirement [SII D6-4] for the pilots training. This does not mean that two days are sufficient for the pilots training, but a wider training programme has to be planned for the actual pilots training.

So, hypothetically speaking, if airlines want to "act" to reduce the environmental impact due to their operations by flying a new NAP, they have to invest in the following items:

- Additional aids on the flight deck
  - o Flap deployment cue
  - o Vertical Navigation display
- Additional tools/modifications
  - o Tool for automating the thrust and reaching the gradual thrust increase
  - o Modifications on FMS
- Training of pilots on the new NAPs

### 6.6.2. Operating Costs

As expected, when an aircraft flies a NAP, as a consequence there are changes in the operational way that mean changes in the operating costs that are the responsibility of the airlines.

The operating costs include all of the costs pertinent to the aircraft operations so in the SII project these items have been addressed in this costs category:

- Maintenance and overhead costs
- Delay costs
- Crew and staff costs
- Fuel costs

**6.6.2.1. Maintenance and Overhead Costs**

It is not easy to foresee the impact of the SII NAPs on an aircraft maintenance cycle because changes in the intervals between two succeeding interventions can be done only after years and years of observations on aircraft components once the operational change. That means the SII NAPs implementation has been applied.

If an airline is interested in assessing how much a factor influences the time between two succeeding interventions on a component, it should investigate this factor for years, draw the related conclusions and, eventually, propose a change to the aircraft manufacturer in the maintenance/overhaul cycle. Aircraft manufacturers have the last word on the approval of the proposed changes.

For the Sourdine II specific case, the time interval between two succeeding maintenance interventions could be modified introducing the SII NAPs but it requires long-term studies by the airlines and final approval by aircraft manufacturers.

In any case it is interesting to make some preliminary hypotheses about the possible effects of implementing the SII NAPs on the aircraft maintenance process.

Taking into account the operating aircraft life, the maintenance process is currently based on the hours flown by the aircraft that determine different kinds of interventions, such as a smaller intervention (Group A see Table 6-6) or in-depth overhaul and maintenance intervention (Group D see Table 6-6). Table 6-6 reports a sample of overhaul and maintenance scheme. It has to be read only as a sample, because, actually, the hourly values of the maintenance process depend on the aircraft type and on the airline but it helps in providing an order of magnitude for flown hours the intervention characteristics.

	Aircraft check types		
	A	.....	D
<b>Flight hours between 2 checks</b>	<b>250-600h</b>	.....	<b>4000-5000h</b> <b>(15-20 M/L)</b>
<b>Intervention duration</b>	-	.....	<b>1500-2000</b> <b>HM</b>

**Table 6-6: Sample of maintenance and overhaul scheme**

Looking at the table, the first row reports the aircraft check types, from A to D, where A is the shortest intervention type and D is the longest one. Between A and D there are other intervention types, B and C, with intervention sub-group types. Just to provide an example of how to read the table in the last column, an aircraft with an operating life of 15-20 years, after 4000/5000 flight hours has to be stopped and overhauled for about 1500-2000HM.

In the airline's interests it is clear that an aircraft stop on the ground is optimized and maintenance/overhaul cycles are scheduled combining as many interventions as possible in one stop rather than having aircraft stuck on the ground. In the SII project case some of the arrival procedures could require a change in the hours flown between two succeeding checks because flaps and speed brakes are used for a longer time but at the same time the engines are used differently so related checks could be re-scheduled.

Concerning the departure procedures, past studies have demonstrated that the use of de-rated thrust can affect the maintenance costs (EMCWG, Engine Maintenance Cost Working Group). However, to quantitatively assess these costs is very difficult because they depend on the engine model and operational use conditions.

In the SII project case, the costs assessment could be more difficult because it would be necessary to assess a "typical de-rate". This is not easy to define because it is highly dependant upon the runway characteristics, the takeoff environment conditions, the aircraft TOW and finally the installed thrust. Further analyses are required for investigating the possible effects of the de-rated thrust on the engines maintenance/overhaul.

### 6.6.2.2. Delay Costs

As seen from the fast time simulations assessment, the new arrival SII NAPs bring about an increase in the average delay per flight that has been quantified for each airport and for each procedure. The most recent study on the costs of delay has examined them according to different types of delay: duration, phase of flight and whether the delay is absorbed into schedules (strategic) or in addition to schedule buffers (tactical), then to calculate a single average value of delay costs is difficult. An average value of € 72<sup>2</sup> per minute [SICBA] has been determined for the cost of ATFM delay at the European level. Given the nonlinearity of the cost of delay, it has been suggested to apply this value to delays of 15 minutes and above and to apply a zero cost to delays below 15 minutes.

Since the delays calculated within the SII project are related just to the use of the SII arrival procedures, and they have been calculated on the last part of the flight (from 7000ft to the THR) it has been assumed that all aircraft flying a SII NAAP have accumulated an ATFM delay of 15 minutes before they start the CDA.

Table 6-7 summarizes the results coming from the FTS assessment for the four SII airports and for the assessed NAAPs.

		Baseline	NAAP_II	NAAP_III	NAAP_IV	NAAP_V
Average Arrival Delay (min.)	Naples	2,7	2,9	0,0	4,4	3,7
	Madrid	1,8	3,9	3,6	4,6	3,7
	Schiphol	3,9	4,9	0,0	8,6	5,6
	Paris	2,9	3,2	3,3	0,0	3,3

**Table 6-7: Average arrival delay for SII Arrival noise abatement procedures**

Taking into account the number of daily movements planned to fly in 2015 at the four airports:

Naples	301
Madrid	1799
Schiphol	1800
Paris	1689

**Table 6-8: Total daily movements foreseen at 2015 per airport**

and using as a standard value for the delay the values of € 72, the daily percentage variation of the delay costs due to the SII NAPs implementation has been assessed as shown in the Table 6-9:

<sup>2</sup> 2004 value

Percentage Variation of SII NAAPs delay costs with respect to the Baseline ones				
	<i>NAAP_II vs. Baseline</i>	<i>NAAP_III vs. Baseline</i>	<i>NAAP_IV vs. Baseline</i>	<i>NAAP_V vs. Baseline</i>
<b>Naples</b>	7,41%		62,96%	37,04%
<b>Madrid</b>	116,67%	100,00%	155,56%	105,56%
<b>Schiphol</b>	25,64%		120,51%	43,59%
<b>Paris</b>	10,34%	13,79%		13,79%

**Table 6-9: Percentage Variation of delay costs with respect to those of the Baseline ones**

Looking at Table 6-9 one can see that all of the NAPs bring about an increase in the delay costs that vary from airport to airport. In the Naples, Schiphol and Paris cases, the NAAP II has been assessed as the procedure generating less delay costs while the Madrid the procedures cost less in terms of delay costs is the NAAP V.

Unfortunately no outputs are available for the departures so it has been not possible to make the same type of evaluations on them to assess if airlines can save or not part of the operating costs by using them.

### 6.6.2.3. Flight and Cabin Crew Salaries and Expenses

Crew costs are particularly difficult to assign to particular incidences of delay for the two following reasons. The first one is that the crew payment schemes are very complex. Their calculations take into account total duty hours, flight duty hours, time spent at outstations (with corresponding allowances – which may make up a significant part of overall pay) overtime hours, experience and rating.

The second difficulty is one in allocating costs accurately to a particular leg because if a crew’s hours expire on one rotation due to a delay, and an extra crew is brought in, this extra crew may then be available to serve subsequent rotations so that the cost of delay should not be allocated to only one. These problems are complicated by the fact that crew costs comprise such a relatively high proportion of total costs for many airlines so that errors in these estimations are made more significant (e.g. have greater consequences on the final delay costs per minute calculated than would a proportional error in the fuel cost calculations). In addition, airline practices vary greatly regarding the allocation of crew payments with payments being made on a sector-flown basis in proportion to total hours worked, or only by actual off block.

That is the reason why these costs have been identified among the SII costs categories but they have been not included in the SII costs assessment.

### 6.6.2.4. Noise Charges

The noise charges are primarily based on the certificated aircraft noise-level [SII D1-1] according to the standards of ICAO, Annex 16 or FAR Part 36 and to their MTOW.

They are different for each country where the local government fixes the tax rate but the basic principle is the same. it could be proposed that a third factor for the noise charges calculation be added to the use of a noise abatement procedure. the new SII NAPs are beneficial for noise reduction and in fact they allow the reduction of noise by a variable percentage.

## 6.7. Airport Operator Company

The airport operator company will benefit from the use of the SII NAPs because from a qualitative aspect, the relationship with people living in the airport surroundings will improve due to the decrease in the noise levels around airports.

On the economic point of view they will save money because the noise contour size will be reduced and in all probability the number of houses within a noise contour will decrease which means the number of houses that would need to be insulated could decrease.

The truth of this event is really dependent upon the distribution of houses around an airport. This should be verified by each test site (the four SII airports) and for all the procedures. Unfortunately within the SII project, it has been not possible to assess the change in the number of houses within the noise contours for all the NAPs so only qualitative considerations have been done.

Airport operator companies use residential insulation programs as the instrument for reducing the impact of the aircraft noise on houses in the airport surroundings to improve the quality of life for residents. If the SII NAPs implementation generates a decrease in the number of houses within a fixed noise contour, there would be fewer houses to insulate and the airport operator companies could save money.

Alternatively, the airport operator company can decide against soundproofing houses and instead give money to the people within the fixed noise contours to compensate for the noise nuisance they are subjected to.

## 6.8. Passengers and Cargo

As seen from the fast time simulations assessment, the new arrival NAPs bring about an increase in the average delay per flight that has been quantified for each airport and for each procedure.

The average delay per flight should be a parameter that takes into account the passengers because it is a customer satisfaction index. However, when it is calculated it must be related to the delay accumulated from the departure gate to the arrival gate and so it has been decided to leave out this parameter from the SII CBA.

## 6.9. Third Parties/Citizens Living Around Airports

From the airport financial view, the noise and, in general the environment, are considered as an externality because the environmental aspects are not relevant to the person who makes the decisions but they do influence the community life.

There is a considerable amount of literature written about these types of problems, and, in particular a few studies aimed at pricing the external effects due to aircraft noise nuisance. These studies either use revealed preference methods (e.g., the hedonic price method), or direct stated preference methods (e.g., the contingent valuation method). In the SII project case initially it was proposed to use the Hedonic pricing method and as a metric for the evaluation of the noise assessment the Noise Sensitivity Depreciation Index (NSDI) was selected. This is the average percentage change in property prices per decibel, that means, if the NSDI is about 0.5-0.7 and the noise nuisance increases by 10 units, then, the property prices decrease by 5-7%.

Many studies have been performed on the economic value of aircraft noise and they suggest the use of a NSDI value between 0.5% and 1.0%. A proposal could be to make an assessment with a minimum, a maximum and an average value of a proposed NSDI range and analyze the economic effects through the sensitivity analysis. Unfortunately data on the number of houses within the noise contours for the baseline and the SII NAPs had not been calculated so the previously mentioned methodology was not applicable and only a qualitative analysis of the results has been done. The introduction of the new SII NAPs generates a decrease in the noise contour sizes that could mean a decrease in the number of houses within some noise levels, but it should be assessed airport-by-airport and NAP-by-NAP because people are not uniformly distributed around airports.

## 6.10. Conclusions

As seen from the previous pages it has not been possible to set up a complete picture of the necessary costs and benefits in the case of the SII NAPs being implemented. It is therefore not possible to make further financial analysis.

The results and inputs available from other WPs allowed making a preliminary framework for future developments of CBA for NAPs. This document provides some first ideas about who can benefit and who will have to pay and for what. Further studies are then required to assess a complete picture of costs and revenues, allowing a real financial analysis and giving input to stakeholders on possible choices.

The following table summarizes the qualitative results found with the current CBA preliminary assessment. The first column indicates the costs and the benefits categories, while the first row indicates the involved stakeholders. The cells of the table report the effect of implementing the SII NAPs for each stakeholder and for each cost/benefit categories. Looking at the table, the SII NAPs implementation requires an increase in the equipment and training costs for Airlines and ANSPs. The SII NAPs could generate also an increase in the delays, translated into costs for Airlines, ANSPs and Airport Operator Companies.

Concerning safety, much work has already been done on some NAPs, in fact high level assessment on all the NAPs highlighted critical aspects which needed further and deeper analysis. The qualitative safety analysis on the NAAPs II and V and on NADP 2 has made clear the point where it is necessary to investigate the safety aspect further. Additional work is required for providing more information on the safety aspects of the SII NAPs. That is also one of the reasons why qualitative economic assessment on the safety of the proposed NAPs has not been possible.

If the SII NAPs would be applied there could be benefits for both Airport Operator Company and people living around airports. The Airport Operator improves the relationships with people in the airport surroundings and saves money in housing insulation programs or other noise reduction programs. For the people living around airports the SII NAPs can improve their quality of life.

At the same time the reduction in the noise levels could be internalised in the current noise taxonomy system, increasing the benefits for the airlines applying the SII NAPs. Speaking about the environmental capacity, that is sustainable capacity of an airport compatible with the environmental requirements, it's clear that the introduction of the SII NAPs allows increasing the capacity value guaranteeing the safeguard of the environmental parameters. This is a clear benefit for airlines, ANSPs and Airport Operator Companies.

## 7. Conclusions

As a main part of the Sourdine II validation process various selected procedures were assessed on different parameters like safety, capacity, cost & benefit and noise and emissions, and those assessments gave a broad view and was well appreciated by stakeholders from the expert panels. It provides the broad scope that is of paramount importance during discussions about implementing these kind of noise abatement procedures.

Since data come from different simulation exercises runs, from different groups of people involved and from different airports, some assumptions have been made in order to provide uniformity and coherency to the calculations. For example, when assessing these new flight procedures it was essential to have performance data from manufacturers as input for the various simulations and analysis. This ensured that all assessments used exactly the same procedures.

The two departure procedures produced by Sourdine II are based on the ICAO-A and ICAO-B procedure for departures. Preliminary analysis showed that no capacity problems are foreseen due to the implementation of these procedures in the airport. Wake turbulence separation criteria and the location of the divergence point between departure routes for each runway/airport are far more critical from the capacity point of view than the differences in the speed and/or vertical profile between those departure procedures.

There is a decrease of the peak hour arrival airport capacity when (NAAP)s designed within Sourdine II are implemented. This decrease in capacity is caused by the extended separation required to compensate the speed differences between aircraft. The more speed differences between aircraft types, the more separation was needed in order to maintain minimum safe separation between successive aircraft (e.g. wake turbulence). This increase of separation affects arrival delay negatively and therefore arrival capacity decreases.

The lack of speed control between the beginning of the CDA and the runway leads to larger spacing between successive arrivals. An increased arrival separation at 30NM from the runway threshold is required to achieve the necessary wake turbulence separation at the runway.

Another factor which plays a role in the delay is the route structure close to the airport: the effect of speed differences mentioned above will play a more severe role when the number of RNAV-routes available is smaller. In that case, more aircraft will have to fly a longer trajectory on the same RNAV route.

When an airport is operated in a way that the demand is exceeding the available peak hour arrival capacity during some periods of the day, the introduction of the new procedures will lead to additional delay. However, when the arrivals are distributed more regularly over the day, delays will decrease, or even not occur. When traffic is scheduled in this way and hourly arrival demand does not exceed the available airport capacity, for the traffic foreseen for the year 2015 in the four airports considered in this analysis, there exists no sustained capacity problem.

The noise assessment results show that the sizes of the contours are generally a function of the altitude profiles. The overall effect of this procedure is a reduction in Lden contour size at large airports. Where traffic volumes are less, this effect is less noticeable. The results showed that:

1. All SII procedures noise benefits have been identified compared to a baseline procedure that was already optimised (FMS approach). It should be noted that this FMS Baseline approach procedure is far less noisy than current approaches.
2. The Sourdine II arrival procedure, which features an increased final glide path angle, (Procedure III) provided the greatest benefit. Since procedure III is continually above the baseline, whereas the other procedures are only higher before certain points, it is this procedure that gives the best results (the sizes of the contours are generally a function of the altitude profiles). Procedure IV reduces noise moderately and procedures II and V reduce it slightly.
3. The distribution of the fleet mix would influence the shape of the noise contours considerably (i.e. unbalanced use of runways).

4. Noise assessment conclusions were the same (i.e slight differences depending on fleet-mix flow) for all scenarios.
5. Major noise benefits were mainly determined by higher altitudes for approaches while for departures on the thrust settings.

A population impact study was performed at Madrid-Barajas airport and all four SII arrival procedures showed reductions in impacted population. Procedure III was responsible for the greatest change in impacted population.

The two departure procedures studied had different aims; one to reduce noise close to the airport and the other one to reduce noise further away. The results of the noise analysis showed that the “close-in” procedure was beneficial only within 3.5NM immediately after the end of the runway, whereas the “distant” procedure provided benefits from 2.5NM after the runway end.

A complete detailed safety analysis would have been a very demanding effort. Therefore, only part of the four approach and two departure procedures were identified to fall within the scope of the detailed safety evaluation. To accomplish such a selection, an initial high-level safety evaluation of all six procedures was first done. It should be noted that these procedure definitions did not include an embedding of the procedure within an operation.

The main safety issues related to each of the four approach procedures were:

- 1) Procedure II: Basic CDA with 2° initial Flight Path Angle;
  - A possible excess speed at glide slope intercept possibly leading to an unstabilised approach.
- 2) Procedure III: Basic CDA with 2° initial FPA and increased final glideslope;
  - A possible excess speed at glide slope intercept possibly leading to unstabilised approach; more severe than for procedure 2 due to the fact that the excess speed was more difficult to control on a steep final segment;
  - The steep final glideslope is a non-standard operation and potentially leads to higher workload. This operation required special analysis in relation to acceptance and to obstacle clearance surfaces.
- 3) Procedure IV: CDA with constant speed, variable FPA segment at landing configuration;
  - A possible steep intermediate approach segment resulting to glideslope interception from above, with the potential consequences of a glideslope undershoot and an unstabilised approach;
  - Potential flight path control problems, which could lead to an increased workload and an unstabilised approach in case the path is too shallow;
- 4) Procedure V: CDA with constant speed, variable FPA segment at intermediate configuration;
  - The same issues as for Procedure IV, though both less severe.

Procedure II and II-A (procedure II with speed constraints) do not have significant influence in the level of safety reached with the reference procedure whereas procedure V shows a slight increment of risks.

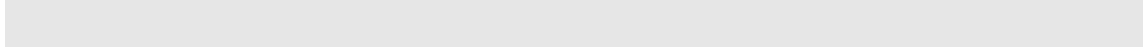
It should be noted that optimised departure procedures (involving deep thrust cutback and gradual thrust increase) can be realised only with aircraft equipped with dedicated FADEC/FMS functionalities, in case of which there are no safety issues. These procedures can not be realised manually, without appropriate systems. The main safety issues related to each of the two departure procedures are:

- 5) Sourdine optimised close-in procedure;
  - Speed control problems with a low power setting at OEI climb thrust
- 6) Sourdine optimised distant procedure;
  - The same issue as for Procedure 2, but less severe.

As the first step the SII CBA methodology had to be developed to provide guidelines for the SII project case that included identifying the required input, the case studies, the actors involved, the cost and benefit categories and how to make the final economic assessment. Later the proposed methodology had to be applied to the SII project on the basis of the input collected from the other SII WPs (WP4 and WP6) and experts' opinions.

It has not been possible to set up a complete picture of the necessary costs and benefits in the case of implementing the SII NAPs. Therefore, it was not possible to do any further financial analysis. The results and inputs available from other WPs were used to create a preliminary framework for later use in developing a CBA for the Noise Abatement Procedures (NAPs). These first provided the ideas as to who would receive any benefits, which would have to pay and what would have to be paid for as well. Further studies are required to assess a complete picture of the costs and revenues to permit an actual financial analysis and provide inputs to the stakeholders on the possible choices.

The results have already clearly indicated that the introduction of SII procedures in airports provides a reduction on the environmental impact of aircraft operations without severely affecting the current airport capacity and safety levels. It must be noted that further analysis in capacity, safety, noise and emissions and CBA aspects should be performed in this field.



## Appendix 1 Glossaries and References

### A1.1 Glossary for Capacity

Term	Description
ALARP	As Low As Reasonably Practicable
ATC	Air Traffic Control
ATM	Air Traffic Management
CDA	Continuous Descent Approach
CS	Conflict Scenario
DCPN	Dynamically Coloured Petri Net
ESARR	EUROCONTROL Safety Regulatory Requirements
FMS	Flight Management System
FPA	Flight Path Angle
ft	Feet
IAF	Initial Approach Fix
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
kts	knots
LNAV	Lateral Navigation
NM	Nautical Mile
NTZ	No Transgression Zone
OEI	One Engine Inoperative
PANS-OPS	Procedures for Air Navigation Services and Operations
P-RNAV	Precision Area Navigation (RNP-1 compliant)
RNAV	Area Navigation
RNP	Required Navigation Performance
SID	Standard Instrument Departure
SourDine	Study of Optimisation procedures for Decreasing the Impact of Noise
SRC	Safety Regulation Commission
TMA	Terminal Manoeuvring Area
TOGA	Take-off Go Around
TOPAZ	Traffic Organization and Perturbation Analyzer
WP	Work Package

## A1.2 Glossary for Noise and Emissions

Term	Description
CBA	Cost Benefit Analysis
CDA	Continuous Descent Approach
NAAP	Noise Abatement Approach Procedure
NADP	Noise Abatement Departure Procedure
INM	Integrated Noise Modelling
FAS	Final Approach Speed
FIR	Flight Information Region
FL	Flight Level
FTS	Fast time simulations
INM	Integrated Noise Model
KTS	Knots
Lden	Day-Evening-Night community noise Level
Lnight	Night level with a penalty of 10 dB (A).
NM	Nautical Mile
RNAV	Area Navigation
RTD	Research, Technology development and Demonstration
RTS	Real time simulations
RWY	Runway
SES	Single Event Simulations
SID	Standard Instrument Departure
SOURDINE	Study of optimisation procedures for decreasing the impact of noise

## A1.3 Glossary for Cost Benefit Analysis

Term	Description
CBA	Cost Benefit Analysis
CDA	Continuous Descent Approach
NAAP	Noise Abatement Approach Procedure
NADP	Noise Abatement Departure Procedure
ANSP	Air Navigation Service Provider
APP	Approach Procedure Cost
CBA	Cost Benefit Analysis
CDA	Continuous Descent Approach
CVM	Contingent Evaluation Method

Term	Description
FTS	Fast Time Simulation
GDP	Gross Domestic Product
HH	Household
HP	Hedonic Pricing Method
Ku	Kosten Unit, an “objective” measure of aircraft noise nuisance used in the Netherlands)
ICAO	International Civil Aviation Organisation
MTOW	Maximum Take Off Weight
NAP	Noise Abatement Procedure
NAAP	Noise Advanced Abatement Procedure
NEF	Noise Exposure Forecast
NNI	Noise and Number Index
NSDI	Noise Sensitivity Depreciation Index (the average percentage change in property prices per decibel)
RTS	Real Time Simulation
TMA	Terminal Manoeuvring Area
WTP	Willing to Pay

#### A1.4 Reference Documents for Cost Benefit Analysis

Short Reference	Author / Organisation, Title, Edition, Date and Reference
[ANRPV]	Collins & Evans “Aircraft Noise and residential property values: an artificial neural-work approach”, 1994
[ATM_ACE]	Eurocontrol “ ATM Cost-Effectiveness (ACE) 2003 Benchmarking Report, 2005
[BMATS]	Phil Smith “Barriers to Marginal Social Cost Pricing in the Air Transport Sector”, May 2004
[CATDE]	Institut du Transport Aérien “Cost of air transport delay in Europe”, November 2000
[MEVTA]	Carlsson, Lampi, Matinsson “Measuring marginal values of noise disturbance: Does the time of the day matter?” February 2004
[PAMELA]	Eurocontrol “Parametric ATM Model for Long Term Economic Assessment, Validation report”, December 2001
[REBEIN]	Opschoor, J.B, A review of monetary estimates of benefits of environmental improvements in the Netherlands, 1986
[SAEVN02]	Ståle Navrud, “The State-of-Art on Economic Valuation of Noise” Final Report to European Commission DG Environment, April 14 <sup>th</sup> 2002

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[STCBA]	Eurocontrol "Standard Inputs for EUROCONTROL Cost Benefit Analyses", 23 September 2002
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[De Jong]	Jong, H.H. de, <i>Guidelines for the identification of hazards. How to make unimaginable hazards imaginable?</i> NLR report for EUROCONTROL, NLR-CR-2004-094, March 2004; also published as SAF.ET1.ST03.1000-MAN-01-01-03-B2, Ed. 2.0, April 2004, <a href="http://www.eurocontrol.int/safety/downloads/sam/Level2/FHA_V2.0/FHA_V2-0_Chapter_3_Guidance_B2.doc">http://www.eurocontrol.int/safety/downloads/sam/Level2/FHA_V2.0/FHA_V2-0_Chapter_3_Guidance_B2.doc</a>
[ED-78A]	EUROCAE ED78-A, <i>Guidelines For Approval Of The Provision And Use Of Air Traffic Services Supported By Data Communications</i> .
[ESARR 4]	EUROCONTROL Safety Regulatory Requirement, <i>ESARR 4, Risk assessment and mitigation in ATM</i> , Edition 1.0, Released issue, 5 April 2001.
[Everdij & Blom, 2002]	Everdij, M.H.C, Blom, H.A.P., <i>Bias and Uncertainty in accident risk assessment</i> , Tosca-II WP4 Phase 2 final report, TOSCA/NLR/WPR/04/05/10, 2002
[Everdij & Blom, 2003]	Everdij, M.H.C., Blom, H.A.P., <i>Petri nets and hybrid-state Markov processes in a power-hierarchy of dependability models</i> . In: Engel, Gueguen, Zaytoon (eds.), <i>Analysis and design of hybrid systems</i> , Elsevier, pp. 313-318.
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[S II D4.2-2d]	Sourdine II D4.2-2d, Everdij, M.H.C. (Editor), <i>Safety assessment of approach procedure II-A on Schiphol airport (Collection of expert interviews)</i> , version 2.0, August 2005.
[S II D4.2-3]	Sourdine II, D4.2-3, Antón Cruz, M.F., and Vinagre, L., <i>Safety assessment of approach procedure V and departure procedure 2 on Barajas airport</i> , version 2.0, August 2005.
[S II D5.3]	Sourdine II, D5.3, <i>Single Event Noise Calculations</i> , Airbus
[S II D6.1]	Sourdine II, D6.1, <i>Prototyping results ATC simulator</i> , NLR
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## A1.6 Reference Documents for Noise

Short Reference	Author / Organisation, Title, Edition, Date and Reference
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EEA	European Environmental Agency Glossary ( <a href="http://glossary.eea.eu.int">http://glossary.eea.eu.int</a> )
[SII D2-1]	SOURDINE II "D2.1 Validation Methodology Report", April 2004
[SII D2-1_Appt]	SOURDINE II "D2.1 Validation Methodology Report, Appendixes", April 2004
[S II D5-2]	Noise & Emission modelling methodology
[S II D4-1-2b]	Noise and Emission Results Schiphol
[S II D4-1-3b]	Noise and Emission Results Barajas
[S II D4-1-4b]	Noise and Emission Results Charles de Gaulle
[S II D4-1-5b]	Noise and Emission Results Capodichino

## Appendix 2 Methodology for Capacity Calculation

### A2.1 Introduction

The effectiveness of a transportation system is commonly measured in terms of its ability to efficiently process the transported unit. Since the system performance is dependant upon the individual components of that system, it is usually necessary to evaluate these components to determine overall system capabilities. In cases where use of the system requires the sequential utilization of a group of processors, the overall efficiency of the system is usually limited by the characteristics of the least efficient component.

Considerable emphasis has been placed upon research to analyse the level and causes of capacity deficiencies. It is now possible to accurately determine the capability of airport and aviation system components to process demand and to pinpoint the causes of deficiencies in these systems. This knowledge allows the technicians to propose solutions to the problems identified.

The problem will then consist on providing sufficient capacity to accommodate fluctuating demand with an acceptable level or quality of service. Typically, this level of quality of service means that a relatively high percentage of the demand will be subjected to some minimal amount of delay.

### A2.2 Objective

The aim of the document is to establish a common and agreed methodology between the WP4 partners in order to assess the impact on the airport capacity of the new noise abatement procedures (NAAPs) designed within the Sourdine II Project. Thus, the results obtained after the FTS exercises developed in each site will be comparable and the conclusions derived easily validated.

### A2.3 Capacity Definitions and Assumptions

#### A2.3.1 *Definitions of Capacity*

The term capacity means basically the processing capability of a service facility over some period. For airport planning, the airfield capacity has been defined in two ways:

- **Practical capacity:** is the number of aircraft operations during a specified time corresponding to a tolerable level of average delay.
- **Ultimate capacity:** is the maximum number of aircraft operations that an airfield can accommodate during a specified time when there is a continuous demand of service. This means that there are always aircraft ready to take off and land. However, this is not the case of any of the airports considered within the capacity assessment in Sourdine II project. Neither in Madrid Barajas, Amsterdam Schiphol, Paris Charles de Gaulle nor in Naples Capodichino a continuous demand throughout the day is foreseen for the year 2015.

For Sourdine II purposes, we define capacity as the maximum number of operations (arr/dep) that each airport can manage per hour with a maximum tolerable delay value.

#### A2.3.2 *Methodology for Capacity Assessment*

In the following paragraphs, we describe the methodology to assess the capacity impact of inserting the new procedures designed within Sourdine II project for each FTS site.

**A2.3.2.1 Establish the Maximum Tolerable Delay Value**

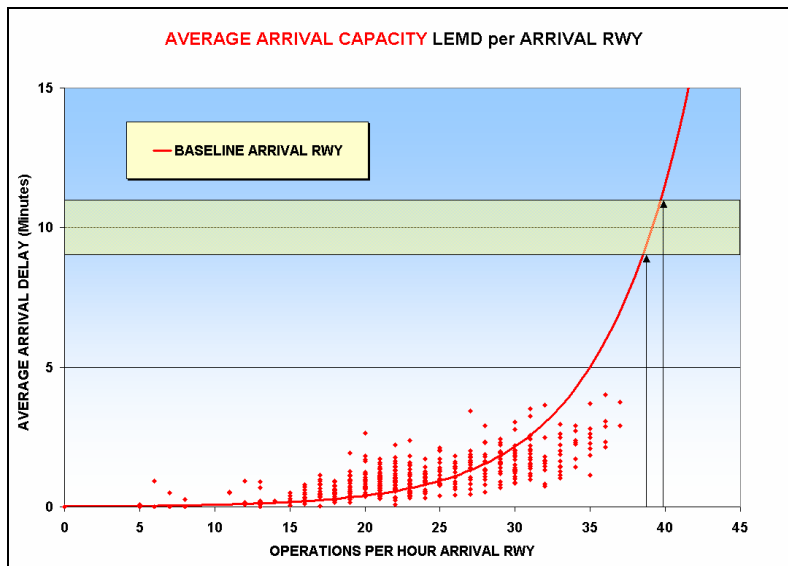
There has been a general lack of agreement on the specification of acceptable levels of delay applicable to all airports and their components. Because policies, expectations, and constraints differ from airport to airport, the amount of delay differs from airport to airport.

The magnitude of delay is greatly influenced by the pattern of demand. As an example, when several aircraft wish to use the airfield at the same time, the delay will naturally be larger than if these aircraft were spaced some interval of time apart. Since the fluctuation of demand within any hour can vary widely, there may be large variation in average delay from the same level of hourly aircraft demand.

It has been shown that when traffic volumes reach hourly capacity levels, average delays may range from 2 to 10 minutes. As the number of aircraft operations per hour approaches the hourly capacity, the average delay of each aircraft may increase rapidly with relatively small increases in aircraft operations, thereby causing levels of service on the airport to deteriorate.

In order to establish the maximum tolerable delay value per each airport, the different FTS partners may use the baseline scenario since this scenario does not take into account any NAP and there are information about the capacity figures foreseen for the year 2015.

In the case of Madrid-Barajas airport, the expected arrival capacity per runway in the year 2015 with the procedures included in the Baseline scenario is around 39-40 ops./hour. That means, that the maximum tolerable delay value per hour for arrivals is around 10±1 minutes.

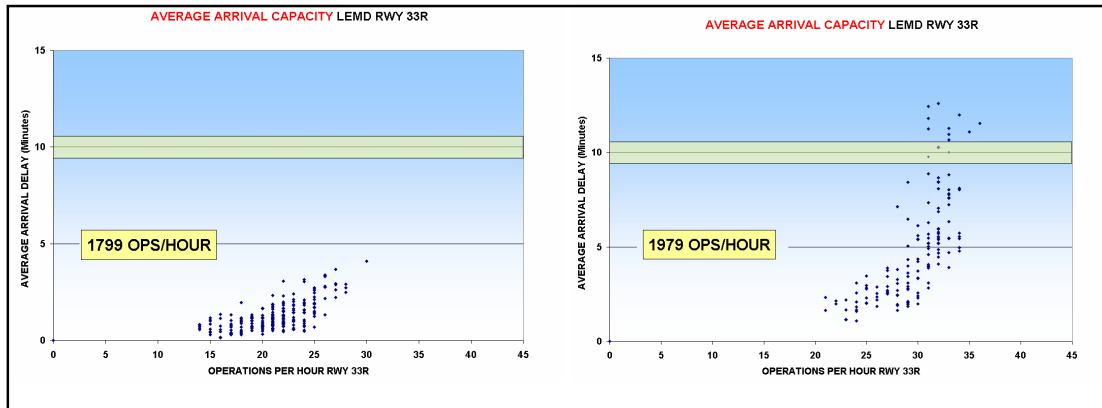


**Figure A2-1: Establish the maximum tolerable delay value per hour. Baseline scenario. Madrid-Barajas airport 2015.**

**A2.3.2.2 Increase the Traffic Sample**

In order to have a good estimation of the capacity impact of the new procedures defined within Sourdine II project, each partner increased progressively the traffic sample foreseen for the year 2015 if the number of operations expected for that year is far from the capacity limit.

For example, for Madrid-Barajas airport (with a traffic expected for the year 2015 of 1799 ops./day), increments of 5% and 10% were necessary obtaining respectively traffic samples of 1889 ops/day and 1979 ops/day.



**Figure A2-2: Increase of the traffic sample expected (2015).**

**A2.3.2.3 Calculation of the Average Delay Per Hour**

The following step consists of calculating for each scenario and each run the average delay per hour dividing the total amount of delay (arrival or departure) generated during each hour between the number of operations (arrival or departure).

It is important that the calculation must be made separately for each run in order to consider non-decimal values in the number of movements per hour. This is something that can be achieved easily both in TAAM and in SIMMOD although the process is a little bit more consuming than considering average values for the set of 10 iterations:

- In TAAM, after loading the report files into the TAAM reporter, the user can obtain results individually for each run.
- In SIMMOD, the user should run 10 iterations of the same scenario varying the simulation seeds before running the simulation once.

**A2.3.2.4 Report the Average Delay Per Hour vs Number of Movements Per Hour**

In the same graph, data obtained after running several times the scenario with progressively increased traffic samples should be shown together.

For example in the case of Madrid-Barajas airport, for the runway 33L at least 510 points have been considered in each graph (10 runs x 3 traffic samples x 17 hours/day).

The final results consist of a cloud of points that follows approximately certain pattern.

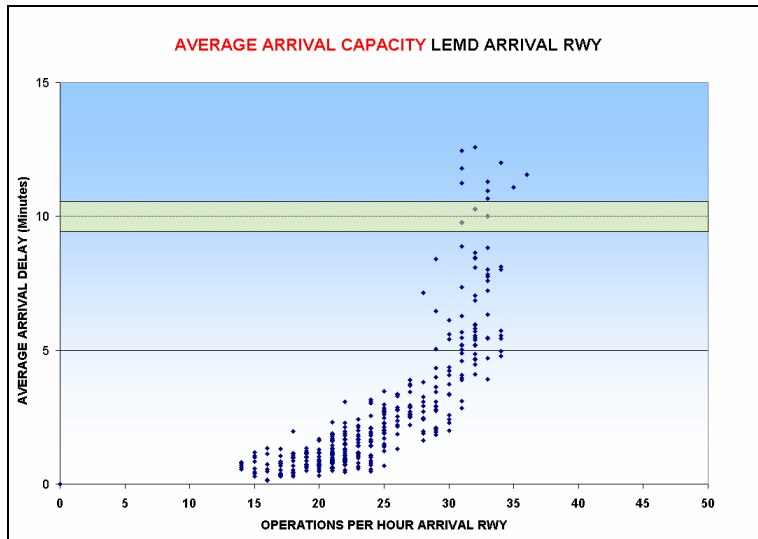


Figure A2-3: Cloud of points average hour delay vs. number of movements.

**A2.3.2.5 Choose the Best Tendency Curve**

Next, the tendency curve with the best correlation factor (respect to the distribution of points in the former graph) should be selected. This curve should represent the behaviour of the average delay per hour of the airport respect to the number of movements per hour with the highest fidelity.

Usually, the delay increases exponentially especially when the number of movements per hour approaches the hourly capacity. Then, the average delay of each aircraft may increase rapidly with relatively small increases in aircraft operations.

An indication of the goodness of the selected tendency curve is its correlation factor. We could consider that the curve represents well enough the behaviour of the model if that correlation factor is above 80%.

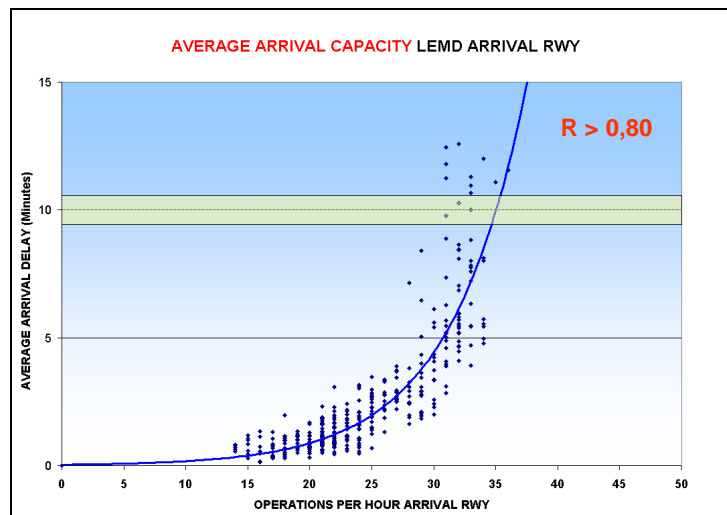
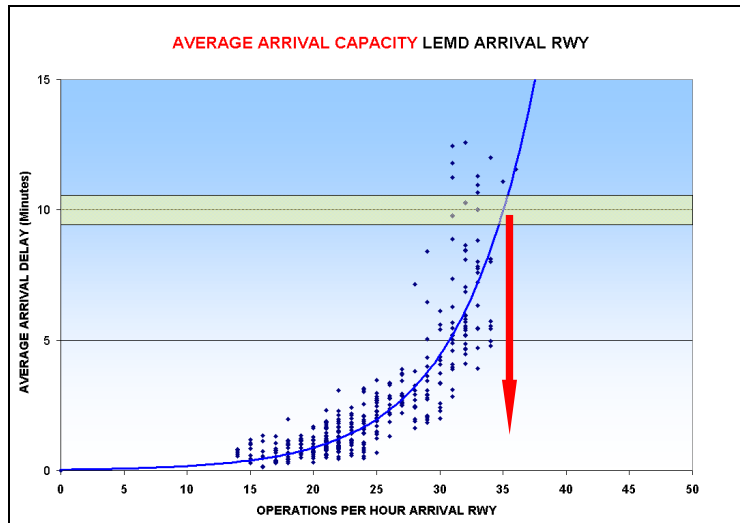


Figure A2-4: Selection of the best tendency curve.

**A2.3.2.6 Intersection Between the Curve and the Selected Maximum Tolerable Delay Value**

The intersection between the selected curve and the maximum tolerable delay value per hour will indicate the practical capacity of each scenario. This capacity will be an interval since the maximum tolerable delay value is  $10 \pm 1$  minutes.

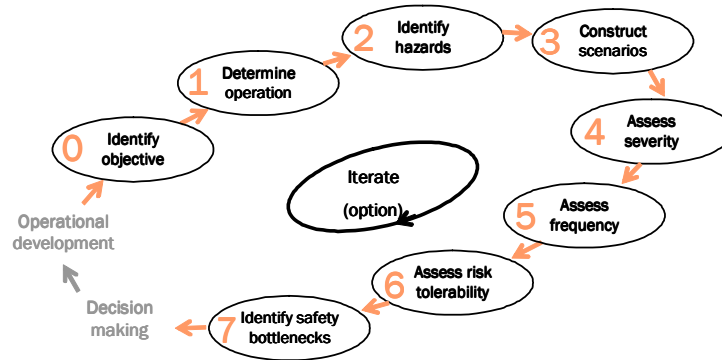
Thus, comparing the intersection of the curves obtained for each scenario with the result obtained for the baseline scenario we can assess the impact on capacity (gain or loss) of each procedure defined within SourDine II project.



**Figure A2-5: Capacity assessment.**

## Appendix 3 Safety Assessment Methodology

This appendix provides a description of the TOPAZ safety assessment methodology used. Sections A3.1 to A3.9 include a general description of this methodology. Section A3.10 describes how this methodology was used since some variations have been made. The description provided is the methodology description presented in [TOPAZ]. An overview of the steps in a cycle of safety assessment is given in Figure A3-1.



**Figure A3-1: Overview of the steps in a TOPAZ safety assessment cycle.**

In step 0 the objective of the study is determined, as well as the safety context, the scope and the level of detail of the assessment. The actual safety assessment starts by determining the operation that is assessed (step 1). Next, hazards associated with the operation are identified (step 2), and clustered into conflict scenarios (step 3). Using severity and frequency assessments (steps 4 and 5), the risk associated with each conflict scenario is classified (step 6). For each conflict scenario with possibly an UNACCEPTABLE risk, safety bottlenecks are identified (step 7), which can help operational concept developers to find improvements for the operation. Should such an improvement be made, a new cycle of the safety assessment should be performed to investigate whether all risks have decreased to an acceptable level.

### A3.1 Step 0: Identify objective

Before starting the actual safety assessment, the objective, scope and level of detail of the assessment are set. This should be done in close co-operation with the customer. Also, the safety context must be made clear, such that the assessment is performed in line with the safety management framework of the customer.

#### Objective

Generally, the objective of the safety assessment is to obtain a first indication how safe the developed operation is, in order to decide about implementation of the operation, or redevelopment.

#### Safety context

An important issue for the safety context is the choice of safety criteria with respect to which the assessment is performed. Example criteria are the risk classifications of EUROCONTROL ([ESARR 4]) or JAA ([JAR AMJ 25-1309]). These criteria imply severity classifications and frequency classifications, which can be combined using a risk classification scheme.

## Scope

The scope of the assessment concerns, for instance the boundaries of the operation under consideration. These can be physical boundaries as well as boundaries of the procedures or technical systems under consideration.

Furthermore, it must be decided whether an absolute or relative safety assessment is to be performed. Also, it must be decided which risks are to be considered. Options can be to consider all internal risks of the operation, such as aircraft - aircraft conflicts or wake vortex encounter conflicts, or to consider only certain conflict types.

## Level of detail

The assessment can be performed with varying level of detail. It is possible to assess the severity and the frequency of the conflicts purely qualitatively, but one can also choose to use advanced modelling techniques to obtain a quantitative estimate of the frequency. It is also an option to use first an approach with limited level of detail, such that a good overview is retrieved that identify which risks are of primary importance and such that the areas with highest risk can be identified, and next deepen the analysis of those areas by a more quantitative approach.

In the current assessment two approaches with varying levels of detail were used: an 'argumentation-based' approach and an 'simulation-based' approaches. The simulation-based approach heavily depends on advanced mathematical modelling using inputs from statistics and experts, and Monte Carlo simulation of these models. The argumentation-based method relies on structuring of inputs retrieved from experts and statistics into argumentations. Here, the mathematics used is simple.

The simulation-based method can be used to gain detailed insight in the accident risk of a conflict scenario, including an unbiased risk estimate with a 95% credibility bracket. The argumentation-based method is used to retrieve estimations in terms of orders of magnitude for the frequency of each severity class for a conflict scenario.

In Section A3.6 some more details about the differences between these approaches are given, and some criteria for deciding which approach to use for each case.

## A3.2 Step 1: Determine Operational Concept

Important aspects that need to be covered in the operational concept description are:

- The *objective* of the operation;
- The *operational context* of the operation, describing e.g. the geometry of the airport or the air route structure, the timeframe, and the traffic characteristics;
- The roles and responsibilities of the *people* involved in the operation, especially air traffic controllers and pilots;
- The operational *procedures*, both from an ATC and from a pilot point of view; and
- The *technical systems* used in the operation. These systems are usually divided according to communication, navigation and surveillance functions. Questions like how the systems serve the human, what is their performance, and how are they used need to be answered.

The operational context of the operation should be described in generic terms if possible in order to promote universality of application. On the other hand, the description should provide all the necessary assumptions used in the safety assessment.

Note that it is no part of the safety assessment to develop the operation. This is a task outside of the scope of the assessment that definitely should be performed by operational concept designers. Step 1 just provides the safety assessors with a means to obtain a complete and concise overview of the operation, and to freeze this description at least through the cycle of the safety assessment. It is impossible to assess an operation that is changing in the meantime. Therefore changing viewpoints with respect to the operation during the production of the assessment are not taken into account.

To patch up holes and inconsistencies in the description of the operation, it may be necessary to have them repaired by the concept developers, and also to make some *assumptions*.

The main input to step 1 is a description of the operation from concept developers, while the output is a sufficiently complete, structured, consistent and concise description of the operational concept.

### A3.3 Step 2: Identify Hazards

In the TOPAZ safety assessment methodology, a hazard is a non-nominal event or situation with possibly harmful effects. Such a non-nominal event or situation may evolve into danger, or may hamper the resolution of the danger, possibly in combination with other hazards or under certain conditions. The goal of step 2 of the methodology is to identify as many hazards as possible, while these hazards should also be as diverse as possible. The hazards should be within the scope of the assessment, and thus within the boundaries of the operation and the relevant conflict types, as has been determined in step 0.

[De Jong] gives guidelines how ‘functionally unimaginable’ hazards can be identified using brainstorming sessions. Necessary participants in these sessions are an air traffic controller, a pilot, a moderator, somebody taking notes, and preferably an expert on the operational concept. The participants should all have a sufficient level of understanding of the operation under consideration. The moderator should prepare by identifying some hazards to trigger the brainstorm when necessary, and by making an initial list of general conflict types that should at least be covered.

It is important that the brainstorming sessions are only used to identify hazards, and not to analyse them, as seemingly unimportant hazards may turn out important in the later steps and they may trigger the invention of more relevant ones. Hazards are usually described as they were recorded from the brainstorm session.

As secondary means to identify hazards, previous studies on similar subjects and NLR’s ATM Hazard Database [TOPAZ hazard database] are consulted to check for completeness. Furthermore, during the progress of the study additional hazards may be identified.

### A3.4 Step 3: Construct Scenarios

When the list of hazards is as complete as reasonably practicable, it is processed to deal with duplicate, overlapping and verbosely described hazards. The output of this process is a list of *events*. Each event is a group of similar hazards, and for each event a concise and unambiguous hazard description is given.

To cope with the complexity of the various possible causes and results of the conflicts to be considered, *clusters* of events are formed. A cluster is a group of events that may cause, or that may result from, the same more general hazardous situation. A cluster of events could for instance be the set of ‘events causing a missed approach to deviate from the normal path’.

Each cluster that is formed plays a role in one or more *conflict scenarios*. A conflict scenario is a bundle of event and state sequences, centred on a general kind of conflict (such as for instance ‘conflict between two aircraft merging onto one route’ or ‘aircraft encounters wake vortex of parallel departure’). Accordingly, in such a conflict scenario all ways in which this conflict type can occur, and in which way it can end, are bundled.

A conflict scenario is represented by the various sequences of events in combination with certain states that may lead to and result from the conflict. Often, a conflict is caused by a hazard in combination with a state. The conflict scenarios should be constructed in such a way, that all relevant ways in which a hazard can play a role in a conflict are taken into account. Together, the conflict scenarios should cover all relevant ways in which an incident or accident can happen.

Each of the identified hazards can be of the following types:

- A root hazard, which may cause a conflict; or
- A resolution hazard, which may complicate the resolution of a conflict.

Usually, clusters of root hazards and clusters of resolution hazards play a role in the conflict scenarios.

### A3.5 Step 4: Assess Severity

For each of the identified conflict scenarios it needs to be determined which of the severity classes, as defined in step 0, are applicable. The severity classification of [ESARR 4], for instance, distinguishes between SIGNIFICANT INCIDENT, MAJOR INCIDENT, SERIOUS INCIDENT, and ACCIDENT severity.

Usually, safety experts assess which of the classes are applicable for a conflict scenario, by consultation of and review by operational experts.

If a conflict occurs, then the consequences and the severity of its consequences depend strongly on many factors, such as the conditions under which the conflict occurs, the geometry of the conflict, and on whether (timely) resolution of the conflict takes place. Therefore, often a range of severity classes applies to a conflict scenario. Depending on the scope and level of detail of the assessment as chosen in step 0, it can be chosen to imply all of the applicable severity classes in the assessment. In that case, the spectrum of all possible conflict scenario outcomes should be divided into 'bands' of reasonably determined severity that moreover have a clear operational interpretation. The choice and the structuring of the events in a conflict scenario (step 3) are then updated such that each applicable severity category is linked to the occurrence of specific event sequences.

### A3.6 Step 5: Assess Frequency

Next, for each possible severity outcome of each conflict scenario the frequency of occurrence is assessed. Within TOPAZ, one can opt for an argumentation-based approach, or use a, more quantitative, simulation-based approach. These are outlined next, and then it is explained how conflict scenarios can be allocated to these approaches.

#### Argumentation-based approach

A main source of data for the frequency assessments using an argumentation-based approach is formed by interviews with operational experts, who are familiar with the local ATM systems and procedures in, or (in case of a newly developed concept of operation) similar to those in the operation under consideration. The interviews aim to get insight in the expert's opinion on safety issues concerning the operation, and more specifically, to identify frequencies of root hazards and conditional probabilities of the possible outcomes of the conflict scenarios. Assessing root frequencies uses answers of questions like: *'How often have you experienced this hazard? Will the hazard become more or less probable in the operation under consideration?'* For assessing conditional probabilities of the possible outcomes of the conflict scenarios use is made of the following type of questions: *'Suppose the pilots do not detect and resolve the conflict. What is the probability that your actions as a controller would prevent a collision?'*

Each of the interviews needs to be evaluated by a team of safety analysts. Often, it was necessary to make an interpretation of the answers given by the experts, and accordingly, results obtained for one subject were generalised for the other subjects where possible. Some qualitative expressions were to be translated in quantitative assessments, as the applicable safety criteria were expressed in numbers. Additionally, statistical databases can be used, as for instance NLR's Air Safety Database [Air safety database]; also, information from real-time experiments can be used, as for Sourdine II from [S II D6.3].

The frequency is usually assessed using frequency classes, which have a qualitative interpretation. For instance, PROBABLE, REMOTE, EXTREMELY REMOTE, and EXTREMELY IMPROBABLE.

Complicating factors in assessing the frequency of a conflict ending in a given severity at once can be that there is often little or no experience with the new operation, and that the situation may involve several variables. This holds especially for the more severe outcomes of the conflict, since these

situations occur rarely, and accordingly less information is at hands about the behaviour of air traffic controllers and pilots in such situations.

As a result, there will be uncertainty in the frequency estimates. This uncertainty should be dealt with carefully; one of the following approaches can be chosen:

- Ranges can be identified, which contain the true value with a given confidence; or
- One can stay on the safe side by using conservative frequency estimates.

For more details on the argumentation-based approach, we refer to [QSA method].

### **Simulation-based approach**

For a simulation-based approach, the following activities are executed:

1. Develop a stochastic dynamical model of the accident risk for the conflict scenario within the operation. The stochastic dynamical model takes the form of a Dynamically Coloured Petri Net (DCPN), which models the hazards identified, and which uses an advanced human performance modelling.
2. Perform Monte Carlo simulations and mathematical analysis techniques to assess the accident risk based on this stochastic dynamical model.
3. Perform a Bias and Uncertainty assessment; i.e., first identify all assumptions adopted, such as numerical approximation assumptions, model structure assumptions, non-coverage of hazards assumptions, parameter-value assumptions; next, evaluate the effect of all adopted assumptions on the accident risk. The effect of each assumption can be as follows:
  - Bias: due to the adoption of the assumption, the model-based risk is systematically higher or lower than expected for the real operation,
  - Uncertainty: due to the adoption of the assumption, there is uncertainty in the model-based accident risk.
4. Combine the results of steps 2 and 3, leading to an estimation of accident risk for the real operation (i.e. the model-based accident risk, compensated for all assumptions adopted), and a 95% credibility interval for this accident risk.

For more technical details on DCPN, refer to [Everdij & Blom, 2003]. For details on the development of DCPN and the Monte Carlo simulations, refer to [Blom et al., 2001] and [Blom et al., 2003b]. For more details on human performance modelling, refer to [Blom et al., 2003a]. For the Bias and Uncertainty assessment refer to the methods described in [Everdij & Blom, 2002] and [Stroeve et al., 2003].

### **Allocation of approaches to conflict scenarios**

For the risk assessment of each conflict scenario, a simulation-based approach and/or an argumentation-based approach can be adopted. Criteria that support the allocation of conflict scenarios for the approaches are:

- A simulation-based approach can give more detail into the risk than an argumentation-based approach. Therefore a simulation-based approach may be chosen for conflict scenarios that are expected to be more safety critical, more typical for the operation under consideration, or in another sense more important.
- The simulation-based approach is more effective in tackling risk estimation in which the exact flight paths play an important role.
- Applying the simulation-based approach needs the development of a detailed mathematical model, which is relatively labour extensive if a model is not available yet.

- For conflict scenarios for which an argumentation-based approach suffices to show that the risk related to it is acceptable, it is generally not efficient to apply a simulation-based approach. The same holds for conflict scenarios for which an argumentation-based approach suffices to show that the risk related to it is unacceptable.

### A3.7 Step 6: Assess Risk Tolerability

Next, for each conflict scenario the associated risk is classified. This is done by combining the severity and frequency assessments.

For instance, it could be derived that conditions with the following combinations of severity and frequency are allowed:

- SIGNIFICANT INCIDENT severity may be PROBABLE.
- MAJOR INCIDENT severity must be no more frequent than REMOTE.
- SERIOUS INCIDENT severity must be no more frequent than EXTREMELY REMOTE.
- ACCIDENT severity must be EXTREMELY IMPROBABLE.

To assess the risk associated with each conflict scenario, the classified severity outcomes can be combined with the corresponding frequency outcomes in a risk matrix. In such matrix, the combinations of severity and frequency listed above are classified as TOLERABLE. Conflict scenarios with a higher level of severity and/or a higher frequency of occurrence are classified as implying UNACCEPTABLE risk; the risk for the remaining conflict scenarios is classified as NEGLIGIBLE. An example of the result is shown in the following table:

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE

**Table A3-1: Example risk tolerability diagram containing the tolerability assessment results for a particular conflict scenario**

In this example, the frequency for the SIGNIFICANT INCIDENT class and for the MAJOR INCIDENT class have been assessed rather precisely; for the other two classes there is still some uncertainty.

Conflict scenarios that are analysed using a simulation-based approach often allow a more precise risk tolerability representation.

### A3.8 Step 7: Identify Safety Bottlenecks

From the risk tolerability assessment, it may follow that some conflict scenarios have a risk that is UNACCEPTABLE, or that some conflict scenarios have a risk that is possibly (i.e. in case of uncertainty in the frequency classifications) UNACCEPTABLE. For these conflict scenarios so-called safety bottlenecks are identified. These are hazards or conditions that cause the conflict scenario to have a risk that is (possibly) UNACCEPTABLE. Knowledge about these bottlenecks can be used to support further development of the operation.

A systematic way to search safety bottlenecks for a conflict scenario with (possibly) UNACCEPTABLE risk is the following: For hazards playing a role in the conflict scenario, see what would happen to the risk of the conflict scenario if this hazard would occur with zero probability. If the risk is then no longer UNACCEPTABLE, the hazard apparently plays a large role in causing the large risk of the conflict scenario, and it is called a safety bottleneck.

In principle, other aspects of the operation, such as meteorological conditions may also play an important role in high risks. A similar way of working can be adopted to check these for safety bottlenecks: Re-assess the risk for an alternative for the condition; if the risk is then no longer UNACCEPTABLE, the condition is a safety bottleneck.

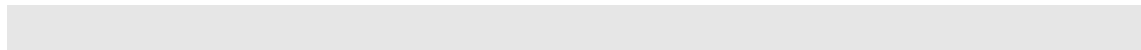
The identification of safety bottlenecks is important as it gives operational concept designers clues to finding potential risk mitigating measures for the operation.

### **A3.9 Optional Iteration of the Assessment**

The above steps constitute the TOPAZ safety assessment methodology. Following the assessment, decision-makers can consider whether the operation as assessed will be implemented as such, or if the operation will be adapted or redeveloped, or that the operation will not be implemented at all. If there still exists too much uncertainty on the risk level, the decision might be to broaden the assessment.

Risks classified as NEGLIGIBLE usually do not form an objection to implement the operation as assessed. Risks that are classified as UNACCEPTABLE are considered to identify aspects of the operation that need some adaptation or further development. Finally, for risks classified as TOLERABLE, the ALARP principle is assumed to hold, which states that the operation could be implemented as long as the risk is kept As Low As Reasonably Practicable, i.e. anything technically and commercially possible will be done to minimise the risk.

In case adaptation or redevelopment of the operation takes place, a new safety assessment should be performed that adopts the same wide view as the first cycle, not limiting to the adapted operational details. The reason for this is that adaptations of the air traffic operation may improve safety in one respect, but may cause safety problems in another part of the operation.



## Appendix 4 Aircraft Substitution for the Noise Modelling Study

### A4.1 Introduction

Bearing in mind that INM's reliability depends on the database, a problem was brought to the forth once the project understood that no mixing of aircraft was possible outside those for which the data was reliable.

The data available to SII is only valid for certain aircraft belonging to the Airbus and Boeing family.

The question raised is thus the need to substitute aircraft the best way possible to either make sure that the capacity levels are maintained or the noise produced is comparable.

This task was already considered by the Sourdine (4<sup>th</sup> Framework) project, which will be later detailed.

### A4.2 Objective

The aim of the document is to try to answer the question on how and with which Airbus and other family aircraft may substitute the future and current fleet mixes.

### A4.3 Reference Documents for Noise Modelling Study

- [1] Sourdine D3-001 document "Establishment of Noise Abatement Solutions", chapter 6.1 to 6.3.
- [2] Sourdine Annex G D3v83 Table G4 and G5
- [3] Madrid traffic fleet mix forecast for Madrid Barajas (email received on the) from Aena.
- [4] Naples-Capodichino Fleet mix forecast (email received on the) SICTA.
- [5] FAA AC 36-1H, Noise Levels for U.S certificated and foreign A/C, 11/15/01
- [6] Technical WebPages on Civil Airliners ([www.airliners.net/](http://www.airliners.net/))
- [7] "World Airliners Part 1 & 2" by Flight International (26Oct.—1 Nov. & 2-8 Nov 2004 issues)

### A4.4 Analysis

#### A4.4.1 *INPUT Needed for the Analysis*

Below the inputs available at the time and the source of the data, used for substitutions:

1. Fleet mix for Madrid Barajas Airport both current and the foreseen (2015) [3]

The main companies operating at the airport and the corresponding percentage of operations have been determined from the data of the representative day. Results are summarised below:

Company	Percentage (%)
Iberia	50
Spanair	14
Air Europa	10

<b>TOTAL</b>	74
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	Actual			2005			2015		
	Número	Modelo	Motor	Número	Modelo	Motor	Número	Modelo	Motor
<i>AIR EUROPA</i>	9	B737/300-400	CFM56	22	B737-800	CFM56	22	B737-800	CFM56
	11	B737/800	CFM56						
	6	B757/200	RB211	3	B767-300	CF6	3	B767-300	CF6
	3	B767/200	CF6						
<i>SPANAIR</i>	3	MD-87	JT8D	10	MD-80	JT8D	29	A320	V2500
	23	MD-83	JT8D						
	11	MD-82	JT8D	19	A320	V2500	5	A319	V2500
	3	A320-200	V2533						
	3	A321-200	V2527	5	A319	V2500	9	A321	V2500
	3	B767/300	PW4060						
	4	B717	BR715	9	A321	V2500			
<i>IBERIA</i>	24	MD87	JT8D	24	MD87	JT8D	24	MD87	JT8D
	13	MD88	JT80	13	MD88	JT80	13	MD88	JT80
	8	B747	JT9D	18	A340-313	CFM56	18	A340-313	CFM56
	18	B757	RB211	3	A340-600	CFM56	3	A340-600	CFM56
	3	A300	JT9D	4	A319	CFM56	4	A319	CFM56
	4	A319	CFM56	22	A320-211	CFM56	22	A320-211	CFM56
	54	A320	CFM56	33	A320-214	CFM56	33	A320-214	CFM56
	4	A321	CFM56	2	A321	CFM56	2	A321	CFM56
	16	A340	CFM56	16	B757	RB211	16	B757	RB211
	2	DC-8	JT3D						
	19	FOKKER-50	PW125	24	CRJ-200	CF34	24	CRJ-200	CF34
	5	ATR-72	PW124						
	24	CRJ-200	CF34						

**Table A4-1: Fleet mix for Madrid-Barajas Airport.**

New noise regulations have been taken into account as the replacement of Chapter 2 aircraft. Chapter three aircraft have time till the 1/01/05 to certify to the new noise limits.

2. Foreseen fleet-mix for Naples Capodichino airport

Currently, operating aircraft by Naples airport are indicated below.

<b>Current scenario</b>			
<b>Aircraft type</b>	<b>Engine type</b>	<b>Aircraft number</b>	<b>Percentage</b>
A319	CFM56	8	4%
A320	CFM 56	26	14%
ATR42	PW127F	16	9%
ATR700	PW127F	6	3%
B734/7/8	CFM56	6	3%
CRJ2/700	CF34	22	12%
D328	PW119C	18	10%
FOKKER 100	RR TAYMK -620-15	10	5%
MD80	PWJT8D	36	20%
MD82	PWJT8D	36	20%
		184	

**Table A4-2: Fleet mix for Naples Airport.**

Assuming the following list of possible aircraft substitutions:

<b>Aircraft</b>	<b>Substitutions aircraft</b>
<b>A319</b>	A319
<b>A320</b>	A320
<b>ATR42</b>	ATR72, CRJ200,EMB145,D328
<b>ATR700</b>	ATR700
<b>B734/7/8</b>	B737/8
<b>CRJ2/700</b>	CRJ200
<b>D328</b>	D328
<b>FOKKER 100</b>	ATR72, CRJ200,EMB145,D328
<b>MD80</b>	80%(A319, A320, B737/8)
<b>MD82</b>	20%(ATR72, CRJ200,EMB145,D328)

**Table A4-3: List of possible aircraft substitutions.**

And on the basis of current available data, of airline requirements and local airport needs, the following aircraft fleet has been hypothesised for Naples Capodichino airport:

Fleet mix al 2015 (email Naples 24/06/04)		
A319	12%	CFM56
A320-211	23%	CFM56
ATR72	10%	PW127F
B734/737/738	20%	CFM56
CRJ100/200	15%	CF34
EMB145	9%	AE3007A
D328	12%	PW119C

**Table A4-4: Hypothesised Fleet mix for Naples Airport.**

At a first glance we may find turboprops, which will not be simulated: ATR72 and D328, these a/c cannot be simulated, resulting in a 22% derived traffic lowering.

3. Aircraft Values:

- a. Values for Sideline<sup>3</sup> Noise certification level for civil airliners (EPNdb)[5], [6]. Where weight and aircraft engine type was available (Airbus) the nominal value was taken, in other cases the maximum value was used.
- b. Values for Range, MTOW and passengers were also collected from different sources. [6], [7]

**A4.4.2 PARAMETERS**

Classification was based on the following aircraft characteristics:

SL EPNdb: Max Sideline (SL) Effective Perceived Noise Level (EPNdb) range measured at a standard distance of 450 m. during FAA type certification with takeoff trust cut back applied unless otherwise noted, and corrected to sea level, 77 °F and 70% relative humidity conditions. The EPNdb range takes into account engine models, flap settings and the aircraft maximum and minimum takeoff weights. Were the engine type and series was known the correspondent SL EPNdb values were used, otherwise for those cases where type, engine and MTOW was not known a range of values was used. To later include the maximum value (or worst case).

MTOW: Maximum Take-Off Weight, precise values for MTOW were used where possible although knowing only the right values for Airbus a/c and a few Boeing, for the other aircrafts a range of values was assumed..

PASSENGERS: Passenger number was chosen based on 2-class accommodation and type or series of aircraft. In certain cases Range was coupled to determine the number of passengers and class disposition.

RANGE: dependant on aircraft type and series comes as a result after choosing the number of passengers or vice versa.

The following drawing explain the steps taken for the classification:

---

<sup>3</sup> Max Sideline (SL) Effective Perceived Noise Level (EPNdb) range measured at a standard distance of 450 m. during FAA type certification with takeoff trust cut back applied unless otherwise noted, and corrected to sea level, 77 ° F and 70% relative humidity conditions. The EPNdb range takes into account engine models, flap settings and the aircraft maximum and minimum takeoff weights.

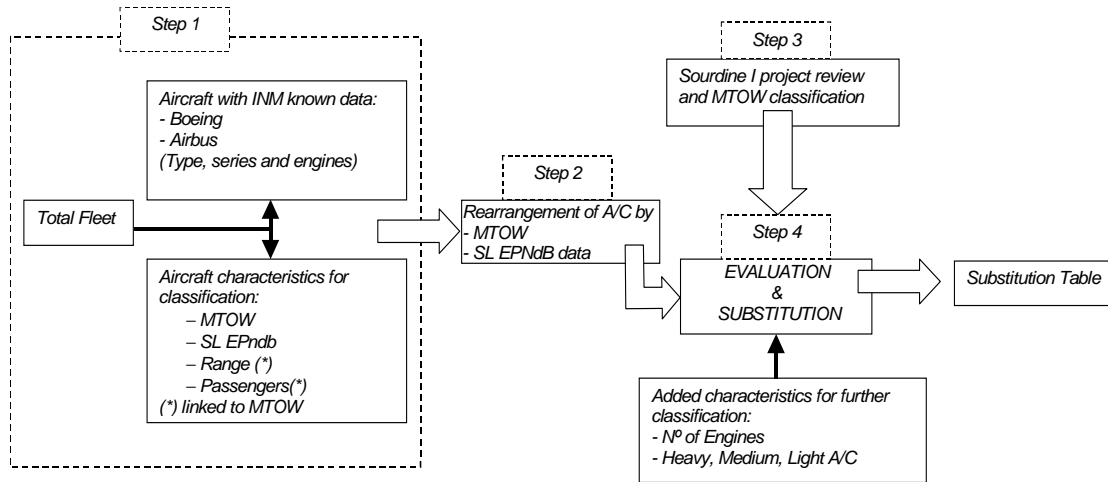


Figure A4-1: Classification of aircraft Models.

### A4.4.3 STEP1 Aircraft Belonging to Fleet Mix

Since the main objective is to substitute aircrafts we do not know, for others for which we have data, the first step was to see for which aircraft data was available:

Available Aircraft	Not Available and present in Fleet Mix
A319-111	B737-400
A320-211	B737-700
A320-214	B757-300
A320-232	B767-300
A321-211	MD-88
A321-232	MD-87
A330-301	CRJ100
A340-313	CRJ-200
B737-300	EMB145
B737-800	Fokker100
B757-200	747-400
B777-200	MD 81(S80)
	CRJ-700

Table A4-5: Data Available

### A4.4.4 STEP2 Rearrangement of Data

To this first table the other parameters where added: SL MaxEPNdb, MTOW, Range and Passengers, from the lowest values to the highest.

To rearrange the data background colours for different groups and classes were used, some of the groups are only there to make classification easier. During the analysis of the data the four parameters where cut down to two those being the MTOW: range depends on number of passengers

and the number of passengers in general to MTOW; and the Noise certification levels (in general) strongly dependent on the MTOW value.

#### **A4.4.5 STEP3 Review of Past Methodologies [1], [2].**

Previously done work and classification was studied to see if it was also applicable to the Sourdine II INM study.

In the Sourdine project the same problem occurred where data was available for only two Airbus aircraft: A320 and A340.

The main difference since then is that the \_INM software now admits configuration changes and subsequently possesses the NPD curves related to these changes.

Below we may find the hypothesis used and the approach to the problem, besides the reader must bear in mind that the study was conducted specifically for the Schiphol Airport case.

##### Fleet mix used

The airport implementation studies to be carried out within the SOURDINE project are limited by the fact that optimised noise abatement procedures are 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 implementation study of the proposed procedures, a surrogate aircraft fleet is constructed in which other aircraft types are replaced as far as practical by available and representative (Airbus) aircraft types. 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. For the airport implementation studies, two different aspects will be investigated, both of which require a specific representative aircraft fleet.

##### *Implementation aspects of a certain procedure with respect to airport capacity:*

The focus of such a study is on the effect of a given procedure on the airport capacity, i.e. the number of aircraft movements from and to the airport, given the operational behaviour of the different aircraft. A study into the capacity effects of a proposed operational measure should reflect the aircraft mix for the reference situation, i.e. the current situation. If possible, the best option here would be to apply the *actual* fleet mix and daily traffic load for an airport, with the procedures for the different aircraft types (turboprop and jet a/c) adjusted to the proposed measure, where possible. In case this is not possible, the daily traffic load, including variations over the day and aircraft differences in operational behaviour, should remain comparable to that of the original fleet mix, when replacing relevant aircraft types by comparable Airbus aircraft.

##### *Implementation aspects of a certain procedure with respect to overall airport noise:*

The focus is on the amount of noise exposure as a result of the aircraft movements on an overall basis. The fleet mix used in the study should reflect current noise impact around the airport, i.e. the overall noise contour as a result of the fleet used should be *comparable* to the current contour. Practically this might be achieved by replacing specific aircraft by *x* Airbus aircraft in such a way that the footprint area and shape are more or less equal. The value of *x* is dependent on the specific aircraft, noise contour value, and flight mode (eg. departure and approach) and should be determined with the national noise model available at the airports under consideration.

##### Determination of aircraft type conversion factors

For both types, noise footprints of all procedures will be calculated. For the purpose of this study, the Airbus data are added to the Schiphol database, which was used to determine the aircraft conversion factors for the different airport implementation studies in the current project.

In the procedure implementation within the airport noise contour calculation model currently used for Amsterdam Airport Schiphol, aircraft are categorised with specific performance and noise data

representative for the specific category. Categorisation is based on maximum take-off weight and noise characteristics.

Since no Airbus data is used at the moment as a representative category in the current Schiphol database, conversions from Airbus data to the current representatives have to be made for the relevant representative aircraft, in order to be in compliance with the current Ke-zone. The following method has been used:

For each representative aircraft a conversion factor is calculated based on comparison of shape and area of footprints. For departures, the footprint of the highest distance class available is used, i.e. that for the heaviest take-off weight. For approaches, the full flap configuration is used for a 2000-ft. descent. The take-off factor and approach factor for each corresponding category will be used to multiply the number of movements. Because of this the number of aircraft movements changes drastically but the aim is to keep the total noise exposure more or less constant.

In short, for the determination of the conversion factors the following method has been applied:

1. For take-off the area enclosed by the 65 dB(A) noise contour has been calculated, for approach the noise level of 75 dB(A) (for reasons of having a closed contour)
2. The noise level of the relevant Airbus type matching the same area as the representative aircraft has been determined.
3. The difference in dB (A) has been converted into a conversion factor
4. Conversion Factor =  $10^{((65 - \text{dB})/10)}$   
 e.g. a delta dB (A) of 3 gives a conversion factor of 2.

This leads to the results summarised in Appendix II and III. The aircraft categorisation as provided in these tables is according to the official classification used at Schiphol Amsterdam Airport. In addition, the conversion factors that were determined have been added to the table. Tables G-1 and G-2 in Appendix III provide more information on the calculation of the factors.

After calculation of the baseline scenario with surrogate Airbus fleet (2 aircraft), the contours are compared with the original scenario, obtained using the original traffic mix. Subsequently the alternative scenario is calculated and compared with the baseline scenario, to illustrate the differences resulting from the implemented noise abatement procedures.

#### **A4.4.6 STEP 4 Evaluation**

We cannot apply the Sourdine's method since although practical, INM hadn't at that time the option for change in configuration with relative NPD curves. As such the change in configuration cannot be modelled or compared with the Airbus or Boeing family aircraft.

With older versions of INM it would be possible to see the difference in SEL area as produced by a known airbus aircraft and the others, but it would only estimate the difference between a constant configuration of the old aircraft versus a changing configuration.

Of course it would be possible for smaller aircraft to see how the substitution could affect the noise area (since a big difference can be estimated), but that would only include those noise levels for which at a certain height and speed we have compared the values. This does not include the time and resources that would be needed and not foreseen by the project.

Over more the calculated conversion factors from the Sourdine project are only available for a certain amount of aircraft, some current aircraft were not even flying at that time, while others are not present in the fleet mix sent by either Aena or SICTA.

The Sourdine analysis has been used where possible as a guideline, i.e. MTOW classification (Appendix IV), but we do not think it is applicable to the current SII situation.

BASIC Hypothesis and comments

A/C from Boeing as the 747, have no straightforward substitution (as can be seen in tables from Appendix I), others can be substituted on the noise basis but not by using the MTOW or Passengers (B757, B767,..).

Only those aircraft that were sent by Aena and SICTA were taken into account by this analysis.

Small regional jet aircraft cannot be substituted completely without twitching with passenger numbers and a/c weights. Noise wise they create less noise than the A319, but this is the would be the only close enough aircraft available for substitution.

## A4.5 PROPOSAL

In general, the purpose of substitution techniques (as far as noise modelling is concerned) is to represent an actual fleet-mix by a limited number of aircraft types (i.e. those available in the database of the noise model), in such a way that the calculated noise contours are equivalent to the actual noise load produced at the airport.

This is not an easy process, given that noise footprints are a mix of noise source characteristics and aircraft performance (i.e. through the resulting flight profiles, which define the source-to-receiver geometry, and the aircraft state along the trajectory). In particular, applying a one-by-one substitution method (i.e. one movement of an unlisted aircraft is replaced by one movement of an "equivalent", listed aircraft) cannot completely capture these two effects. Some more sophisticated methods, based on the concept of "equivalencies" (i.e. one movement of an unlisted aircraft is replaced by 2.16... movements of an equivalent listed aircraft) give better results, but are more complex to implement.

The objective of the noise study is to simulate and weigh the improvement in noise surrounding the airports based on using the new procedures, thus we must do the following:

1. Use only an Airbus and Boeing (known) fleet-mix for the Baseline Noise study
2. Use only an Airbus and Boeing fleet-mix for the Future scenario (2015)
3. Avoid the mixing with aircraft for which we have no data, no NPD curves and no values for configuration changes.
4. Maintain the same traffic number, thus maintain the airports capacity (n° of flights).
5. Try to maintain where possible the number of heavies substituting them for other heavies (although the noise values are an may turn to be different).

Thus we may compare the difference and evaluate the procedures' benefits, not the eventual changes in fleet or aircraft.

The INM study should then be approached by using the following aircraft substitution classes that are a balance between MTOW (SourDine class values were taken into consideration) and Max SL EPNdb values.

MTOW Class [1000kg]	Aircraft	MTOW [1000kg]	SL Max EPNdb	Noise Assessment Substitution	
				substitution	optional
$15 \leq MTOW < 40$	CRJ-100/200	21.5	86	none	
	EMB145	22-24	84.6	none	
	ATR42	16	80.7	none	
	Dornier 328	16	83.8	none	
	Embraer RJ145	22	84.2 – 84.6	none	
$40 \leq MTOW < 60$	FOKKER70 FOKKER100	45.18	91.7	B737-300	A319-111
$60 \leq MTOW < 100$	B737-300	62.8	90.4	B737-300	
	A319-111	64-75.5	92	A319-111	
	B737-400	62.9-68.1	93.2	B737-300	
	B737-700	60-70	94.7	B737-800	
	MD-88	72.5	97.2	A321-232	
$60 \leq MTOW < 100$	MD-87	63.5	97.1	A321-232	
	MD 81(S80)	63.5	97.3	A321-232	
	MD82	67	96.3	A321-232	
	A320-211	73.5-77	94.4	A320-211	
	A320-214	73.5-77	94.4	A320-214	
	A320-232	73.5-77	94.4	A320-232	
	B737-800	78-79	93.1	B737-800	
	B737-900	78-79	94.3	B737-800	
	A321-211	83-93.5	94.3	A321-211	
	A321-232	83-93.5	95.6	A321-232	
$100 \leq MTOW < 160$	B757-200	98.8-115.6	94.2-94.4	B757-200	
	B757-300	123.6	94.5	B757-200	
$160 \leq MTOW < 230$	B767-300	184.8-186.8	97	A330-301	B777-200
$230 \leq MTOW < 300$	A330-301	230-233	97.2	A330-301	
	A340-313	271-275	95.8	A340-313	
	MD11	275	96.1- 96.5	B777-200	
	B777-200	253-305.97	96.1	B777-200	
$300 \leq MTOW < 400$	747-400	363-396.6	103.8	A340-313	
	A340-600	368-380	98	A340-313	

**Table A4-6: Substitution Table**

The MTOW class used is as defined in the Sourdine project [see Appendix II]. Blue and red colour for aircrafts designate aircraft for which we have the INM profiles data.

The table above shows the suggested aircraft substitutions as seen comparing the combination of the two parameters as far as possible (MTOW and SLMaxEPNdb).

In the extremities of the table we may find those aircrafts for which there are no possible straightforward substitutions, both on weight basis and certified noise since differences are quite great. Further study, which is not in the scope of the Sourdine II project, such as establishment and “use” of conversion factors (as done in the Sourdine project) could probably solve this substitution more precisely although the best way remains having the INM7 data format available for all aircraft.

Four engine aircraft have been substituted with the nearest available four engine aircraft (B747-400 with A340-313, above).

Substitution options have been put on a second column.

## A4.6 Conclusion

Now, in the context of Sourdine II, the proposed one-by-one substitution method (incl. discarding some aircraft types from the airport noise studies) can be considered as a reasonable choice, given that the purpose is to compare the noise effect of different procedures, applied to a given - unchanged - fleet mix, and that using a more sophisticated method would be anyway too much time consuming. As a result of that choice, the calculated noise contours may not reflect the actual noise load, but this has to be considered as a limitation of the project.

The objective of the noise study is to show if benefits will be gained by using New Advanced NAPs, designed by the SII consortium. In order to obtain these results we need to perform an INM study comparing a baseline and a the future scenario procedure with an operational Fleetmix.

Since the only data provided is the Airbus data for eight aircraft and the Boeing Data for four aircraft, the possibility for substitution of unknown aircraft with known aircraft was envisaged and then performed. The substitution took into account parameters as: MTOW, SLMaxEPNdb, Passengers and Range, giving a higher importance to SLMaxEPNdb coupled with MTOW (when possible).

A table containing the substitutive aircraft valid for the fleet-mix of both Barajas Madrid airport and Naples Capodichino was completed (see table Sec A3-5). The above table will also be used in Schiphol Airport for the relative INM study.

The table must be seen as a proposal since certain substitutions (the extremities of the table) cannot be substituted directly without a more in depth analysis.

*Two open questions still remain, how do we behave with the small aircrafts and how do we behave with the heaviest?*

For the heaviest the decision was taken to substitute them for known heavy aircraft, while for the smaller aircraft the decision was taken to not consider them, bearing in mind the scope of the SII project and the time schedule.

As such the question above is still open to future answers that we hope will come from future projects.

## Appendix 5 Noise Study Tables for the Traffic Substitution Process

### A5.1 Aircraft Parameters for the Fleet-Mix.

Type	SL Max EPNdb		Type	MTOW (tons)		Type	Passengers		Type	Range X 1000 (km)	
CRJ100	82-86		CRJ100	21.5		CRJ100	50		CRJ100	1.8	
CRJ-200	82-86		CRJ-200	21.5		CRJ-200	50	C1	CRJ-200	1.8	
EMB145	84.2 - 84.6		EMB145	22-24	C1	EMB145	50		EMB145	2.7-3.7	
Fokker100	91.7	C1	Fokker100	45.18		Fokker100	107		Fokker100	3.1	C1
A319-111	92		B737-300	62.8		MD-87	114	C2	MD 81(S80)	2.9	
B737-400	88.2 - 93.2		A319-111	64-75.5		A319-111	124		MD82	3.8	
B737-300	90.4		B737-400	62.9-68.1		B737-300	141		B737-300	3-4.8	
A320-211	92.8 - 94.4		B737-700	60-70		MD-88	144		MD-87	4.4	
A320-214	92.8 - 94.4		MD-88	72.5	C2	B737-400	146	C3	MD-88	4.6	
A320-232	92.8 - 94.4		MD-87	63.5		B737-700	146		B737-400	4-4.6	C2
A321-211	94.3	C2	MD 81(S80)	63.5		A320-211	150		A319-111	4.7	
B737-800	93.1		MD82	67		A320-214	150		A320-211	5.35	
B757-300	94.5		A320-211	73.5-77		A320-232	150		B737-800	5.44	
B737-700	94.7		A320-214	73.5-77	C3	MD 81(S80)	155	C4	A320-214	5.55	
B757-200	95.1		A320-232	73.5-77		MD82	155		A320-232	5.55	C3

Type	SL Max EPNdb		Type	MTOW (tons)		Type	Passengers		Type	Range X 1000 (km)	
MD 81(S80)	94.5 - 97.3		B737-800	78-79		B737-800	160		A321-211	5.55	
A340-313	95.3 -95.8	C3	A321-211	83-93.5		A321-211	185		A321-232	5.55	
A321-232	95.6		A321-232	83-93.5	C4	A321-232	185	C5	B737-700	6 (126)	
MD82	95.9 -96.3		B757-200	98.8-115.6		B757-200	201		B757-300	6.41	C3-4
B767-300	94-97		B757-300	123.6	C5	B767-300	218	C6	B757-200	5.5-7.4	
B777-200	96.1		B767-300	184.8 - 186.8	C6	B757-300	243	C7	A330-301	10.4	
MD-87	97.1	C4	A330-301	230-233	C7	A330-301	295	C8	B767-300	11.4	C5
A330-301	97.2		777-200	253-305.97		A340-313	295		777-200	10.7-14.3	
MD-88	97.2		A340-313	271-275	C8	777-200	305		747-400	11.4-13.4	
A340-600	98		A340-600	368-380		A340-600	380		A340-600	13.9 - 14.8	
747-400	99.5 - 103.8	C5	747-400	363-396.6	C9	747-400	416	C9	A340-313	16-16.4	C6

Table A5-1: Aircraft parameters for the fleet mix

## A5.2 Classification of Aircraft (Sourdine)

Classification of aircraft into capacity categories and noise conversion factors for A320  $\Delta\text{EPNdB}^* = (\Sigma\text{H3 certification level}) - (\Sigma\text{H3 limit values})$ , (H3 = Chapter 3).

Capacity Category	MTOW [1000kg]	Noise classification			
		1 $\Delta\text{EPNdB} > 0$ not H3	2 $0 \geq \Delta\text{EPNdB} > -9$	3 $-9 \geq \Delta\text{EPNdB} > -18$	4 $\Delta\text{EPNdB} \leq -18$
<b>Representative a/c (in bold) relative to A320</b>	1 $6 \leq \text{MTOW} < 15$			<b>Saab SF-340</b> EMB-110/120 Dornier 228/328 Bae Jetstream 31 Shorts 330 DEP 0.03 APP 0.2	
	2 $15 \leq \text{MTOW} < 40$	F-28 N/A	<b>F-27</b> N/A	<b>F-70</b> FK50 ATR-72 Dash 8-300/400 BAe-ATP BAe146-100 DEP 0.5 APP 0.5	ATR-42 Canadair RJ100 Saab 2000 DEP 0.4 APP 0.3
	3 $40 \leq \text{MTOW} < 60$	B737-200 Tupolev 134 Bac-1-11 DC-9 N/A	<b>DC9 Hushkit</b> Yakovlev 42 DEP 21.5 APP 4.1	<b>B737-300</b> B737-500 BAe AVRO RJ100 F-100 DEP 1.4 APP 1.6	BAe-146-300 BAe-146-200 L-188 DEP 1.6 APP 0.8
	4 $60 \leq \text{MTOW} < 100$	B727-200 Antonov 12 N/A	<b>B737-400 OC<sup>4</sup></b> A-319 MD-83 B727-200 RE <sup>5</sup> Lockheed Hercules DEP 1.8 APP 2.0	<b>B737-400 HBC<sup>6</sup></b> MD-82 MD-88 A-320-100/200 MD-81 MD-87 A-321-200 B737-600/700/800 DEP 1.4 APP 1.6	

**Table A5-2: Classification of aircraft into capacity categories and noise conversion factors for A340**

<sup>4</sup> Other carriers

<sup>5</sup> Re-engined

<sup>6</sup> Home based carriers

Capacity Category	MTOW [1000kg]	Noise classification				
		1 $\Delta\text{EPNdB} > 0$ & not H3	2 $0 \geq \Delta\text{EPNdB} > -9$	3 $-9 \geq \Delta\text{EPNdB} > -18$	4 $\Delta\text{EPNdB} \leq -18$	
Representative a/c (in bold) relative to A340	5	100 ≤ MTOW < 160	B707 DC-8  N/A	<b>TUPOLEV 154</b> A-300F B767-200 DEP 1.3 APP 2.2	<b>B757-200</b> A310-200/300 Short Belfast DEP 0.8 APP 1.7	
	6	160 ≤ MTOW < 230	Illushin 76  N/A	<b>B767-200 ER</b> Lockheed Tristar 200  DEP 1.7 APP 4.6	B767-300 ER A-300B4 A330-300 A300-600 DEP 0.7 APP 2.5	
	7	230 ≤ MTOW < 300	N/A	<b>DC10-30</b> DC-10-40 Lockheed Tristar 500 DEP 7.7 APP 5.7	<b>MD-11</b>  DEP 3.3 APP 3.1	<b>B777-200</b> A-340-200/300 0 DEP 1.4 APP 2.2
	8	300 ≤ MTOW < 400	B747-100	<b>B747-300</b> B747-200 B747-SP DEP 20.3 APP 5.7	<b>B747-400</b>  DEP 9.0 APP 5.9	

Table A5-3: Classification of aircraft into capacity categories and noise conversion factors for A340

### A5.3 Amsterdam Schiphol Simulation

<b>DEPARTURE</b>	Representative aircraft in class dB (A)	A320-214/P DB (A)*	Noise footprint area	Conversion Factor
Category Class				
013	65.0	79.9	4.15	0.03
023	65.0	68.2	18.22	0.5
024	65.0	69.5	12.35	0.4
032	65.0	51.7	217.37	21.5
033	65.0	63.4	42.64	1.4
034	65.0	63.0	45.43	1.6
042	65.0	62.4	49.22	1.8
043	65.0	63.4	42.64	1.4
Category Class	Representative A/C dB (A)	A340-311 DB (A)*	Area	Conversion Factor
052	65.0	63.8	61.97	1.3
053	65.0	65.9	44.24	0.8
062	65.0	62.6	71.26	1.7
063	65.0	66.3	44.95	0.7
072	65.0	56.2	154.43	7.7
073	65.0	59.8	99.89	3.3
074	65.0	63.6	63.24	1.4
082	65.0	51.9	249.46	20.3
083	65.0	55.4	168.08	9.0

*\* Noise level of A320/A340 with the same area size at representative aircraft noise level*

**Table A5-4: Aircraft (category) conversion factors for departures**

<b>APPROACH</b>				
Category Class	Representative aircraft in class dB (A)	A320-214/P DB (A)*	Noise footprint area	Conversion Factor
013	75.0	82.9	2.42	0.2
023	75.0	78.4	3.88	0.5
024	75.0	80.8	3.11	0.3
032	75.0	68.9	9.43	4.1
033	75.0	73.1	6.10	1.6
034	75.0	75.7	4.79	0.8
042	75.0	71.9	6.89	2.0
043	75.0	73.1	6.10	1.6
052	75.0	71.6	6.95	2.2
053	75.0	72.6	5.68	1.7
062	75.0	68.4	11.01	4.6
063	75.0	71.0	7.68	2.5
072	75.0	67.5	12.28	5.7
073	75.0	70.1	8.85	3.1
074	75.0	71.6	6.98	2.2
082	75.0	67.4	12.42	5.7
083	75.0	67.3	12.95	5.9
* Noise level of A320/A340 with the same area size at representative aircraft noise level				

**Table A5-4: Aircraft (category) conversion factors for approaches**

### A5.4 Re-Arrangement and Application of Noise & MTOW Cat. to Sourdine II Fleet

MTOW (tons)			Noise Category	SL Max EPNdb
15 ≤ MTOW < 40	CRJ100	21.5	CRJ100	82-86
	CRJ-200	21.5	CRJ-200	82-86
	EMB145	22-24	EMB145	84.2 -84.6
	CRJ-700	33	CRJ-700	89.5
40 ≤ MTOW < 60	Fokker 70/100	45.18	B737-300	90.4
			Fokker 70/100	91.7
			A319-111	92
60 ≤ MTOW < 100	B737-400	62.8	B737-400	93.2
	A319-111	64-75.5	A320-211	92.8 - 94.4
	B737-400	62.9-68.1	A320-214	92.8 - 94.4
	B737-700	60-70	A320-232	92.8 - 94.4
	MD-88	72.5	A321-211	94.3
	MD-87	63.5	B737-800	93.1
	MD 81(S80)	63.5	B757-300	94.5
	MD82	67	B737-700	94.7
	A320-211	73.5-77	B757-200	94.2-94.4
	A320-214	73.5-77	MD 81(S80)	94.5 - 97.3
	A320-232	73.5-77	A340-313	95.3 -95.8
	B737-800	78-79	A321-232	95.6
	A321-211	83-93.5	B777-200	96.1
	A321-232	83-93.5	MD82	95.9 -96.3
100 ≤ MTOW < 160	B757-200	98.8-115.6	MD11	96.1 – 96.5
	B757-300	123.6	B767-300	94 - 97
160 ≤ MTOW < 230	B767-300	184.8 - 186.8	MD-87	97.1
			A330-301	97.2
230 ≤ MTOW < 300	A330-301	230-233	MD-88	97.2
			A340-313	98
			747-400	99.5 - 103.8

$230 \leq MTOW < 300$	MD11	275
	B777-200	253 – 305.97
$300 \leq MTOW < 400$	747-400	363-396.6
	A340-600	368-380

**Table A5-5: SII Fleet mix**



## Appendix 6 Final Reference Documents for D4.1

SII\_WP4\_D4.1\_Report\_On\_The\_Global\_Results\_V1.1 was written using the information provided by the following reference documents for WP4:

CAPACITY	VERSION	DATE
SII_WP4_D4-1-1a_Capacity_Results_Summary_V2	V2.0	18-05-2006
SII_WP4_D4-1-2a_Schiphol_v1.3	V1.3	14-12-2005
SII_WP4_D4-1-3a_Madrid Barajas Capacity Report V2.0	V2.0	26-01-2006
SII_WP4_D4-1-4a_CDG_Capacity_v0.2	V0.2	27-09-2005
SII_WP4_D4-1-5a_Naples_v1.2	V1.2	15-03-2006

SAFETY	VERSION	DATE
S II D4.2-1 v2.0.doc (WP 4.2)	V2.0	01-08-2005
S II D4.2-2a Safety assessment of approach Procedure II-A on Schiphol airport (Main document)	V2.0	01-08-2005
S II D4.2-2b Safety assessment of approach Procedure II-A on Schiphol airport (Argumentation-based analysis)	V2.0	01-08-2005
S II D4.2-2c Safety assessment of approach Procedure II-A on Schiphol airport (Simulation-based analysis)	V2.0	01-08-2005
S II D4.2-2d Safety assessment of approach Procedure II-A on Schiphol airport (Collection of expert interviews)	V2.0	01-08-2005
S II D4.2-3 Safety assessment of approach Procedure V and departure procedure 2 on Barajas airport	V2.0	01-08-2005

NOISE & EMISSIONS	VERSION	DATE
SII_WP4_D4-1-1b_Noise Results Summary_v2	V2.0	12-06-2006
SII_WP4_D4-1-2b_Schiphol_v1.0	V1.0	26-01-2006
SII_WP4_D4-1-3b_Madrid-Barajas-Noise_Results_v1.0	V1.0	13-02-2006
SII_WP4_D4-1-4b_CDG-Noise-Results_v1.0	V1.0	28-08-2005
SII_WP4_D4-1-5b_Naples_Capodichino_Noise_Results_v1.0	V1.0	26-02-2006

<b>COST BENEFIT ANALYSIS</b>	<b>VERSION</b>	<b>DATE</b>
SII_WP4_D4-3_v2.0	V2.0	12-06-2006