EUROPEAN COMMUNITY

COMPETITIVE AND SUSTAINABLE
GROWTH PROGRAMME

SOURDINE II

D4-1-1a
Fast-Time Simulation
Capacity Results Summary

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:

NLR	*Stichting Nationaal Lucht- en Ruimtevaartlaboratorium*	*NL*
AENA	Aeropuertos Españoles y Navegación Aérea	*ESP*
AIRBUS F	*AIRBUS FRANCE SAS*	*F*
EUROCONTROL	*European Organisation for the safety of Air Navigation*	*INT*
ISDEFE	*Ingenieria de Sistemas para la Defensa de España S.A.*	*ESP*
INECO	*Ingenieria y Economia del Transporte*	*ESP*
SICTA	*Sistemi Innovativi per il Controllo del Traffico Aereo*	*IT*

Document Change Log

Release	Author	Affected Sections / Comments	Document Nature	Date
0.1	Aena, Alfredo Gómez de Segura	All, Creation	Confidential	29/08/05
0.2	Aena, Alfredo Gómez de Segura	All, Reviewed by Pablo Sánchez Escalonilla	Confidential	2/09/05
0.3	Aena, Alfredo Gómez de Segura	All, Reviewed by Pablo Sánchez Escalonilla	Confidential	27/03/06
0.4	Aena, Alfredo Gómez de Segura	All, Reviewed by NLR, EEC and Sicta	Confidential	11/04/06
1.0	Aena, Alfredo Gómez de Segura	All, Reviewed by NLR, EEC and Sicta	Confidential	12/05/06
1.1	Aena, Alfredo Gómez de Segura	Acknowledgment of comments by the EC (Summary-Conclusions)	Confidential	17/05/06
2.0	Aena, Alfredo Gómez de Segura	EC approved version	Public	18/05/06

Document Distribution

Partner	Distribution list
AENA	Pablo Sánchez-Escalonilla Alfredo Gómez de Segura
Airbus France	Michel van Boven
Eurocontrol Experimental Centre	Peter Hullah Laurent Cavadini
Ineco	Peter Lubrani
Isdefe	Marcos Esteban Carlos Juste
NLR	Ruud den Boer Collin Beers
SICTA	Patrizia Criscuolo Mariacarmela Supino

Review and Approval of the Document

Organisation Responsible for Review	**Reference of comment documents**	**Date**
Aena	E-mail	11/04/06
EEC	E-mail	11/05/06
NLR	E-mail	11/04/06
Sicta	E-mail	10/05/06
Organisation Responsible for Approval	**Name of person approving the document**	**Date**
Project Manager	Ruud den Boer	11/05/06
Work Package Leader	Pablo Sánchez Escalonilla	11/05/06
EC Official	Morten Jensen	18/05/06

Document Information	
Document title	D4-1-1a Capacity Results Summary
Version	V2.0
Date	18-05-06
Classification	Public
Work Package	WP4
Document identification	D4-1-1a_SourdineII_Capacity_Results_Summary_v2

Contributing Partners	**Authors**
Aena	Alfredo Gómez de Segura

Contact Information
Aena, Spain
Attn. Mr. Alfredo Gómez de Segura
C/ Josefa Varcárcel 30 office 3.07
Madrid
Spain
Tel.: +34-91- 321 34 68
e-mail: agomez@aena.es
Aena, Spain

Summary

This document summarises the different results deriving from the capacity assessment carried out within Sourdine II activities of a series of new noise abatement arrival and departure procedures on Madrid-Barajas, Naples-Capodichino, Amsterdam-Schiphol and Paris-Charles de Gaulle airports and provides general conclusions about the impact on the airport capacity of the new Sourdine II Noise Abatement Approach Procedures (NAAP)s.

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 rather 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.

Four Noise Abatement Procedures (NAPs) 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 are based on data provided by Airbus and were simulated in each airport situation for the year 2015.

A brief description of the four arrival procedures considered:

- Procedure II: **Basic CDA with 2 degrees initial Flight-Path Angle (FPA) with a 3 degree 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 (4º)**. The difference between procedure II and procedure III is the steeper flight path angle on the ILS (3ºproc. II vs. 4º 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 nº 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.

Two platforms have been used to validate the new set of procedures from the capacity point of view: TAAM (Total Airport and Airspace Modeller) from Preston Aviation Solution and SIMMOD (Airport and Airspace Simulation Model) from ATAC Corporation. They 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. Naples Capodichino airport selected SIMMOD as the FTS platform to validate the new procedures.

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 large amount of average delay.

Arrival procedure V and II are the most promising procedures in terms of capacity. The Sourdine II procedures II and V are 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, 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).

Procedure IV shows a significant reduction of performance and capacity. Within this procedure aircraft have to fly the final approach speed (FAS) over the last 15NM.

The Sourdine II procedures show 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 show 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 extended separation used.

In the baseline scenario there is 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 speed control , 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 will be spoiled with respect to the baseline scenario.

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

- An Arrival Manager (AMAN) is 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.

Table of Contents

1. Introduction

The goal of this document is, on one hand, to summarise the different results deriving from the capacity assessment carried out 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. On the other hand, this document tries to provide general conclusions about the impact on the airport capacity of the procedures designed within Sourdine II activities.

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

- 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 document is exclusively focused on the final 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 rather 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.

Four Noise Abatement Approach Procedures (NAAP)s 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 already a good noise abatement procedure when compared to standard (current) approach procedures.

The Sourdine II procedures are based on data provided by Airbus and were simulated in each airport for the situation in 2015 based on RNAV trajectories.

A brief description of the four arrival procedures considered:

- Procedure II: **Basic CDA with 2 degrees initial FPA with a 3 degree 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 (4º)**. The difference between procedure II and procedure III is the steeper flight path angle on the ILS (3ºproc. II vs. 4º 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 nº 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 have been used to validate the new set of procedures from the capacity point of view: TAAM (Total Airport and Airspace Modeller) from Preston Aviation Solution and SIMMOD (Airport and Airspace Simulation Model) from ATAC Corporation. They 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.

2. Assumptions and Hypothesis

As the main scope of the Sourdine II project is to assess the impact on capacity of inserting new procedures in the different airports analysed within the project (Madrid-Barajas, Paris Charles de Gaulle, Amsterdam Schiphol and Naples Capodichino) all the components of the system not directly related with the analysed procedures should be modelled in such a way that they should not be a bottleneck for the airport capacity. Thus, the possible loss or gain in capacity will be strictly due to the implementation of the new procedures designed within the Sourdine II project.

The main assumptions and hypothesis taken on during the capacity assessment include the following:

I. Airport modelling

The airport system has 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 requires 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. Wind and weather modelling

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

III. Aircraft equipment

All aircraft are supposed to be RNAV equipped. Simulations have been carried out under 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 more close to current practise, but in order to maintain consistency among the simulations all simulations will be carried out under P-RNAV conditions. This will result in less lateral track deviation as well.

IV. Iterations per Scenario

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

V. Parallel runways, same CDA in both arrival RWYs

The CDA approaches selected by Sourdine II have been adapted to each airport environment. The design of the procedures cannot be segregated from the control technique that they intend to use. In this aspect SII means a huge conceptual change, since the operational concept eliminates the possibility to issue 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 NTZ (Non-Transgression Zone). During the simulations, the same CDAs were inserted in both parallel runways, even though this might mean that the vertical separation is not maintained at the entrance of the NTZ. This is applied to all FTS scenarios with at least two arrival parallel runways: Madrid, Amsterdam, and Paris.

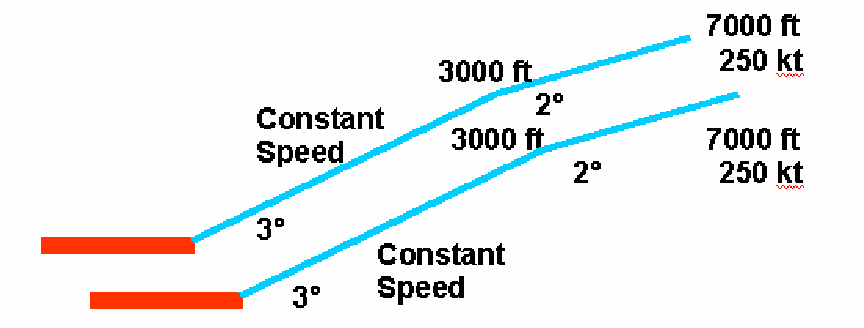


Figure 2-1: CDA Approaches for parallel runways

VI. 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 show 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 show 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 extended separation used. For those aircraft with different motorization available, the common most ones for the year 2015 were selected.

VII. Vertical profile

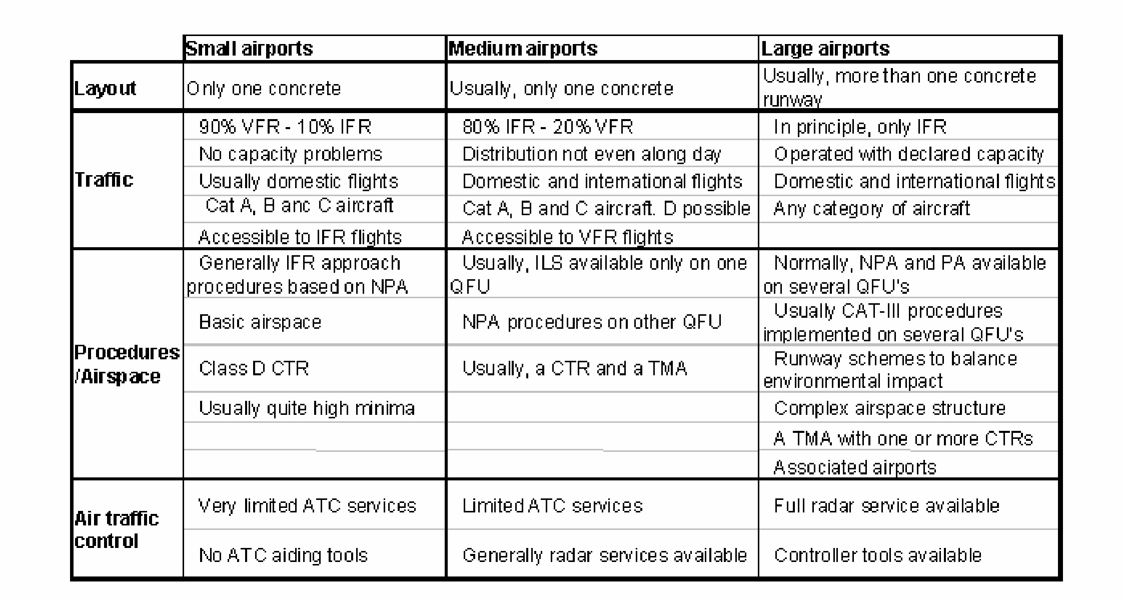
All the aircraft inside each of the previously described groups flied the same vertical profile for each single procedure.

3. Scenarios and traffic

3.1. Geographical Scope

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

These four airports selected are: Madrid-Barajas, Naples-Capodichino, Amsterdam-Schiphol and Paris-Charles de Gaulle airports. The different environment and dimensions of the selected airports demonstrate the validity of the new NAAPs for different airport types and validate the SII concept for the ECAC area. In the simulation scenarios not only the airport has been taken into account but also the TMA structure expected in 2015.Basically, a series of scenarios consisting in noise abatement procedures for arrivals have been 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 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.



	Small airports	**Medium airports**	**Large airports**
Layout	Only one concrete	Usually, only one concrete	Usually, more than one concrete runway
Traffic	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 anc C aircraft	Cat A, B and C aircraft. D possible	Any category of aircraft
	Accessible to IFR flights	Accessible to VFR flights	
Procedures /Airspace	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	Usualy 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
Air traffic control	Very limited ATC services	Limited ATC services	Full radar service available
	No ATC aiding tools	Generally radar services available	Controller tools available

Table 3-1: Airport classification

The specific airports described in Sourdine II classified into three categories: large (Paris-Charles de Gaulle), medium (Amsterdam Schiphol and Madrid Barajas) and small (Naples Capodichino). The following table contains information about each of the airports analysed in Sourdine II Project in the year 2015.

Airport	Runways	2015 Operations	Procedures
Madrid-Barajas	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
Paris-Charles de Gaulle	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
Amsterdam-Schiphol	4 runways: Inbound for ARR (18R & 18C)Outbound for DEP (18L & 24)	910 Arrivals 10% Turboprops	RNAV
Naples-Capodichino	1 runway (24-06): 100% of ARR RWY24 74% of DEP RWY24 / 26% RWY06	304 TOTAL 152 Arrivals 22% Turboprops	Conventional

Table 3-2: Sourdine II Airports configuration

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

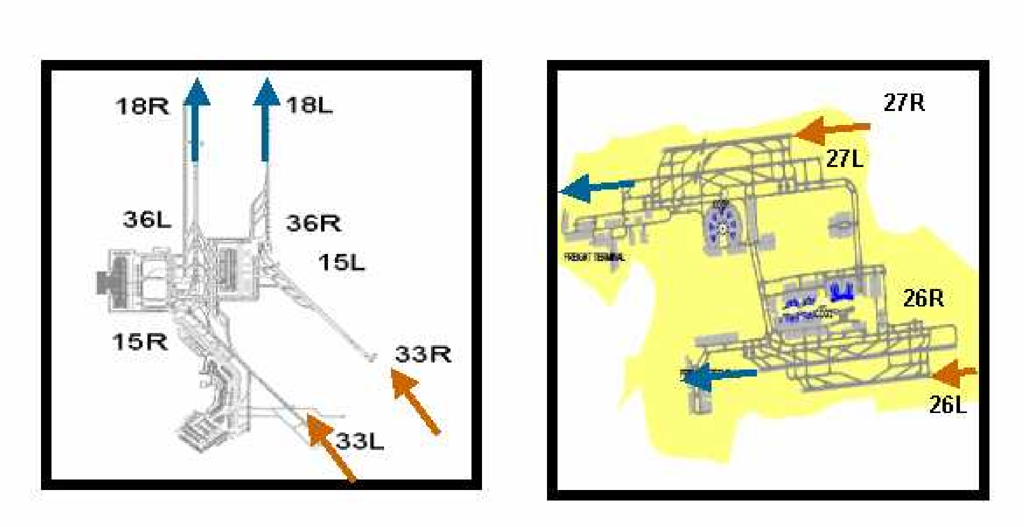


Figure 3-1: Sourdine II airport scenarios for Madrid-Barajas & Paris-CDG

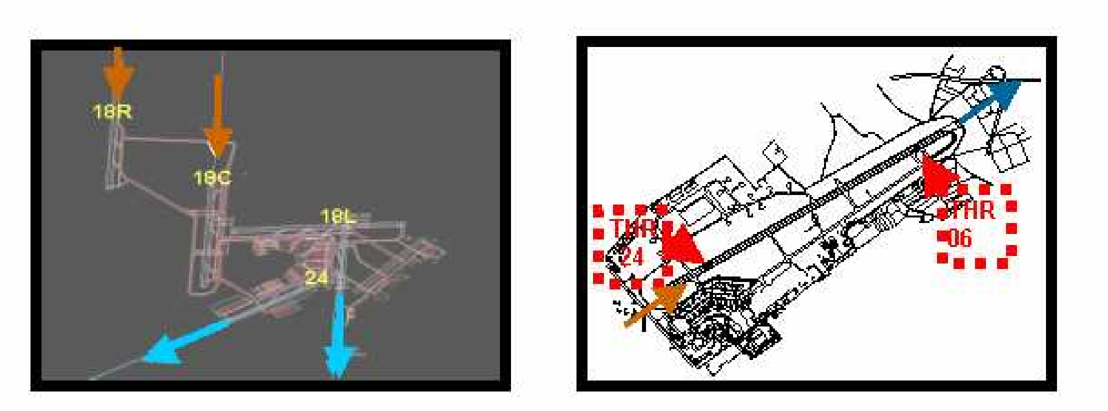


Figure 3-2: Sourdine II airport scenarios for Schiphol & Naples

3.2. Type of experiment

The capacity assessment of the new NAAPs designed within Sourdine II activities has been developed based on relative and quantitative experiments. Basically, a series of capacity metrics and indicators have been 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 provides 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.

3.2.1. Level of detail

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

3.3. Time Scope

2015 will be used as the timeframe for all the scenarios, including the baseline scenario.

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 these traffic data, a representative day was chosen, together with current airspace rules, to calibrate the simulation model to ensure that simulation results are sensible and that the model represents reality.

In order to obtain a realistic traffic sample, a set of criteria has been established to exclude days from the analysed period that will 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 depends on the airport traffic pattern and on the kind of traffic involved in each TMA. Table 3-3 shows some of the points to consider when selecting the reference day.

Airport Regular Traffic	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 3-3 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 have been taken into account to obtain the final traffic samples. High prediction STATFOR forecasts from EUROCONTROL have 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.

4. Metrics and Methodology

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.

4.1. Methodology to assess Airport Capacity

In the following points, the methodology agreed by the consortium for assessing the capacity impact of inserting the new procedures designed within Sourdine II project for each FTS site is briefly explained. For further details, refer to appendix 1.

- 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

5. Simulation Results

A brief summary of results obtained during the capacity assessment will be 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, results will be focused exclusively on arrivals.

The issues that will be described are:

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

These metrics and indicators have been obtained for Sourdine II scenarios and compared against those obtained from the baseline scenario described above. Not all the sites analysed the whole set of arrival procedures designed within Sourdine II activities and, consequently, results for certain procedures are not available[1].

Some of the graphs included in the following section are intended to be an example of the type of simulation 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 were the whole set of results for each airport are contained.

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 are mentioned (max / ave). 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 5-1 Maximum/ Average Arrival Throughput

The first conclusion that can be obtained is that, although during peak periods the Sourdine II scenarios seem to have problems accommodating the same traffic demand as in the baseline scenario, these problems are solved in the following hours without causing a large amount of average

---

[1] Amsterdam-Schiphol has also considered a variant of procedure II, called Procedure II-A that consists, basically, of Procedure II with some speed constraints in order to make more homogeneous the speed profiles of the different aircraft types expected in 2015.

delay (see Figure 5-1). Procedure IV seems to have a more negative effect on airport arrival throughput than the rest of procedures.

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

As an example, Figure 5-1 shows the inbound movements and the arrival delay for Amsterdam-Schiphol airport. The period was distributed by one hour. Within this chart it is important to compare results with the baseline scenario. The baseline movements can be considered as the “planned” movements, during comparison.

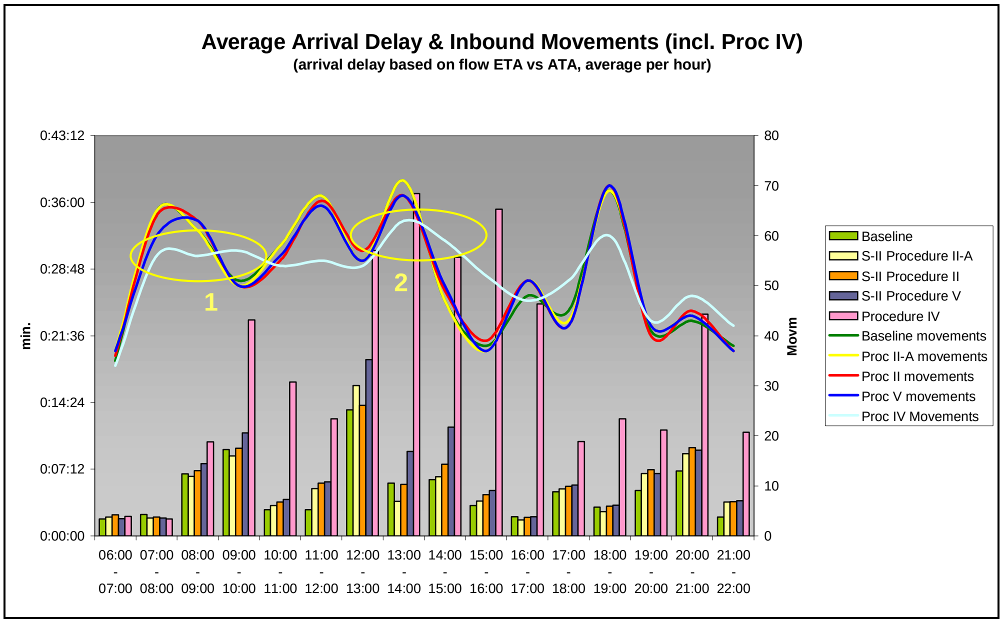


Figure 5-1 Inbound movements and arrival delay (Schiphol)

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

In the Baseline scenario, there is a homogeneous distribution of speed profiles between the different aircraft models. Controllers apply 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 aircraft on final. Controller actions to provide and optimise separation between aircraft from the TMA entry to the RWY include:

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

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

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

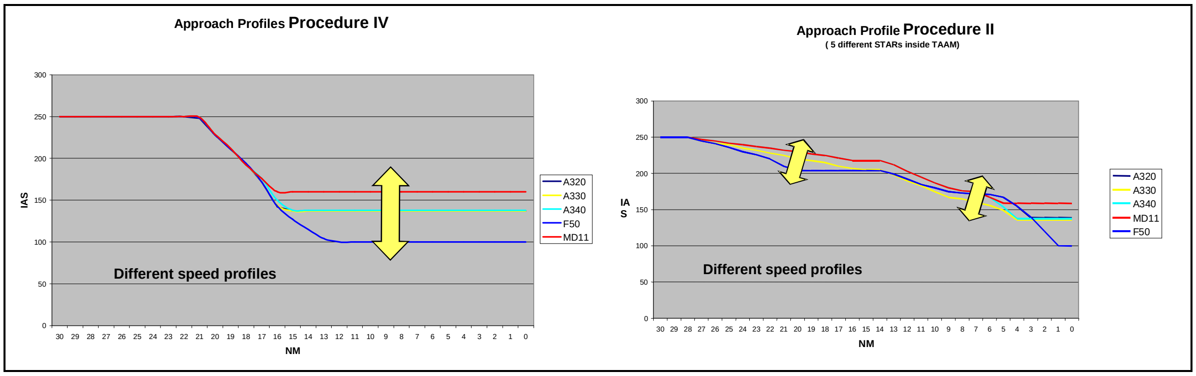


Figure 5-2 Different speed profiles Procedure IV vs. Procedure II.

In the Sourdine II scenarios, the controller actions to provide separation between the TMA entry and the beginning of the CDA are the same as in the Baseline scenario. But once the aircraft have begun to fly the CDA to the runway, they cannot apply speed control, holding or vectoring. That means that if the separation based on wake turbulence must be secured, the separation between different aircraft at different stages on the approach will be spoiled with respect to the baseline scenario.

Figure 5-3, 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 is beginning the CDA, the F50 must be separated at least 5 NM due to safe wake turbulence separation. Since during the CDA the speed profile is fixed, the initial separation grows along the time and at the end instead of 5 NM there is 7.45 NM.

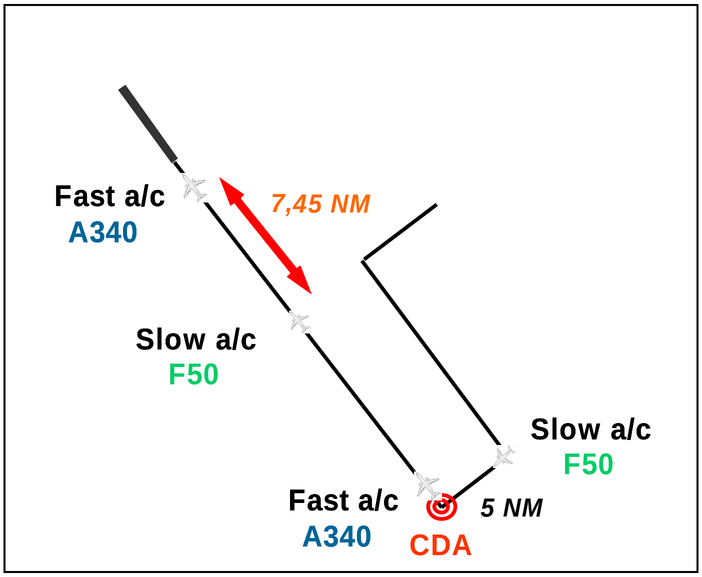


Figure 5-3 Slow aircraft trailing a fast aircraft

Figure 5-4, below, shows a faster aircraft (for example a A340) trailing a slower aircraft (for example a F50) flying the same procedure than in Figure 5-2. On the runway threshold they should maintain at least 3 NM. That means that the separation between aircraft at the beginning of the CDA should be increased to avoid overtaking or violation of separation during the approach.

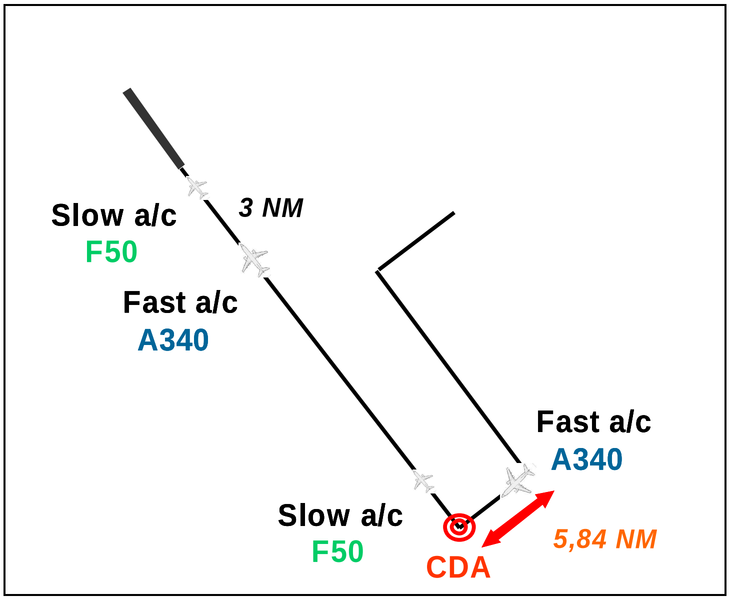


Figure 5-4 Fast aircraft trailing a slow aircraft

5.2. Cumulative & Average Arrival Delay

The Average Arrival Delay provides 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 provides, hour per hour, delay cumulated until that moment of the day. Both metrics have been calculated for the NAAPs designed in 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 5-2 Average Arrival Delay

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

As explained in the previous section, this happens because the new NAAPs require an increase in the separation distance between successive arrival aircraft respect to the same situation in the Baseline scenario since safe separation distances (i.e. wake turbulence criteria) must 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 is needed.

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

The rest of NAAPs provide bigger delays than the Baseline scenario, but not so significant as the Procedure IV

The amount of arrival delay is also caused by the fleet mix. The fleet mix determines 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 is required due to the speed differences. Therefore, It should be clear that changes with respect to the fleet mix will also have implications to the results. It is therefore worth mentioning that results should 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 chapter 2 of this document, and more deeply, inside the individual report simulation for each airport (Madrid-Barajas, Amsterdam-Schiphol, Naples-Capodichino and Paris-Charles de Gaulle).

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

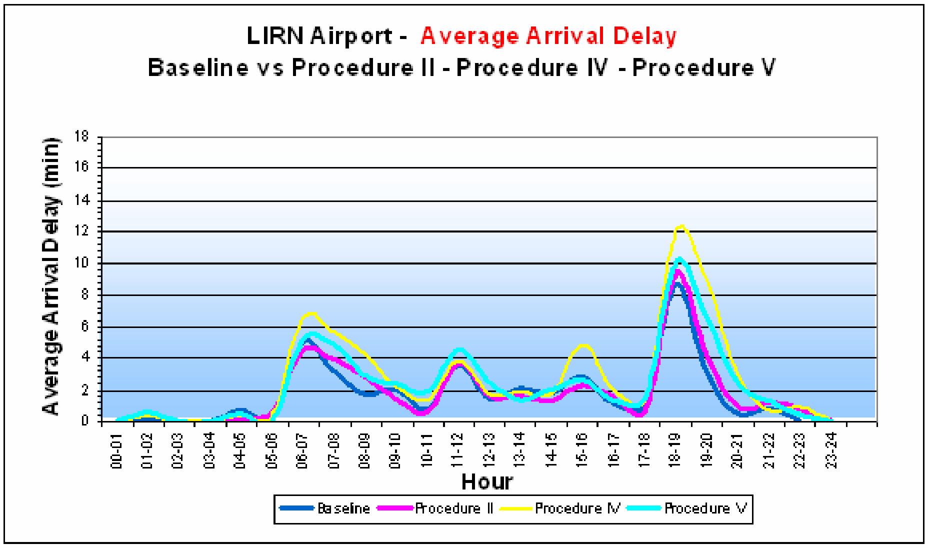


Figure 5-5 Average Arrival Delay (Naples)

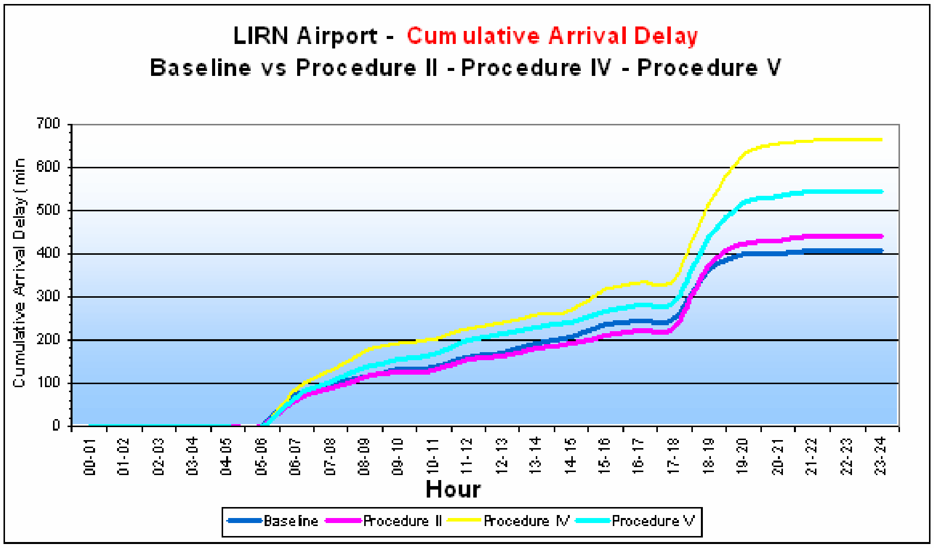


Figure 5-6 Cumulative Arrival Delay (Naples)

The figures 5-5 and 5-6 confirm a negative effect of NAAPs on arrival delay, in particular the procedure IV that generates the worst cumulative and average delay of all the set.

5.3. Average Arrival Capacity

The obtained capacity figures are based on the methodology for capacity calculation, agreed within the consortium (see Appendix 1). The capacity calculation stated by Sourdine-II provides 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 will be based on 10±1 minutes. In order to have 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 1.

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 5-4 Arrival Capacity

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

The figure 5-7 shows the way these capacity figures were obtained, e.g. Madrid-Barajas.

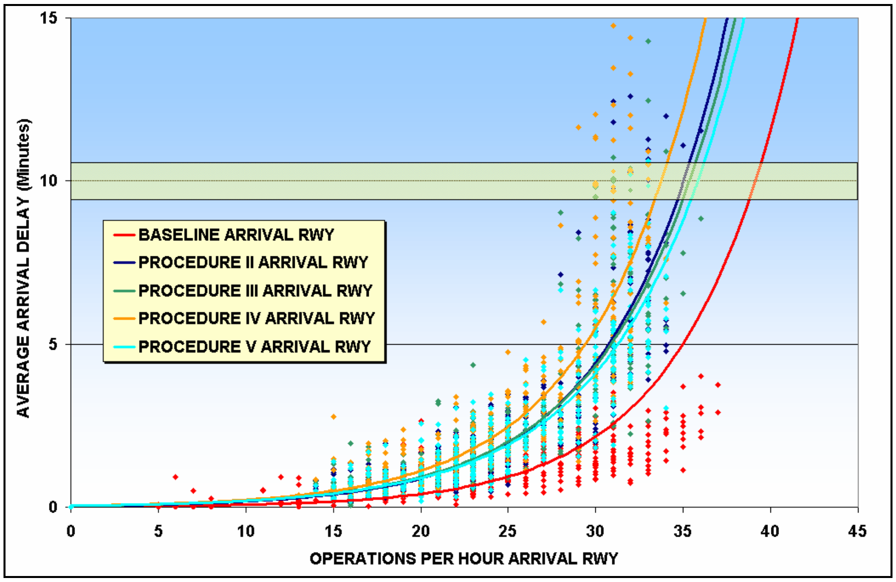


Figure 5-7 Arrival capacity (Madrid-Barajas)

5.4. Number of arrivals delayed 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 are not available since the simulation tool used in that case (SIMMOD) does 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 5-3 Average Arrival Delay

The histogram showed in Figure 5-8 provides the percentage of arrival operations delayed within 1 minute periods for all the NAAPs considered and the Baseline scenario, e.g. Madrid-Barajas airport.

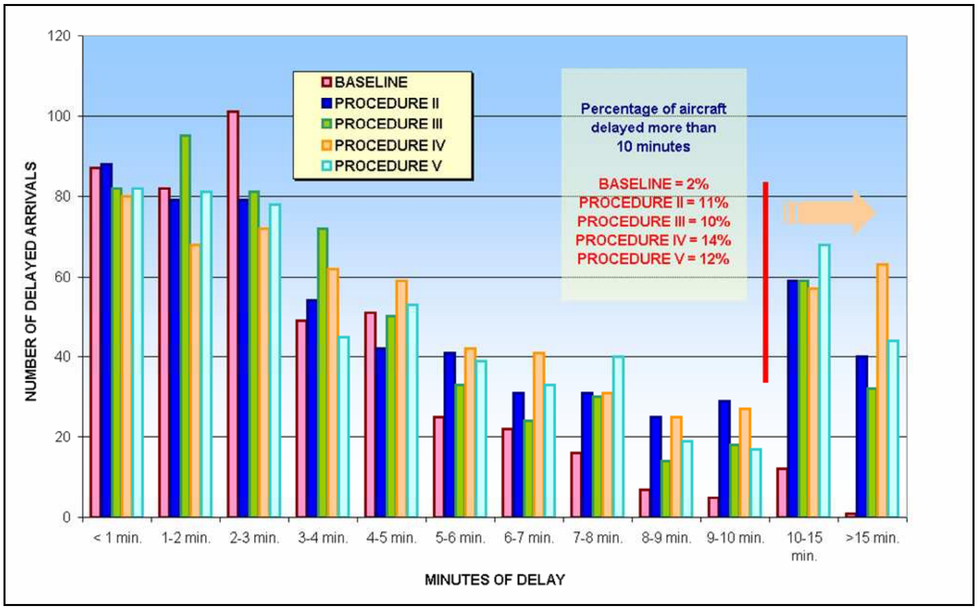


Figure 5-8 Number of delayed arrivals (Madrid-Barajas)

In the baseline scenario, most aircraft are affected by an arrival delay between 0-5 minutes. The more the delay distribution is build up, the less the number of affected aircraft. However, for Sourdine II procedures, especially in procedure IV case, the percentage of delayed aircraft seems to increase as the delay distribution increases. All Sourdine II procedures require an additional separation between successive aircraft since once the aircraft begins the CDA speed control should not be applied to tune the in trail separations. That means that if the minimum separation can not be fulfilled, by means of speed control before the beginning of the CDA or applying RNAV diversion, controllers only can send the aircraft on a holding. So, the number of holdings increases and a holding means usually an extra delay per aircraft.

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.

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.

6.2. 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[2].

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).

---

[2] It should be emphasized that the increased flying time in SII procedures is not part of the calculated delay.

6.3. 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.

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.

6.4. 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 (aircraft FMS system).

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. More details on this can be found in de real time simulation results document, SII deliverable D6-3.

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.

Appendix 1 Methodology for Capacity Calculation

A1.1 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.

A1.2 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.

A1.3 Definitions and assumptions

A1.3.1Definitions 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.

A1.4 Methodology for capacity assessment

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

A1.4.1 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 approach 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.

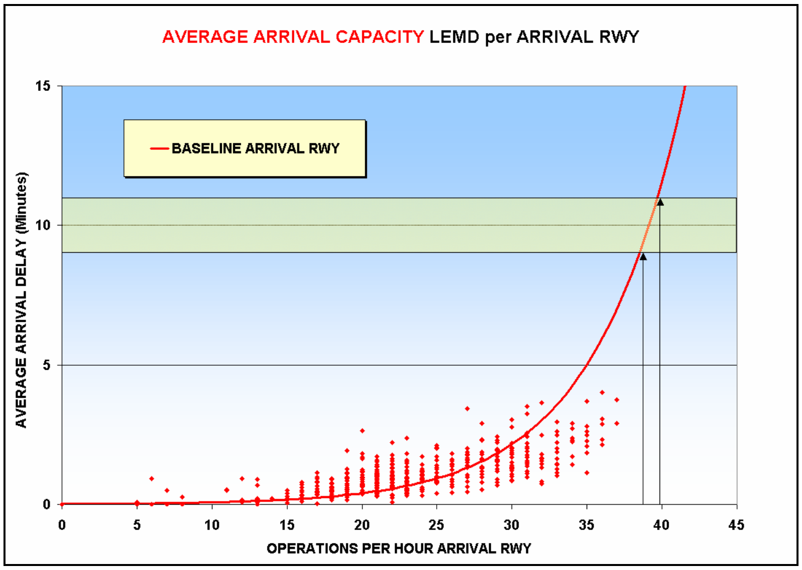


Figure A1-1 Establish the maximum tolerable delay value per hour. Baseline scenario. Madrid-Barajas airport 2015.

A1.4.2 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.

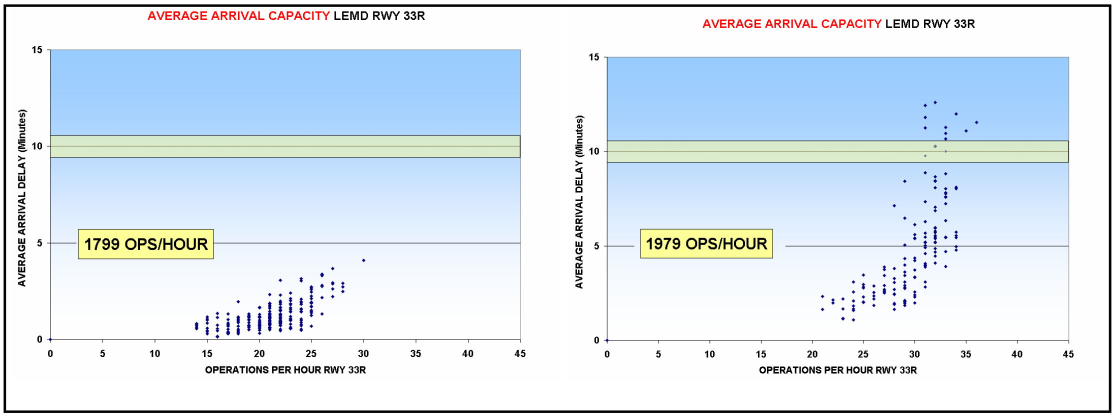


Figure A1-2 Increase of the traffic sample expected (2015).

A1.4.3 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.

A1.4.4 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 result consist of a cloud of points that follows approximately certain pattern.

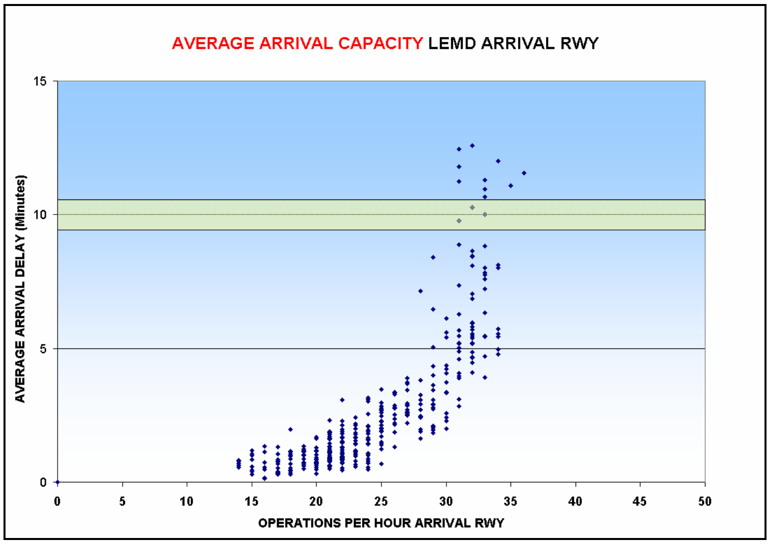


Figure A1-3 Cloud of points average hour delay vs. number of movements.

A1.4.5 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 approach 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%.

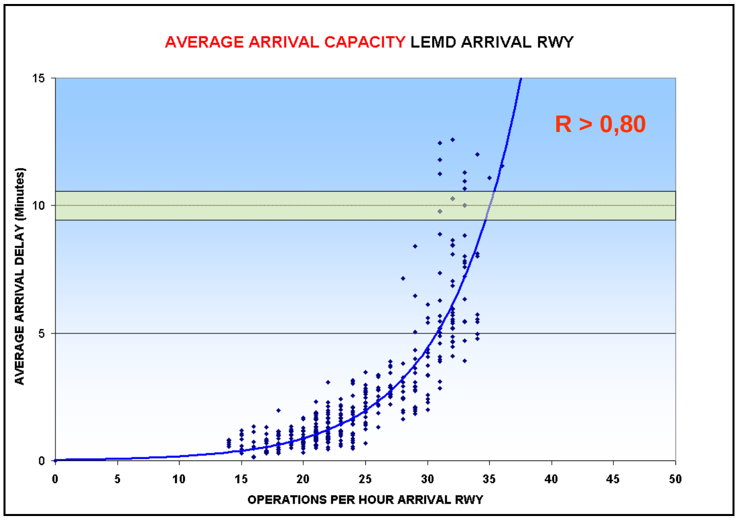


Figure A1-4 Selection of the best tendency curve.

A1.4.6 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±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.

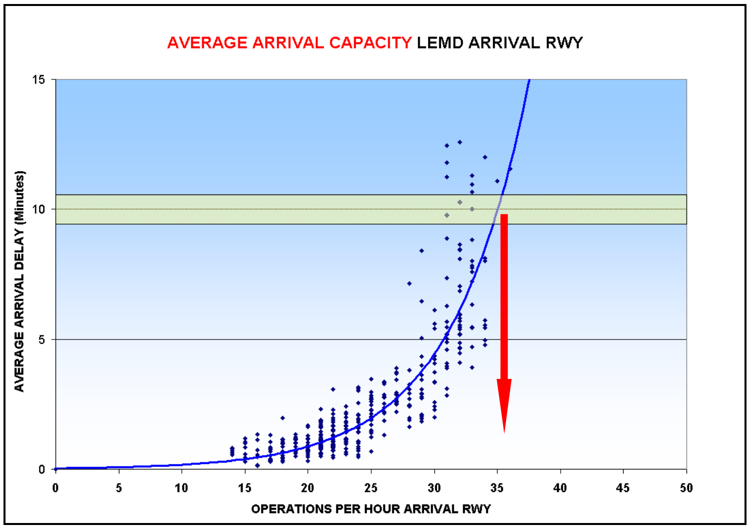


Figure A1-5 Capacity assessment.