



EUROPEAN COMMUNITY
COMPETITIVE AND SUSTAINABLE
GROWTH PROGRAMME



SOURDINE II

D4-1-4a

Paris CDG Capacity Results

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	EEC Cristiana Cafiero Massimo Conte	All, Creation	Confidential	23/05/03
1.0	EEC	All	Confidential	30/06/06
2.0	EEC	EC approved version	Public	03/07/06

Document Distribution

Partner	Distribution list
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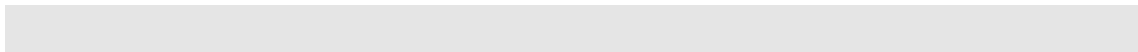
Review and Approval of the Document

Organisation Responsible for Review	Reference of comment documents	Date
SICTA	E-mail	01/08/05
Organisation Responsible for Approval	Name of person approving the document	Date
Project Manager	Ruud den Boer	30/06/06
Work Package Leader	Pablo Sánchez-Escalonia	30/06/06
EC Official	Morten Jensen	03/07/06

Document Information	
Document title	D4-1-4a Paris CDG Capacity Results
Version	V2
Date	03-07-2006
Classification	Public
Work package	WP4
Document identification	SII_D4-1-4a_Paris-CDG_V2

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Summary

This document describes the results obtained from an Fast-time Simulation (FTS) assessment of the effect of three of the four Sourdine II arrival procedures on capacity at Paris Charles-de-Gaulle (CDG) airport – LFPG - for the year 2015. The Sourdine II departure procedures are considered to not have any particular impact on capacity compared with standard departure procedures and were not, therefore, the subject of FTSES.

The main FTS study was preceded by a calibration study whose objective was to allow a comparison between the results of the simulator and real life. Only through such a method can we be sure that the results of the simulation for future capacity will correctly predict what will be the true situation at the time and with the data simulated.

This calibration simulation was, itself, preceded by a “pre-calibration” study whose role was twofold: to ensure that the fast-time simulator used, TAAM, was capable of correctly simulating the Sourdine II procedures and to compare the methods undertaken by three of the four study organisations, SICTA, AENA and EEC, in order to ensure that these were well co-ordinated. The pre-calibration study was conducted by all four organisations on a Naples scenario.

Traffic at CDG was simulated using three of the four Sourdine II Noise Abatement Approach Procedures (NAAPs) and compared with the same traffic over a conventional 3000ft arrival procedure, the “baseline” scenario, NAAP I.

The four Sourdine II arrival procedures may be summarised as follows:

- Procedure II: a 2 degree continuous descent approach followed by a 3 degree ILS path. A variable speed profile is used.
- Procedure III: a 2 degree continuous descent approach with a 4 degree ILS path. Again, a variable speed profile is used.
- Procedure IV: a steep two-segment approach using a constant speed profile. This procedure was not simulated in the CDG study.
- Procedure V: a 3 degree glide path again using a constant speed profile.

The traffic used was an extrapolation to 2015 densities using current STATFOR estimations of traffic growth (around 5% per annum) and involved some 1108 landings per day. These predictions assume that of this traffic, 38% will be of Airbus aircraft, 35% of Boeing aircraft and the rest from other manufacturers. This traffic was segmented into seven groups based on Final Approach Speed (FAS) and wake turbulence properties. These groups were each represented by a single aircraft type: A319, A320, A321, A330, A340, F50 and MD11. The performance of aircraft over the Sourdine II procedures was based on data provided by Airbus. Characteristics of the F50 and MD11 were produced by modifying data for A320 and A340 respectively.

CDG has two pairs of runways – 26L, 26R and 27L, 27R. The inner runways, 26R and 27L and used for take-offs and the two outer ones, 26L and 27R, for landing. A major alteration between today’s traffic at CDG and that of 2015 is due to the introduction of the fourth runway, 27R, in 2001. In the 2001 traffic sample used as the basis for this study, this new runway is hardly used. In 2015 it is assumed that about half of landings will take place on this runway: arrivals from the south using 26L and arrivals from the north, 27R. Because of the geographic origin of runway use, demand is different on the two runways and so they were analysed separately in this study, in addition to the global airport analysis.

The simulations showed that all aircraft are speed constrained during the Sourdine II approach procedures. Procedure II involves the smallest number of holdings and speed change instructions. Procedure V is the worst for both of these.

The Sourdine II procedures show very little difference in cumulative delay on runway 26L with NAAP II producing the highest capacity at 41-42 movements per hour. On runway 27R, average delay on the Sourdine II procedures is around half a minute greater than on the baseline, procedure II showing the least increase in delay. Procedure V, on the other hand, produces the best capacity.

In general terms for the whole airport, procedure II is responsible for the highest peak delay, the lowest cumulative delay and average delay, and the highest peak throughput and the highest overall capacity. (The baseline is always better than the Sourdine II procedures – this is expected.) Procedure II is also responsible for the highest individual delayed aircraft – over 21 minutes.

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1. Introduction

1.1. Purpose

The purpose of this document is to present the main results of the capacity assessment of Paris Charles-de-Gaulle (CDG) airport – LFPG – supposing the implementation of three Noise Abatement Approach Procedures (NAAPs) in 2015.

1.2. Background

Noise is now the major cause of public complaint about airports and the greatest constraint to the growth of airports and, therefore, the airline industry as a whole. The International Civil Aviation Organisation (ICAO) has developed a four-point “balanced approach” to combatting the problem of aircraft noise:

- Reduction at Source;
- Land-use planning;
- Operating Procedures;
- Operational restrictions. (These should be implemented as a last resort.)

As a response to the third of these points, the Sourdine II project has proposed six highly innovative Noise Abatement Procedures (NAPs), two for departure and four for approach.

It is an objective of the Sourdine II project to evaluate these procedures not only for their effect on noise, but to ensure that they are also viable in terms of their effect on efficiency, emissions and capacity. The present document presents the Fast-Time Simulation (FTS) studies performed to analyse the effect of these procedures on capacity at CDG.

1.3. Structure

Chapter 2 of this document presents an overview of the study, including a description of the airport, the traffic sample and the tools and methods used. The study involved three separate simulations. The pre-calibration exercise performed to ensure compatible working over the four Sourdine II partners performing such studies is described in Chapter 3 and the calibration exercise, where today's traffic was simulated and compared with real-life data to ensure faithful reproduction is presented in Chapter 4. Chapter 5 covers the main study simulation and the results and conclusions are given in Chapter 6.



2. Overview of the study

2.1. Objective

The objective of the fast-time simulation phase of the Sourdine II project is to assess the capacity and environmental impact (noise and emissions) of a series of new noise abatement arrival and departure procedures. It will also provide figures for a cost-benefit analysis.

2.2. Scope

The study presented in this document is a series of fast-time simulations of noise abatement procedures for arrivals to be compared to a baseline scenario using current procedures.

2.2.1. Location and Geographical extent

Paris CDG is located some 23km north-east of Paris on the outskirts of the suburbs.

Paris Charles-de-Gaulle (CDG) has been designed following the model of the airport in Dallas, USA. CDG is made of two pairs of runways. They are all east-west oriented.

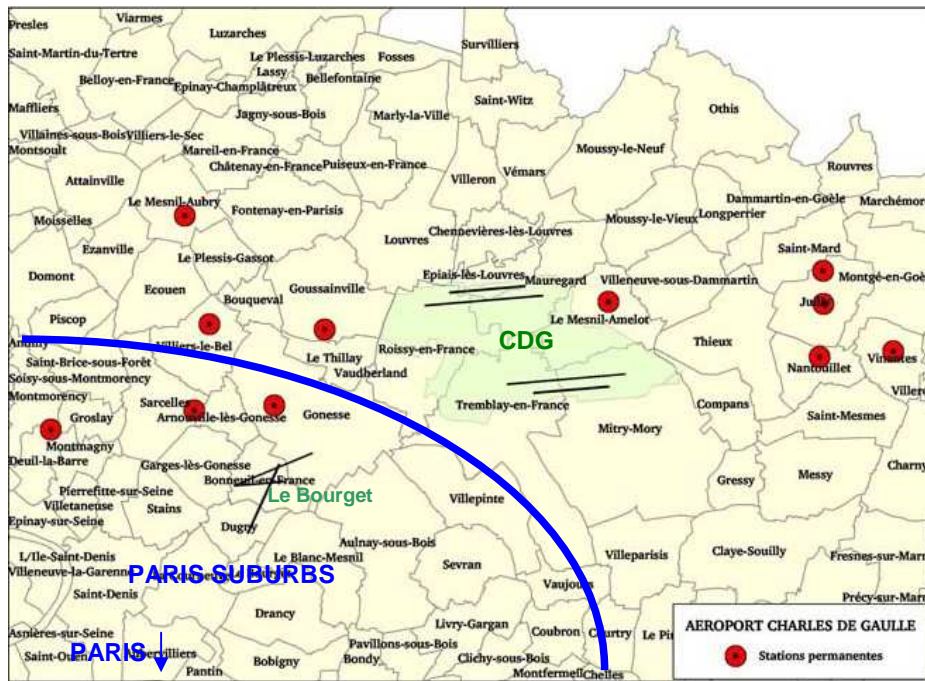


Figure 1 CDG position

(The red dots on this map show the position of noise monitors.) The present airport structure, with the two pairs of parallel runways, is the definitive airport configuration for the next years, in particular for the period considered in Sourdine II (2015). This means that a real comparison can be made between the current and the future situation, the first with the use of the existing procedures, and the second with the employment of the new noise abatement procedures. There are four entry points: N-W; N-E; S-E and S-W. The whole traffic is divided into the north and the south runways. Each southern

corridor is separated into two sub-corridors, one for jet aircraft and another for propeller-driven aircraft plus traffic directed to Le Bourget.

There are two possible airport configurations, east and west. The global statistic for the airport configuration selection for 2001 is the following:

	West	East
I trimestre	67%	33%
II trimestre	65%	35%
III trimestre	72%	28%
IIII trimestre	56%	44%

There are two main terminals:

- Terminal 2, dedicated to the Air France hub and its partners
- Terminal 1 handles most other airlines

The two sets of parallel runways, the “southern” pair and the “northern” pair, are independent in the sense that their usage is symmetric. In both cases, for security reasons, the internal runway is reserved for departures and the external for arrivals.

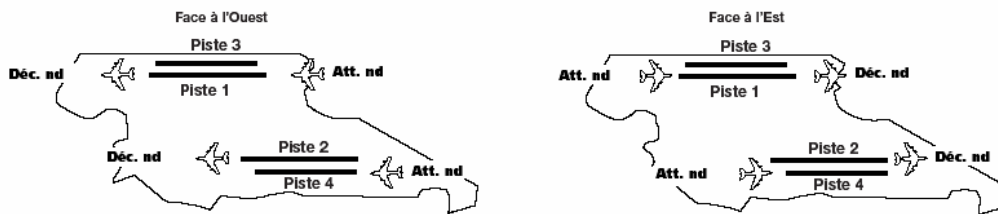


Figure 2 CDG West & East configuration

When one aircraft lands, if there are no departing aircraft, it can cross the take-off runway to reach its gate; otherwise it has to wait before crossing the departure runway until the other aircraft takes off. In any case interactions can take place only between steady aircraft, reducing the probability of accidents.

When runway exits are full, departing flights wait and let the arrival flights crossing the take-off runway. The difficulty effected by this management is that it is not easy to estimate the taxing duration for both arrival and departures.

For arrivals it is hard to know how much time they will have to wait before crossing the take-off runway. For departures, it can happen that queuing aircraft had reached the maximum number (8) and that the ready to take-off aircraft has to wait until the arrived aircraft cross the runway.

Since the two pairs of runways are symmetric only the description of the southern-pair runway management is given.

If the weather is fine, the two runways are completely independent; one is used for arrivals and one for departures. However, if visibility is reduced to less than 1NM the two runways are not independent in the sense that the departure is linked to the arrival. The departing aircraft can start to roll when the arrival aircraft is at 2NM from the runway threshold. This security measure is taken to deal with the possibility that the aircraft has to carry out a missed approach. Following this procedure there will be a distance of at least 3 NM between the two aircraft.

The worse case concerns the situation in which there are problems of perturbation of the ILS signal. This is called Low Visibility Procedure (LOP) and it prescribes that the departing aircraft starts its roll phase when the arrival aircraft is at 4NM from the runway threshold.

The outer runway, used for arrivals, has been displaced toward east because people living in the west side of the airport were complaining for the noise caused by the low altitude of the aircraft. As a consequence the inner runway has been extended to avoid turbulence interactions between aircraft in the two runways.

TMA Structure

Inside the Paris TMA, in addition to CDG, there are:

- Le Bourget airport, which is specialised in general aviation and taxi flights
- Orly airport, which is the other large commercial airport in the south of the city
- Villacoublay.
- Toussus le Noble.

These last two are military airports. An agreement was found and accepted by civil and military airports that allows to the civil part the use of the whole airspace apart from the circumstances in which there is a request from the military session. There is a letter of agreement signed by civil and military airports that specifies the method to be followed in certain conditions.

Normally the airspace is available for civil aircraft and they can use all the corridors designed to follow the trajectory. If there is a need for the militaries to use the airspace for a certain period of time, they call the controllers who have to clear the requested airspace until the militaries need to use it.

Normally the request is not frequent, so that civil airport can use the entire airspace during the year.

ATS and ATC

Three different centres control air traffic in the Paris area:

- The Paris ATCC in charge of flights between the TMA and the cruise phase
- The Paris CDG Approach control centre, in charge of the northern part of Paris TMA that deals with approaches for CDG and Le Bourget
- The Orly approach control centre, in charge of the southern part of Paris TMA, that deals with approaches for Orly, Toussus and Villacoublay airports.

On Paris CDG airport one approach room and two control towers, north and south, share responsibility for the area. A third tower is under construction.

Special Procedures

Simultaneous parallel approach operations may be in force and apply to runways 09R & 09L, 08R & 08L or to runways 27R & 27L, 26L & 26R and Le Bourget, runway 27. Pilots will be advised that these procedures are in force through the ATIS.

In the event of a missed approach, non standard missed approach instructions may be issued to turn at or above 800 and climb to 1500 initially. From 800 onwards, compliance to clearances will be radar monitored.

Reduced radar separation on final approach

In order to optimise capacity arrival rates, radar separation spacing of 2.5 nm has been introduced under particular conditions.

Pre-departure procedures

High performance departures

Aircraft capable of maintaining a rate of climb of 10% until FL150 may benefit from shorter departure routes. De Gaulle Departure will provide radar vectors.

Simultaneous parallel departures are conducted from runways 27R & 27L, 26R & 26L or from runways 09R & 09L, 08R & 08L. Aircraft must adhere strictly to the published initial climb segments.

Runway use

Outer runways (08R/26L & 09L/27R) preferential use for arrivals.

Inner runways (08L/26R & 09R/27L) preferential use for departures.

Specific measures for the use of the close parallel runways:

The inner runway ILS is "off" most of the time.

The inner runway approach lighting system and touchdown zone is switched off.

Crew co-operation.

The final TMA reorganisation has been terminated in 2002 and not many changes are foreseen for the next years. The current Paris CDG structure in terms of both airspace and airport configuration, is considered definitive.

2.2.2. Timeframe

2015 for all the scenarios including baseline.

2001 scenario for calibration purposes

2.2.3. Traffic sample

Paris CDG is the largest airport in France and the first in Europe for aircraft movements. It is the number six in the world behind US Airports.

In 2001 it had 71 million passengers and 731 000 aircraft operations. In 2002 there was a reorganisation of the airport. All the corridors have been reviewed and reorganized.

In Paris CDG the level of traffic is high not only during the day but also during the night. During the night there are flights of the carrier companies (Fed-ex) coming from everywhere in the world, those contribute to increase the level of noise around the airport even during the night.

CDG Annual Traffic (2001)	
Approach	592 000 movements
Airport	525 000 movements
Satellites & Transits	67 000 movements

Maximum Traffic Capacity Levels			
	Daily	Hourly	Per 15 min
Approach	2 045	162	41/42
CDG Airport	1 689	125	34
South Pair Runways		82	22

Traffic distribution among runways					
	North	East	South	EVX	LGL
Prop	27L	26R	26R	27L	26R
Jet	27L	26R	26R	27L	26R
Other	27L	27L	27L	27L	27L

2.2.4. Traffic Mix

Aircraft types included in the prognosis for 2015

A306	A30B	A310	A319	A320
A321	A343	A343	A346	AT72
B462	B733	B734	B735	B736
B737	B738	B742	B744	B752
B762	B763	B767	C525	CN35
CRJ1	CRJ2	CVLT	DC10	DH8C
E120	E145	EA32	F100	F27
F50	F70	G159	J328	MD82
MD83	MD87	MD88	MD90	RJ85
SB20	SH36	SW3	SW4	T154

Summary of aircraft types grouping similar aircraft:

Some of the previous types representing a low percentage of movements have been embedded into other similar types. The number of movements and percentage are gathered in the following table:

Aircraft type	Number	Percentage
A300	13	1,17
A310	13	1,17
A320	532	48,01
A340	56	5,05
B737	282	25,45
B757	15	1,35
B767	28	2,53
B747	28	2,53
MD80	47	4,24
MD11	5	0,45
F50	165	9,17
CRJ	52	9,51
TOTAL	1108	100

2.3. Outline of the study

The Sourdine II FT simulation activities are divided into three main phases:

- Pre-calibration phase
 - The Pre-calibration phase has been developed by three WP4 partners (Naples-SICTA, Madrid-AENA and Paris-EEC) testing in one single airport (Naples Capodichino) in one single configuration a single event.
- Calibration phase
 - One scenario of the current Paris CDG airport layout: two pairs of parallel runways 26L & 27R (arrivals) and 26R & 27L (departures), operating in West Configuration and current Paris TMA structure and operational concept (radar vectoring to sequence arrivals, holding stacks, speed constraints, etc) . The calibration scenario includes a detailed definition of current SIDs and STARs.
- Baseline vs. Sourdine II simulation phase
 - One Baseline scenario with the future configuration of Paris-CDG airport foreseen for the year 2015 with the current/conventional procedures.
 - Four different scenarios: one for each of the Arrival Noise Abatement Procedures designed within Sourdine II Project (Procedures II, III, IV and V).

2.4. Tools and Methods

2.4.1. Simulation tools

At EEC TAAM (Total Airport and Airspace Modeller) from Preston Aviation Solution has been used as the fast time simulator for the different phases of the Sourdine II project.

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.

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 randomized to reflect the spread of such characteristics in real-life operations.

2.4.2. Hypothesis

The following lines describe the main hypothesis assumed before running the simulations:

- Weather effects or variations are not considered in the Sourdine II FT Simulations.
- Runway usage combination for Paris CDG airport:
 - Calibration scenario (2001): RWY 26L & 27R for Arrivals, RWY 26R & 27L for Departures
 - Baseline and Sourdine II scenarios (2015): RWY 26L & 27R for Arrivals, RWY 26R & 27L for Departures
- Traffic will be simulated for one average day.

The schedule is based on an average day in 2015, for FTS only one day for simulation is used in practice and provides a good representation of operational effects.

- Arrival and departure segregation based on origin/destination of each flight.
 - For safety reasons, crossing SIDs are not allowed. Departing aircraft will be separated by using one runway for northbound and one for southbound traffic.
- No ground movements
 - Simulated aircraft will be “terminated” at the end of the runway, departing aircraft will appear on runway entry. No taxiways, no gates considered.
- All aircraft are supposed to be RNAV equipped, Simulations will be carried out under P-RNAV circumstances. No airport taxiways are included, hence their influence is not simulated.
- Aircraft configuration

TAAM does not consider either thrust or configuration setting. It is necessary to translate the procedures into parameters understandable by TAAM (rate of climb and descent, climb speed etc, specified in Level Bands). After some pre-processing, aircraft configuration, such as flap setting and gear has been taken into account within the TAAM performance file. The performance data used inside TAAM is quite detailed and encompasses the essential performance characteristics of aircraft such as speed changes, rate of climb, rate of descent, turning rates, max take off factors, and fuel burn data.

2.4.3. Simulation and analysis methods

The following assumptions have been taken into consideration within the simulation. Each assumption will be described in more detail within the following section:

- Conflict resolution off (TAAM specific)

Simulated scenarios will be modelled with conflict detection on, and resolution off.

- Introduction of procedures

In order to create appropriate and reliable noise abatement approach procedures, the following tasks had to be performed within TAAM:

- Creation of new waypoint (WPT) file.
- Creation of new STARs with all altitude and speed restrictions involved for each aircraft type considered in the simulations:
 - This process was necessary for each of the RNAV diversions considered in the future design of Paris TMA.
- Manual editing of aircraft performance data (w.r.t. rate of descent and decent speeds): each aircraft should comply with both the vertical and speed profile of each procedure.

It should be noted that additional workaround was made in order to carry out a steep glide path approach of 4 degrees.

- Randomization

The randomization capabilities of TAAM are limited as.

The waypoints that define routes and STARs are exact latitude & longitude points. There are no probability areas defined around waypoints. This means that when an aircraft has a waypoint in its flight plan or assigned STAR, it flies exactly over it. As a consequence, straight segments are flown by the aircraft independent of the NAVAID that supports the waypoint or the characteristics of the aircraft

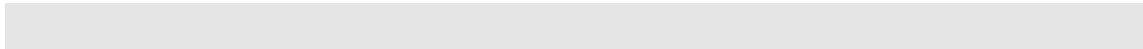
flying the segment. Hence, all runs produce the same horizontal track. In addition, increased rigidity in the definition of speeds and rates of climb reduces vertical randomization.

- Number of runs

Since TAAM is a stochastic model, it uses several random variables to reproduce the effects of random variations in airport and airspace system phenomena. In order to achieve a statistical confidence limit of 95%, 10 iterations (using different random seeds on each of them) have been run for all simulations.

- Traffic samples

Most of the indicators obtained with FTS such as arrival and departure delay, airport throughput, etc. correspond to the simulation output obtained running the scenarios with the traffic sample foreseen for the year 2015 (1108 landing per day).



3. Pre-calibration

3.1. Background

To achieve the objectives of the pre-calibration exercise it was agreed to choose the same simple scenario and the same airport for all fast-time simulation partners, in order to be able to compare the results and to reach the necessary co-ordination between the different sites.

The airport of Naples has been selected since there is only one runway. It was agreed to consider one airport configuration (06), no taxiways and no wind. One STAR is associated to the chosen runway configuration and it is described below.

The horizontal profile of the STAR has been used to represent both the current procedure flown at Naples and the new Airbus procedures. Concerning the vertical profile, for the current procedure the existing profile has been represented, while for the new procedures, profiles provided by Airbus have been inserted.

Concerning the selection of the new noise abatement procedures to be used in the pre-calibration exercise, Airbus provided the simulation partners with a list of procedures to be simulated, each of them with the relative description. All delivered procedures have been designed for A320 or A340 using their performance data and for this reason in the pre-calibration exercise only these two aircraft types have been considered.

The new noise abatement procedures are defined in terms of altitude, speed, configuration setting and thrust. In TAAM configuration and thrust are not taken into account and for this reason a pre-processing was needed to translate parameters defined by Airbus in data usable by TAAM.

In order to consider parameters like configuration setting and thrust attention was focused on the effects of these parameters on speed. For each configuration change there is a variation in speed and this modification has been taken into account adding points with different speed values along the aircraft trajectory. The added points reflect the effects of the variation of configuration and/or thrust on the aircraft performances.

One of the mentioned focuses of the pre-calibration exercise is the analysis of both simulators in order to find out possible limits in the accuracy of the new noise abatement procedures representation. To reach this objective a comparison was pursued between Airbus and TAAM procedures vertical profile and speed profile.

3.2. Objectives

The main objectives of the Pre-calibration phase are the following:

1. Solve the uncertainty about the suitability of the selected FTS platform.
2. Find out whether the simulation platforms selected – TAAM Enhance INM on the one hand and SIMMOD INM on the other hand- are able to simulate, accurately enough, the new procedures designed in Sourdine II considering new concepts as Advance CDA, etc providing accurate and reliable results. The Pre-calibration phase has tried to answer these questions:
 - Is it possible to represent the new SII procedures with an acceptable level of accuracy?
 - Is possible to model a certain degree of both vertical and horizontal track randomization?
 - Is it possible to solve the envisioned sequencing problems of the tools when implementing CDAs in a satisfactory way?
3. Explore the capabilities of the tools to provide, accurately enough, the outputs demanded by the validation methodology regarding capacity, noise, safety and cost-benefit indicators.

4. Harmonize working methodologies with the tools, i.e. the method for translating the SII concept into the models for the three sites involved in the Pre-calibration phase (AENA, EEC and SICTA) to avoid airport specific results instead of comparable and extensible results.

3.3. Pre-calibration Method

3.3.1. Introduction

The Pre-calibration phase has been developed by three WP4 partners (Naples-SICTA, Madrid-AENA and Paris-EEC) testing in one single airport (Naples Capodichino) in one single configuration a single event.

3.3.2. Experimental design

Naples Capodichino airport has been selected as the unique site to test the procedures in both platforms (TAAM-Enhance-INM and SIMMOD-INM), avoiding specificities such as elevation of the fields, etc. Even if this means redundancy, all the partners involved in the simulation will perform the pre-calibration process for the same scenario to perform a cross comparison and harmonize working methodologies with the tools. EEC and Aena built a TAAM pre-calibration model whereas Sicta built a SIMMOD pre-calibration model to reach the same objectives than with TAAM.

The traffic sample used performance files obtained from Bada v.3.3. The performance data coming from BADA were modified to comply with the speed and altitude restrictions included in each procedure to be analyzed during pre-calibration phase regarding rates of climb and descent, rates of turn, altitude and speed indications.

One unique runway configuration of Naples airport has been analyzed during the pre-calibration phase: Runway 06. Physical runway limits and threshold displacement have been considered.

The design of the experiments was not fixed a priori, but it was developed progressively based on the results as they were obtained.

A series of single event simulations were performed using different aircraft performance characteristics. The focus of the simulations was to obtain 3-D trajectories and speed profiles as close as possible to the nominal profiles for the case of:

- Current Naples procedures
- Baseline procedures (ICAO A for departures and the segmented baseline defined in D3-1 for arrivals)
- A set of new SII NAPs for A320s and A340s.

Afterwards, once the correct performance file was selected, an extension to 50-55 movements was simulated to study and analyze the achievable outputs.

3.3.3. Hypothesis

- Wind: Current capabilities of TAAM do not allow simulating different wind conditions.
- Acceleration & deceleration: The same acceleration and deceleration value is applied throughout the whole flight. There is no possibility of defining different acceleration or deceleration values for different flight levels, as can be done for the rest of parameters such as speed, rate of climb and descent, etc.
- Airport: A one-runway/ one-airport (06) configuration is used.
- Taxiways: Simulations are carried out without considering any taxiways.

3.4. Description of the pre-calibration scenario

3.4.1. Naples Capodichino data

Figure 3 Capodichino Airport

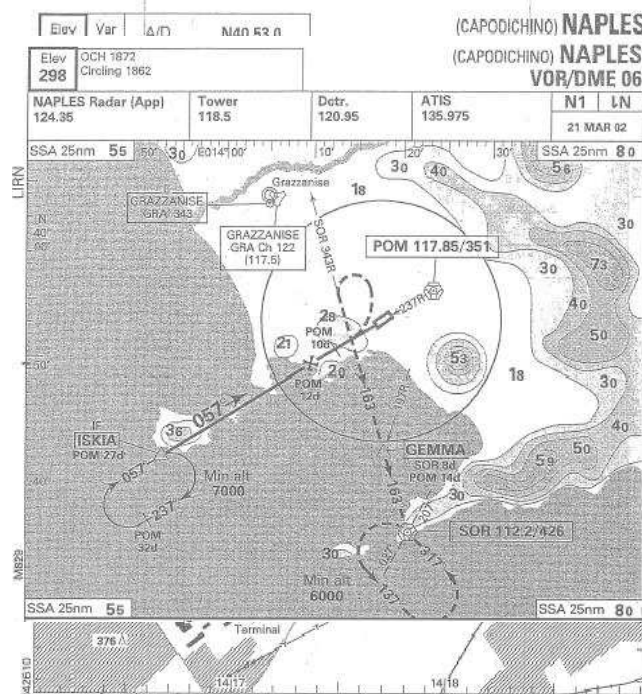


Figure 4 Procedure RWY 06

AD ELEV298	NAPOLI/CAPODICHINO
	LIRN 40°53'00"N 14°17'20"E

Designation RWY number	06	24
Magnetic bearing	057°	237°
Dimensions of RWY (m)	2628 x 45	2628 x 45
THR coordinates (WGS84)	40°52'54.06"N 14°16'53.62"E	40°53'28.95"N 14°18'07.59"E
THR displacement (m)	399	190
THR elevation (ft)	288	226
TORA (m)	2628	2628
TODA (m)	2758	2778
ASDA (m)	2628	2628
LDA (m)	2229	2438

3.5. Problems encountered and corrective actions

1. First point in the STAR:

All simulated Airbus procedures start at about 6/7000 ft. During the simulation it was observed, checking the .rep file, that if the first point of the STAR coincided with the first point of the Airbus provided procedures, the aircraft did not pass thorough the first point and the altitude was totally changed. To avoid this problem it was decided to introduce two other points in the STAR before the first nominal point. The result was that the altitude of the first point was exactly the requested value.

2. 1 NM between two consecutive points:

In TAAM any two points in the STAR path are rejected if they are less than 1 NM apart. If two points closer than 1 NM are introduced along the trajectory, one or even both of them can be rejected, and in any case the altitudes are not respected.

In the reference procedures for example, there is a level segment where the altitude is constant while the speed assumes different values along the horizontal segment. Since in the aircraft characteristic file the only possible option is to assign one single speed value to a specific flight level, the identified solution to represent the change in speed along the level segment was the definition of different "no name" points along the STAR, each with the corresponding speed.

Due to the fact that in TAAM two points cannot be closer than 1NM, there is a limit in the allocation of points with a certain speed value. For that reason a selection of the most important speed modifications was necessary and it was difficult to represent exactly all the real changes in speed along the horizontal segment.

3. 4 degree glide slope:

In TAAM STARs are defined as a sequence of waypoints. The last waypoint of each STAR, which has be on the Extended Runway Centreline (ERC), is assumed as the Final Approach Fix (FAF), and from that point to the runway aircraft can fly a maximum three degree glide slope.

Some of the new Sourdine II noise abatement procedures have an increased glide slope, which means that the last segment of these procedure is at more than three degrees. For these procedures it was necessary to find a way to force all aircraft to descend at more than three degrees. The proposed solution during the pre-calibration exercise to avoid the mentioned constrains for the last approach segment was to introduce a new waypoint at the end of each STAR.

A new waypoint was introduced near the runway threshold in order to have a four degree segment up to that point and a three degree final segment as short as possible to have a correct representation of reality.

Concerning the position of this last waypoint, the described limit of the tool to the introduction of two consecutive points with a relative distance closer than one NM, impedes to position the last waypoint at the runway threshold.

Theoretically, as related is the manual of TAAM, the last defined waypoint of a STAR is the FAF. On the contrary during the simulation TAAM creates another FAF farther from the runway than the last waypoint of the STAR. Probably the reason for this behaviour is that the added last waypoint is too lose to the runway threshold and thus TAAM creates a different FAF.

4. Horizontal segment:

After each simulation run there is the possibility to save the results into different files like .rep, .gldr, hst, etc. The data contained in these files can be used to generate graphics in order to visualize the trajectories flown by all aircraft.

During the pre-calibration exercise, data have been recorded and graphics have been generated to study the results obtained with the simulations. After a first check of the data, which has been done analyzing the .rep file, it was noticed that all the waypoints of the STARs were passed through during the simulation.

A different problem was encountered analyzing the .gldr file. In this file there are altitude, latitude, longitude indicated and calibrated air speed of points along the trajectory, recorded every second by the tool. Analyzing this file and creating the graphics it was evident that there was an error in the way the trajectories were flown.

Starting from a first waypoint, the aircraft were descending as fast as possible to the altitude of the consecutive waypoint, and then they were flying a horizontal segment up to the second waypoint of the TAR. All trajectories were completely modified by the tool, since it was introducing one level segment per waypoint. On the contrary all new approach procedures are continuous descent approaches (CDAs) here no level segment can be present.

Different strategies have been used to try to solve this problem and to eliminate the horizontal segments, but only a reduction of the length of the level segment was obtained.

The Preston group was contacted to have indications about possible solutions, but their opinion was that this problem constitutes a limit of the tool and that at this moment it is not possible to find a way to avoid it.

During the simulations some refinements on the trajectories' design have been obtained simply replacing waypoint names with "no name" points. The length of the level segment has been reduced.

5. Speed:

Aircraft speed can be imposed in TAAM in two ways, in the aircraft characteristic file and during the definition of the STARs.

Concerning the aircraft characteristic file, for every aircraft type it contains three speed values, minimum, normal and maximum, for each predefined flight level. For the pre-calibration exercise attention was given to the descent speed values since the study was focused on the approach procedures. During the simulation the three values, minimum, normal and maximum have been set on the same value in order to force the aircraft to fly exactly with the desired speed.

Moreover some flight levels have been added into the file to take into account some relevant changes in speed due to configuration modification or thrust change, which cannot otherwise be considered. Concerning the definition of the STARs, one of the existing options is the attribution of a speed value or each introduced waypoint. Speed restrictions have been set not only with a single value but also with a range of possible values delimited by minimum and maximum.

6. Speed at threshold:

In order to reach the requested speed at threshold, which for the new proposed procedures has a value around 130 kt, there are some parameters to set in the simulator, like speed at threshold, desired AS, etc.

7. Rate of descent:

In the aircraft characteristic file there is a section dedicated to the rate of descent. As for the speed sections there are different flight levels, and for each of them two rates of descent are provided: normal and maximum.

Due to the problem described above concerning the presence of a horizontal segment, before the simulations were run, values of the rate of descent associated to each segment of the procedures have been calculated in order to impose to each segment exactly the value corresponding to its theoretical slope. As for speed, some new flight levels have been added to the existing list in order to have a bigger precision with respect to the procedures provided by Airbus. Once the simulations have

been terminated and the results have been analysed, it appeared evident that the influence of the modified rate of descent" values and of the added flight levels was almost naught.

In conclusion, modifications on the rate of descent have not been used to the advantage of the elimination of the horizontal segment, since they seemed to have no influence on the results.

3.6. Pre-calibration results and conclusions

The achievement of project objectives is obviously influenced by the encountered limits of the simulation tool. These limits will be partially exceeded in the future versions of TAAM. In version 1.3.2-beta, that will be available in August 2003, the problem of the presence of horizontal segments along the trajectory will be apparently eliminated. The capabilities of the mentioned tools are to be explored to decide if they provide acceptable accuracy in the outputs required by the validation methodology. These outputs allow to evaluate capacity, noise, safety and cost-benefit indicators.

4. Calibration

4.1. Objective

In order to accomplish with the objective of the Sourdine II validation phase, where a comparison between existing and future noise abatement procedures is requested, the correctness and the accuracy of the model have to be tested before starting the analysis. The model has to be regulated to be able to reflect in the simulation output the real situation.

The objective of the simulation of Charles De Gaulle calibration scenario is to represent the current situation at Charles De Gaulle, in terms of airport configuration, fleet mix and procedures, in order to be able to compare the simulation outputs with real data.

The calibration scenario was analyzed to verify tool capabilities in reproducing real airport and airspace conditions. In order to do the comparison, the actual CDG conditions were reproduced in the simulator and real data were collected to be used during the comparison phase.

4.2. Calibration Method

The methodology adopted during the calibration exercise was founded in a first step on the reproduction of the actual real scenario of CDG using the tool capabilities, on a second step on the comparison of the simulation outputs with data provided by ATC experts working at CDG.

To achieve the mention objective, a list of TAAM outputs was selected to be recorded and to be used for the comparison:

- Number of movement per runway
- Runway occupancy
- Runway utilization
- Delays per runway

In addition to these parameters which come directly from the simulation output, in particular from the TAAM reporter, other indicators were analyzed and used at the end of each simulation run, in order to improve the quality of results:

- Holding points
- Abnormally terminated flights
- Separation
- SIDs/STARs usage

4.3. Description of the calibration scenario

4.3.1. Physical layout

4.3.1.1. Airport

Paris Charles De Gaulle current airport layout will remain unchanged during the period of time considered in Sourdine II.

At the moment there are two pairs of parallel runways, all East-West oriented according to wind direction: 27L/R (09R/L) and 26L/R (08R/L). External runways are dedicated to arrivals and internal runways to departures. Theoretically traffic coming from or directed to the north, is managed by the

northern pair of runways, as well as traffic coming from or directed to the south is managed by the southern runways.

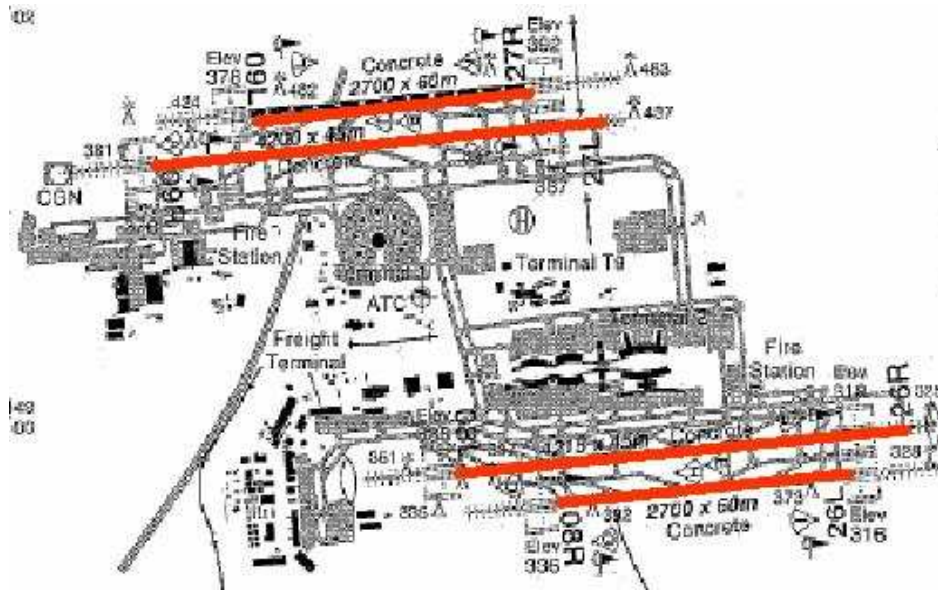


Figure 5 CDG Airport

For all Sourdine II simulations West configuration was considered as representative of a general situation at CDG.

At the moment since a new control tower is under construction, the fourth runway (27R) is used only during the night.

4.3.2. Operational description

4.3.2.1. TMA structure

At CDG there are four TMA entry points, N-W (Merue), N-E (Lorta/Veler), S-W (Balod) and S-E (Omako).

The main aspect that can be noticed looking at the published CDG procedure is that the radar area is defined only in the first part of the TMA, and that after a certain point there is a zone called “vectoring area” where no nominal trajectory is defined, and where controllers have the possibility to manage the traffic freely. On the contrary departure procedures are defined entirely from the runway to the last waypoint of each SID.

Each STAR was defined as a sequence of waypoints, each of them with its real altitude restriction and holding.

At the beginning of the simulation some simplifications were agreed to facilitate the use of the simulator and the collection of outputs. One of these simplifications was to cut both departures and arrivals in a way to save time during the simulation runs, and on the other hand, to have a better sequencing during the approach phase.

The idea was to concentrate the study around the Paris TMA, and to do that, departures were considered from the assigned take-off runway, up to the last point of the SID, eliminating the routes and all points after the TMA to the destination airport. For approaches, they were defined from the first point in the TMA, up to the assigned landing runway. All waypoints from the departing airport to the TMA entrance were deleted.

Since in TAAM for the correct use of the simulator, at least one among ETD and ETA is needed, initially the complete fleet mix was introduced, with the entire route, from the departing airport to the destination airport. Given the ETD in the TAAM timetable, the tool calculates automatically the arrival time.

Once both departing and arrival time were known, as explained before, trajectories were cut. Again the new timetable was introduced in the tool which again calculated the new departing time for arrivals and the new arrival time for departures.

For departures it was decided to introduce one final waypoint after the last point of each real SID, at about 50 NM from the mentioned last point. For arrivals, for each entry point of the Paris TMA, four waypoints were added to become the new starting point for each STAR. Aircraft were distributed among the different trajectories in dependence of their real provenance.

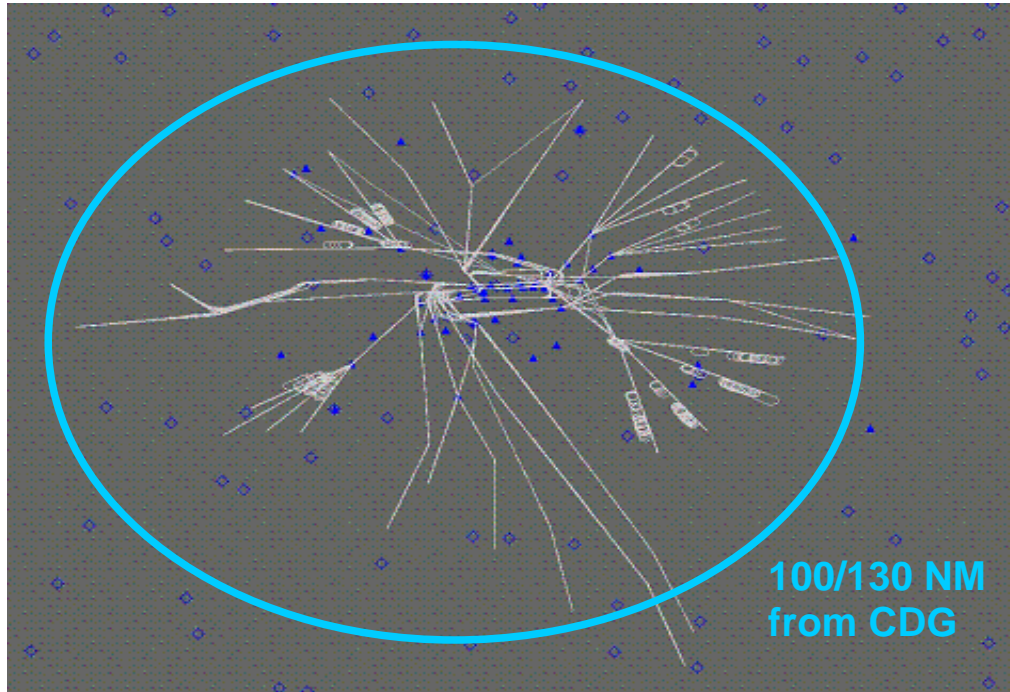


Figure 7 CDG cut take-off and landing procedures

As explained before published procedures are defined up to certain points and after these points there is a vectoring area. In TAAM procedures were described entirely from the first waypoint to the last including the zone of the vectoring area.

Since the scope of the simulation was the representation of the real case of CDG, in order to reproduce the lateral dispersion which appears marked looking at radar trajectories of the airport, for each existing STAR two other user defined trajectories were defined, the inner and the outer path.

This option is one of the possibilities in TAAM to have a horizontal dispersion. Starting from the original STAR, it is possible to move laterally each waypoint along the STAR creating on one side an inner trajectory, which normally designs a shortcut to the runway, and on the other side an outer path, which usually extends trajectory length.

As a function of the amount of traffic and the number of movements, TAAM should be able to choose one of the many existing trajectories between the inner and the outer.

For the calibration scenario, inner and outer paths for each existing STAR were created taking into account maps with the real horizontal dispersion which was present at CDG the selected day. The distance between inner and outer real points along each STAR were measured to build the same scenario within the simulator.

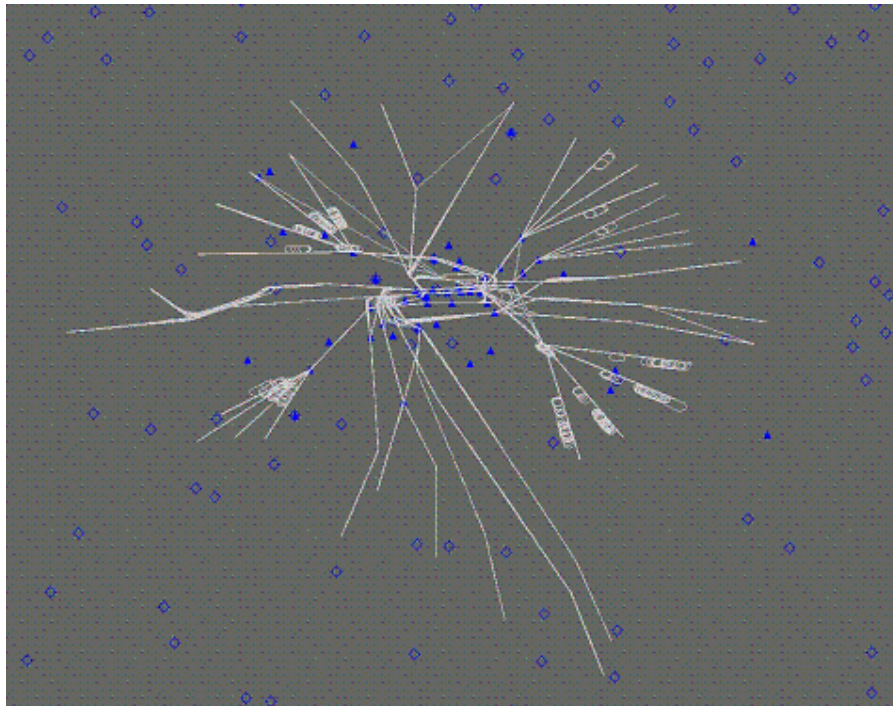


Figure 8 CDG Inner and Outer approach procedures

In TAAM there is also the possibility to add altitude restrictions at each displaced waypoint.

Theoretically at CDG the traffic coming from north should be conducted to the northern runway as well as the traffic coming from the south to the southern runway. Looking at the real traffic sample of the selected day, it is evident that in reality both traffics are mixed. There are aircraft coming from north which land on southern runways as well as the opposite.

When there is the same STAR for two different landing runways, TAAM is not capable to distinguish that they are like two different STARs, and as a consequence there were aircraft descending one on top of the other at the same altitude.

For this reason during the definition of STARs (with inner and outer paths), it was necessary to create a differentiation in terms of altitude between STARs ending on different runways. This vertical distance was generated assigning a separation of at least 1000 ft between aircraft landing on different runways. In particular the criteria used to separate aircraft was, the farther the landing runway the higher the aircraft altitude on the STAR.

4.3.3. Traffic sample

For the calibration exercise the selected day was 28th June 2002

The corresponding number of movements was 1524, with 35% of Airbus aircraft and 37% of Boeing aircraft.

In TAAM the traffic sample is introduced in the timetable identified by the “.acf” file where there are information like call sign, aircraft type, departing airport, destination airport, ETD, ETA, SID/STAR, etc. Since TAAM can read the “.acf” files only in a dedicated format, before the introduction in TAAM the traffic was filtered using a filter available at EEC.

4.3.4. TAAM model parameters

4.3.4.1. General parameters

The following general features are **enabled**

- Conflict detection
- Aircraft performance randomisation
- In trail separation

The following general features are **disabled**

- Flow management
- Conflict resolution
- Wind modelling

Gates and taxiways or other ground structures are **not** used

ATC sectors **are not** used

Time step is set to **6 s**

4.3.4.2. Runways

- Runway 26L/26R/27L/27R:

Open for **all**

All market segments and weight classes are permitted to use this runway

4.3.4.3. Departure separation and sequencing

Holding preference is **100%** airborne

Wake turbulence calculations on the basis of **track distance**

Departures **are** radar separated within a distance of **6.1 NM** from airport with **3.1 NM** recheck entry

Airborne conflict checking on departures is **on** except for overflights

Conflict look ahead time is **1 minute**

Delay time when an airborne conflict is detected is **30 s**

Departure sequence optimisation is **limited**

Selection of SID is within 60NM and 82 degrees of the SID fix

Calculate runway length needed from **acceleration of aircraft**

4.3.4.4. Arrival Sequencing

Default time interval between arrivals is set to 0

Queues & sequencing on the basis of **maximum of distance/time**

- Enter landing queue 40 min or 70NM from airport (whichever is maximum)
- Begin sequencing actions 20 min or 50NM from airport (whichever is maximum)
- Sequence fixed 10 min or 30NM from airport (whichever is maximum)

The sequencing strategy is in order of **flexible ETA**

Flight **may not** overtake on STARs

Desired IAS on final approach is **150 knots**

Doglegs for short air delays **will be** used

Selection of STAR if the route is within **60 NM** and **82** degrees of the arrival fix

4.3.4.5. In trail and flow control

Intrail separation **is not** used with overflights

Intrail separation **is** used beyond top of descent

The target flow rate into the airport is **40** aircraft per hour

Flow is reassessed every **2** minutes

Full speed control is used on cruise

4.3.4.6. Flight trajectory parameters

Speed and altitude limits are **strictly enforced**

Speed limits in level bands **are** ignored

Climb between waypoints **is** allowed

Gradual descent is **not** attempted

Descent rate can **not** be reduced below normal rate

Minimum climb rate is **75%** of normal climb rate

4.3.4.7. Sector parameters

Radar airspace is used

For **ATCO** sector:

- Radar separation is 3 NM

The capacity of the sector is **unlimited**

The maximum number of aircraft holding is **unlimited**

Lower limit: **1000 ft**

Upper limit: **FL200**

Conflicts **are** checked in the sector

For **North/South** sectors:

Radar separation is **3 NM**

The capacity of the sector is **1**

The maximum number of aircraft holding is **0**

Lower limit: **1000 ft**

Upper limit: **FL40**

Conflicts **are** checked in the sector

In TAAM there are three parameters related to sequencing which can be changed as a function of the simulation needs, which have a big influence on the type of scenario that is generated by the simulation. These parameters can fix the moment and the location where the sequencing starts and when the position of aircraft cannot be changed anymore.

In the calibration exercise the objective was the representation of the real situation, and for this reason there was the need to have aircraft using as much trajectory dispersion as possible. In order to have the horizontal dispersion it was noticed that the sequencing had to be fixed not too early, because if aircraft were sequenced right after their comparison in the screen, TAAM had the tendency to manage delays or adjustments using holdings. On the other hand holdings out of their nominal position were undesired.

There was the need to find the best compromise between the presence of holdings and the use of outer trajectories in addition to the use of those nominal.

Several simulations were turned to look at the effects of the sequencing threshold parameter on both holdings and trajectories, and the following values were chosen:

- Enter landing queue: 40 min/70 NM
- Begin sequencing actions: 20 min/50 NM
- Sequence fixed: 10 min/30 NM
- Doglegs option was selected

4.4. Calibration results and conclusions

Once all necessary simulation runs were terminated, the following step was the registration of needed output results, whether graphics and numeric.

To visualize the simulation output from a horizontal point of view in order to have an understanding of the dispersion generated during the simulation, of the presence of holdings and of the correct use of SIDs and STARs, it was necessary the use of another tool, LUCIAD.

LUCIAD needs as input a number of TAAM files and it generates as output horizontal tracks with the relative dispersion and the corresponding flights.

Following there is an example of one of the possible views produced by the tool.

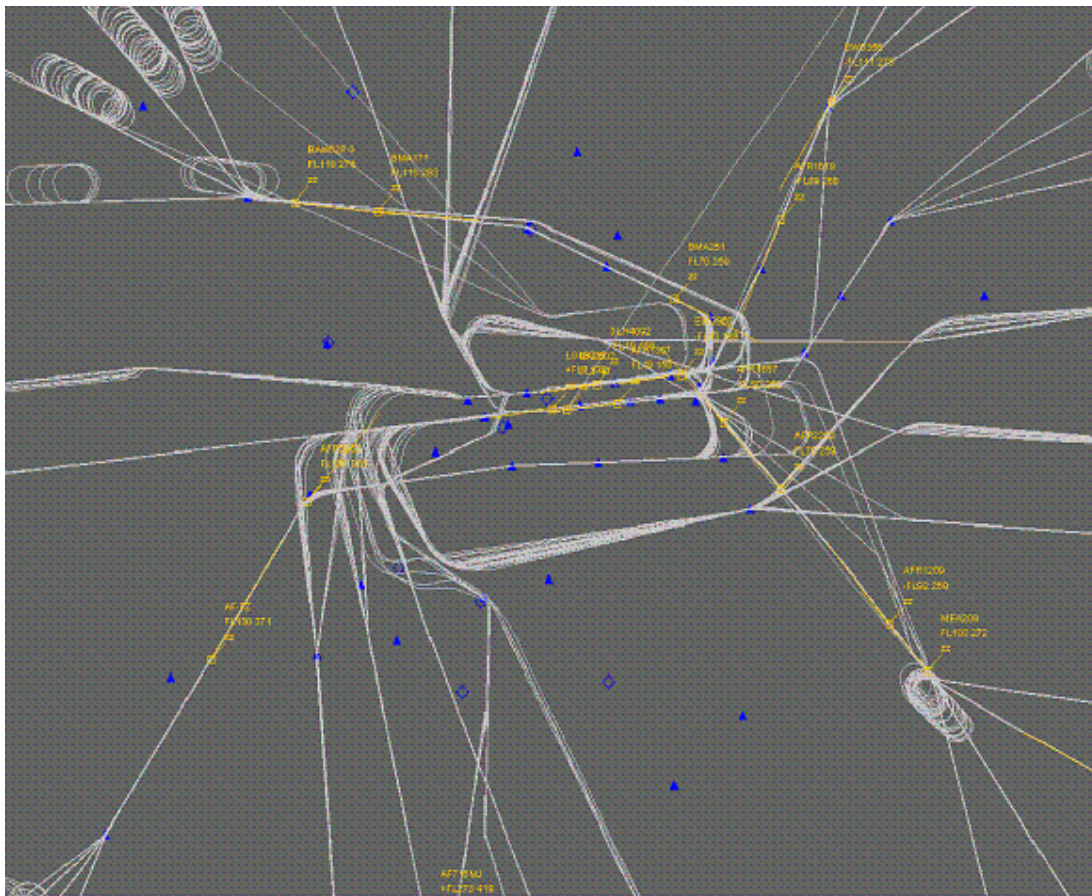


Figure 9 Simulation output: CDG horizontal view

A first check of the validity of results was carried on looking at the prior picture to recognize and locate possible errors in the use of procedures. Once a first acceptance was agreed, some numeric parameters were recorded from the Reporter and visualized as figures to have a better view of the situation in terms of runway usage, delays, etc.

Following there are some diagrams showing the type of results which is possible to get from the TAAM Reporter.

Arrival Delay:

In this figure the arrivals delay per hour expressed in minutes is displayed.

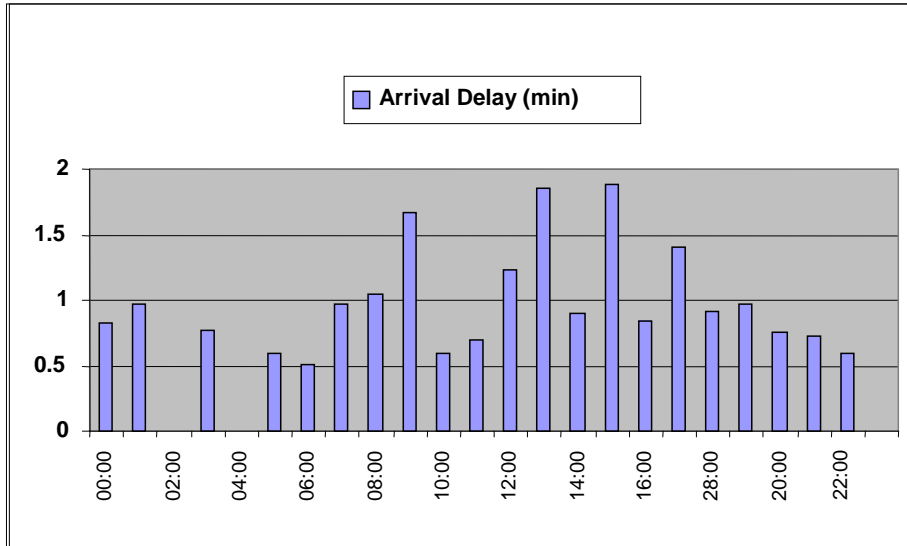


Figure 10 Arrival Delay

Total number of flights:

As explained at the beginning, one of the objectives of the calibration exercise was the comparison between simulation output and real data. To do this confrontation, real data were collected before the beginning of the simulation. Following there is a figure with two curves representing respectively TAAM and Real total number of flights per hour.

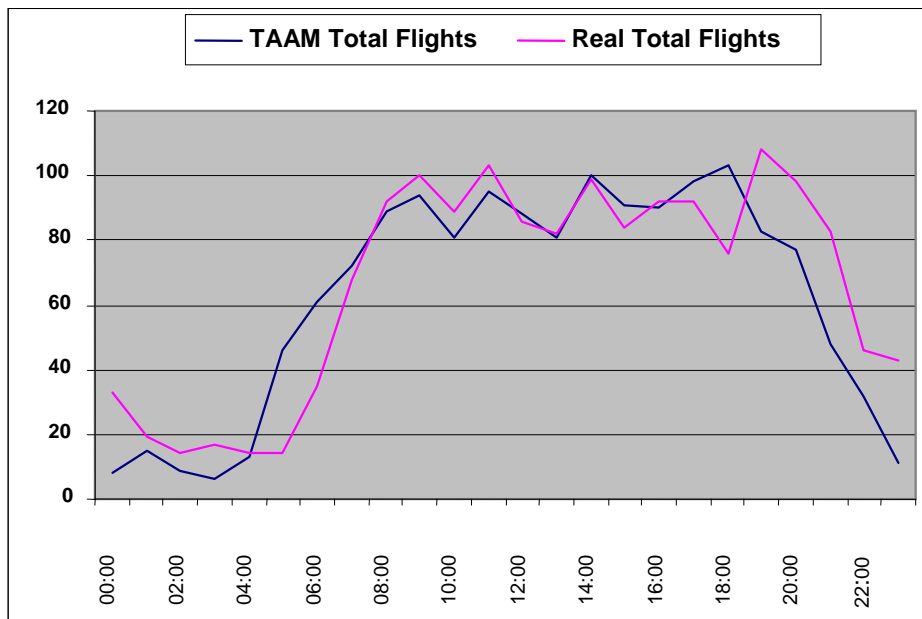


Figure 11 Total Flights

Message file:

Once the simulation run was complete, attention was given to the “messages file”, where there is a list of actions happened during the simulation. First of all, “abnormally terminated” flights were searched, and if they were found, the analysis of the reason for the failure was done, in order to find a solution and to eliminate the problem.

During the simulation, the correct use of SIDs and STARs was checked in order to avoid the presence of trajectories created by the simulator and used by aircraft in place of defined SIDs and STARs. At the same time, since both SIDs and STARs were defined with altitude restrictions, the correct use of introduced constraints was tested.

Focusing the attention on arrival procedures, one of the parameters which can generate critical problems in the final objectives achievement, is the respect of the separation minima. As explained before, at the beginning of the simulation three sectors were created and in all of them the separation was fixed to 3 NM. During the simulation runs attention was focused on the separation compliance.

Normally when TAAM has to manage sequencing it can use speed control, holdings and vectoring. It possible to fix some parameters in the tool in order to give priority to one of the mentioned sequencing options. The values of these parameters are chosen as a function of how traffic is managed in the real situation at the studied airport.

At CDG for example, controllers prefer to move aircraft from their nominal trajectory and to generate big horizontal dispersion, instead of using holding points where aircraft wait for clearance. In order to reproduce Paris TMA picture as close as possible to reality, the presence of holdings and their position was kept under control.

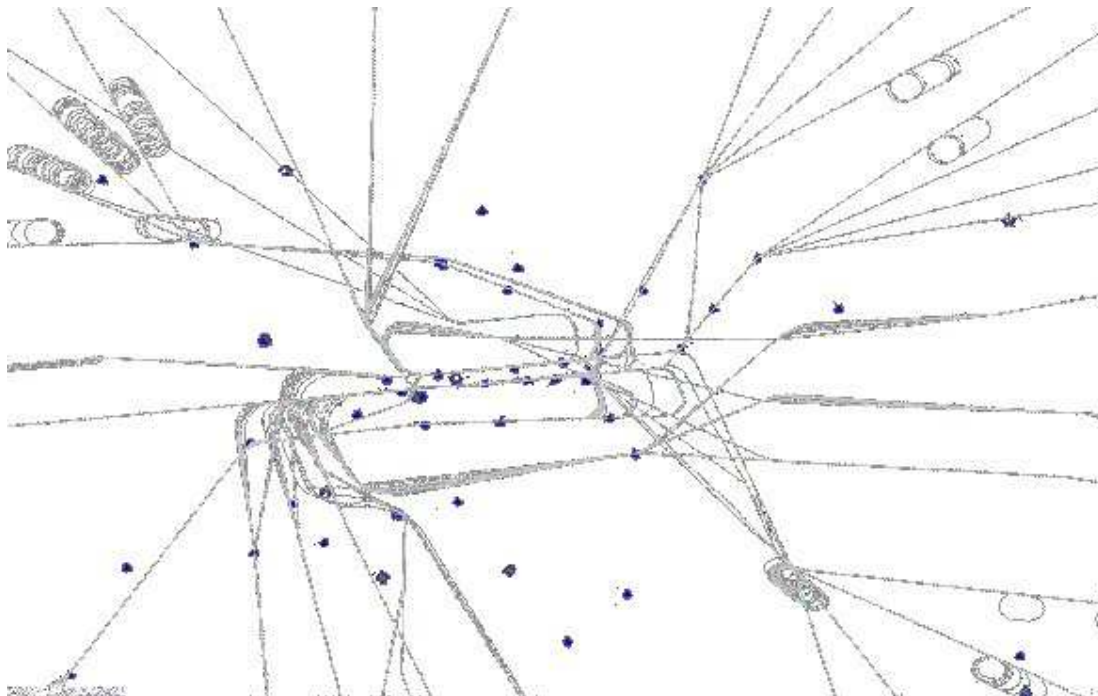


Figure 12 Undesired holding points

At the end of each simulation run it is possible to analyse results and outputs in the TAAM reporter. In the reporter there are some predefined type of outputs which can be visualized, printed and recorded, as well as there is the possibility to create some queries in order to obtain other outputs.

For the calibration exercise these are the recorded data from TAAM output:

Number of movements per runway

Runway utilization

Runway occupancy

Departure and arrival delays

These results can be use on one side to have an idea on the number of movements per hour and per runway, on the other side to compare the actual situation with the one in the future at the same airport.

Problems:

Concerning separation, the main problem encountered during the simulation is linked to the Paris TMA design. As repeatedly explain, at CDG theoretically northern and southern traffic flows are separated, but in reality they are mixed and there are crossing flows of aircraft in the airspace. The presence of crossing flows sometimes created conflicts between aircraft coming from the north and landing on southern runways and vice versa.

Since the objective of the calibration scenario was the reproduction of the current situation at CGD in terms of traffic, procedures and airport structure, looking at results different conclusions can be done for the mentioned studied criteria.

Concerning airport structure, this was reproduced as it is at present (2002), even if from the agreed hypothesis on TAAM simulations, taxiways were not taken into account. The choice of considering only runways has some implications on the results which have to be mentioned to have a clearer picture when reading TAAM simulation results.

At CDG there are two pairs of parallel runways, and normally external runways are dedicated to arrivals and internal runways to departures. As a consequence, when aircraft land, they have to cross the internal runway to reach the assigned gate, thus there is the need to manage ground traffic and crossings.

In the real case, when aircraft land, they can cross internal runway if there are no departing aircraft, otherwise they have to wait until a certain number of waiting aircraft is reached (up to a maximum of 8 aircraft). When there is a need for waiting aircraft to cross, controllers give clearance to crossing aircraft and as a consequence departing aircraft queue to take-off.

This mechanism of queuing/waiting/crossing has impact on take-off and landing delays. If there is an aircraft ready to take-off, but there is the need to cross for other aircraft, departing aircraft will be delayed, as well as if runway exits are complete and there is an aircraft descending to land, if waiting aircraft cannot cross internal runway, landing aircraft waits until there is space on runway exits.

As a conclusion it is evident that considering only runways in the simulation means not to take into account delays due to the airport configuration and design. This is one of the causes which differentiate real outputs and simulation.

Concerning traffic, data were gathered from a real traffic day of CDG, 28/06/2002.

Concerning procedures, as explained before, they were taken from published AIP procedures and introduced in the tool as they are, with all altitude restrictions and altitude differentiation between jets and turboprops.

Looking at recorded pictures with the view of horizontal trajectories followed by aircraft during the simulation, it appears that for approaches aircraft had the tendency to use either inner or outer paths and not to take any other internal trajectory. Discussing with TAAM experts, they justified this behaviour with the absence of a sufficient number of movements, clarifying that if the tool is able to manage traffic using simply holdings and outer paths, it never takes trajectories between inner and outer.

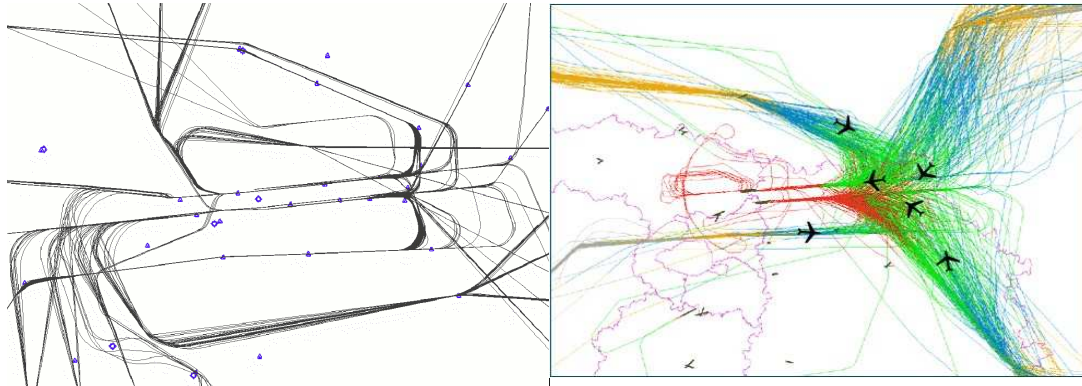


Figure 13 Comparison between TAAM output and radar dispersion

For these mentioned reasons we cannot compare horizontal dispersion created by the tool with the real dispersion at CDG. Even looking at the presence of holdings, while in the real situation aircraft almost never hold, in our simulation there are quite a lot of holding aircraft. Moreover holdings were generated not only in nominal holding waypoints, which at CDG correspond to TMA entry waypoints, but even between starting points and entry points.

As explained before there was the possibility to eliminate undesired holdings using sequencing threshold values and modifying them in order to remove holdings, but on the other side together with holdings outer paths disappeared. For this reason the already explained compromise was chosen and the presence of a certain number of holdings was accepted.

Aircraft performances:

When simulation runs were completed the messages file was analysed to check the presence of abnormally terminated flights and to understand why they were terminated. During the first phases of the simulation there were some messages concerning terminated flights due to the impossibility to build their flight profile for certain SIDs. Analyzing the problem it appeared that the cause for the elimination of these flights was that their assigned SIDs had characteristics like rate of turn or rate of climb that some aircraft types were not able to accomplish.

The first tried approach was to modify the aircraft characteristic file in the section dedicated to the rate of turn and the rate of climb, because it was verified that the problem was related to the aircraft type and that changing the aircraft model the corresponding flight was not terminated.

Unfortunately this strategy did not work and to overtake the obstacle aircraft types which were creating problems were substituted with aircraft able fly the assigned SID.

5. Baseline vs. Sourdine II simulations

5.1. Objective

This chapter describes the baseline and the Sourdine-II procedures conducted by Fast Time Simulation.

5.2. Method

The method followed for the simulations takes the Calibration results into account. The purpose of the calibration phase was to increase the accuracy of the execution method, as well as of indicators and metrics and to apply these to the baseline and Sourdine-II procedures. All Sourdine-II scenarios were finally compared to the baseline.

5.3. Simulations

5.3.1. Physical Layout

The physical layout of CDG airport and its operational description remain the same as for the Calibration scenario (see Chapter 4).

5.3.2. TAAM model parameters

5.3.2.1. General parameters

The following general features are **enabled**

- Conflict detection
- Aircraft performance randomisation
- In trail separation

The following general features are **disabled**

- Flow management
- Conflict resolution
- Wind modelling

Gates and taxiways or other ground structures are **not** used

ATC sectors **are not** used

Time step is set to **6 s**

5.3.2.2. Runways

- Runway 26L/26R/27L/27R:

Open for **all**

All market segments and weight classes are permitted to use this runway

5.3.2.3. Departure separation and sequencing

Holding preference is **100%** airborne

Wake turbulence calculations on the basis of **track distance**

Departures **are** radar separated within a distance of **6.1 NM** from airport with **3.1 NM** recheck entry

Airborne conflict checking on departures is **on** except for overflights

Conflict look ahead time is **1 minute**

Delay time when an airborne conflict is detected is **30 s**

Departure sequence optimisation is **limited**

Selection of SID is within 60NM and 82 degrees of the SID fix

Calculate runway length needed from **acceleration of aircraft**

5.3.2.4. Arrival Sequencing

Default time interval between arrivals is set to 0

Queues & sequencing on the basis of **maximum of distance/time**

- Enter landing queue 40 min or 70NM from airport (whichever is maximum)
- Begin sequencing actions 20 min or 50NM from airport (whichever is maximum)
- Sequence fixed 10 min or 30NM from airport (whichever is maximum)

The sequencing strategy is in order of **flexible ETA**

Flight **may not** overtake on STARs

Desired IAS on final approach is **150 knots**

Doglegs for short air delays **will be** used

Selection of STAR if the route is within **60 NM** and **82** degrees of the arrival fix

5.3.2.5. In trail and flow control

In trail separation **is not** used with over flights

In trail separation **is** used beyond top of descent

The target flow rate into the airport is **40** aircraft per hour

Flow is reassessed every **2** minutes

Full speed control is used on cruise

5.3.2.6. Flight trajectory parameters

Speed and altitude limits are **strictly enforced**

Speed limits in level bands **are** ignored

Climb between waypoints **is** allowed

Gradual descent is **not** attempted

Descent rate can **not** be reduced below normal rate

Minimum climb rate is **75%** of normal climb rate

5.3.2.7. Sector parameters

Radar airspace is used

For **ATCO** sector:

Radar separation is **3 NM**

The capacity of the sector is **unlimited**

The maximum number of aircraft holding is **unlimited**

Lower limit: **1000 ft**

Upper limit: **FL200**

Conflicts **are** checked in the sector

For **North/South** sectors:

Radar separation is **3 NM**

The capacity of the sector is **1**

The maximum number of aircraft holding is **0**

Lower limit: **1000 ft**

Upper limit: **FL40**

Conflicts **are** checked in the sector

In TAAM there are three parameters related to sequencing which can be changed as a function of the simulation needs, which have a big influence on the type of scenario that is generated by the simulation. These parameters can fix the moment and the location where the sequencing starts and when the position of aircraft cannot be changed anymore.

In the calibration exercise the objective was the representation of the real situation, and for this reason there was the need to have aircraft using as much trajectory dispersion as possible. In order to have the horizontal dispersion it was noticed that the sequencing had to be fixed not too early, because if aircraft were sequenced right after their comparison in the screen, TAAM had the tendency to manage delays or adjustments using holdings. On the other hand holdings out of their nominal position were undesired.

There was the need to find the best compromise between the presence of holdings and the use of outer trajectories in addition to the use of those nominal.

Several simulations were turned to look at the effects of the sequencing threshold parameter on both holdings and trajectories, and the following values were chosen:

Enter landing queue: 40 min/70 NM

Begin sequencing actions: 20 min/50 NM

Sequence fixed: 10 min/30 NM

Doglegs option was selected

5.4. Procedures

5.4.1. BASELINE Procedures

5.4.1.1. STARS vertical profile

Condition	Parameter values
7000 ft (Fixed height)	- Speed 250 KTS CAS
	- Level flight
3000 ft (Fixed height)	- Clean configuration
	- Landing Gear up
	- Idle thrust
	- Constant CAS descent
Landing configuration and speed reached (Resulting height, minimum 1000ft)	- Decelerate to intermediate flap speed (IFS) and change to intermediate configuration
	- Fixed descent angle of 3°
	- Landing gear down
	- Decelerate (+) and change to landing configuration (++)
	- Decelerate to final approach speed (FAS)
Landing configuration and speed reached (Resulting height, minimum 1000ft)	- Adapted Thrust for descent at 3°
	- Constant speed (FAS) descent to 50ft

(+) To maximum allowable speed to select landing configuration

(++) Minimum allowable flap deployment

5.4.1.2. STARS horizontal path

The horizontal path is the same for all scenarios.

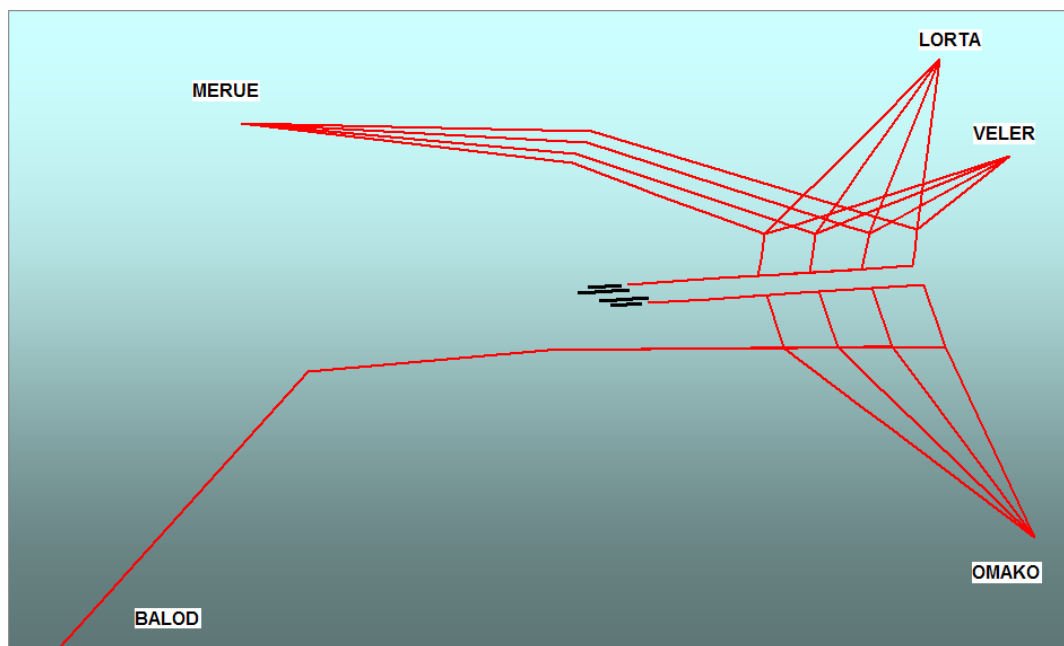


Figure 14 Horizontal Path for all Procedures

5.4.2. SOURDINE-II Procedures

The following paragraphs include the definition of the new arrival noise abatement procedures designed within Sourdine II project activities.

5.4.2.1. STARS vertical profile

Approach procedure II: Basic CDA with 2° initial FP A

Condition	Parameter values
7000 ft (Fixed height)	<ul style="list-style-type: none"> - Speed 250 KTS CAS - Level flight - Clean configuration - Landing Gear up
3000 ft (Fixed height)	<ul style="list-style-type: none"> - Idle thrust - Fixed 2° Flight Path Angle (FPA) - Decelerate to intermediate flap speed (IFS) and change to intermediate configuration
Landing configuration and speed reached (Resulting height, minimum 1000ft)	<ul style="list-style-type: none"> - Fixed descent angle of 3°. - Landing gear down - Decelerate and change to landing configuration (++) - Decelerate to final approach speed (FAS)
	<ul style="list-style-type: none"> - Adapted thrust for descent at 3° - Constant speed (FAS) descent to 50ft

(+) To maximum allowable speed to select landing configuration

(++) Minimum allowable flap deployment

Approach procedure III: CDA with 2° initial FPA and increased (3°) final glide slope

Condition	Parameter values
7000 ft (Fixed height)	<ul style="list-style-type: none"> - Speed 250 KTS CAS - Level flight - Clean configuration - Landing Gear up
3000 ft (Fixed height)	<ul style="list-style-type: none"> - Idle thrust - Fixed 2° Flight Path Angle (FPA) - Delay flap deployment as late as possible - Decelerate and change to intermediate configuration - Decelerate to intermediate flap speed (IFS)
Landing configuration and speed reached (Resulting height, minimum 1000ft)	<ul style="list-style-type: none"> - Fixed descent angle of 4°. - Landing gear down - Decelerate and change to landing configuration (++) - Decelerate to final approach speed (FAS)
	<ul style="list-style-type: none"> - Adapted thrust for descent at 4° - Constant speed (FAS) descent to 50ft

(++) Minimum allowable flap deployment

Approach procedure V: CDA with constant speed, variable FPA segment at intermediate configuration

Condition	Parameter values
7000 ft (Fixed height)	- Speed 250 KTS CAS - Level flight - Clean configuration - Landing Gear up - Idle thrust - Decelerate and change to intermediate configuration - Decelerate to intermediate flap speed (IFS)
Intermediate configuration reached (Resulting FPA)	- Descend at constant speed (IFS) to 3000ft - Idle thrust
3000 ft (Fixed height)	- Fixed descent angle of 3°. - Landing gear down - Decelerate and change to landing configuration (++) - Decelerate to final approach speed (FAS)
Landing configuration and speed reached (Resulting height, minimum 1000ft)	- Adapted thrust for descent at 3° - Constant speed (FAS) descent to 50ft

(+) To maximum allowable speed to select landing configuration

(++) Minimum allowable flap deployment

5.5. Traffic sample

The 28th of June 2002 reference day will be used as the timetable for daily flights, destinations and origins. Based on these data, used for the calibration traffic sample, and applying the growth indexes obtained for the year 2015 a traffic sample consisting of 1108 landings/day has been obtained, with 38% of Airbus aircraft and 35% of Boeing aircraft. Specific traffic characteristics and constraints will be cloned to obtain the baseline samples.

Changes in fleet mix foreseen for 2015 must be taken into account to obtain the final traffic samples.

High predictions STATFOR forecasts from EUROCONTROL will be used to generate 2015 traffic samples. Data for all possible types of aircraft is not available. Initially, only data for A320s and A340s flying the NAPs were defined within the Sourdine II Project. During the next phase, data provided from SEDITEC was considered. These data included, not only the modified A320s and A340s, but also data for other Airbus models such as A319, A321 and A330. For the aircraft for which there was no data, a comparison between FAS values provided and FAS values included in the INM 7.0 database was carried out. These data were also compared to Jane's book, providing satisfactory results.

Due to the new data provided by SEDITEC the aircraft grouping was reorganized based on FAS values and on wake turbulence categories. The following are the final seven aircraft groups considered:

- 139 kt: A320, B737, MD80, B727
- 128 kt: F27, FA20, LJ31, BA46, TU54
- 131 kt: F100, CL600, B757
- 137 kt: A330
- 139 kt: A340, A300, B747, DC10, B767, A310
- 100 kt: All turboprops: HSTA, DHC8, AT42, AT47, F50, SB20
- 160 kt: MD11

In the case of the A320 and A321, vertical, speed and thrust profiles corresponding to different motorizations are available. In this case, data corresponding to the most common motorization in the year 2015 was considered during the FTS exercise.

6. Results and conclusion

6.1. Capacity Assessment

In this scenario there are two different situations for runway 26L and 27R, because the scheduled timetable was developed using real current traffic at CDG, with current rules for runway usage, projected to 2015 with future rules.

Currently external runways are used for landing and internal runways for departure, but runway 27R is not used very often, so most landings are performed on runway 26L; envisaged the future configuration will be the same, but the external runways will be used for simultaneous approaches, with all traffic coming from the north landing on runway 27R, and all traffic from the south landing on 26L.

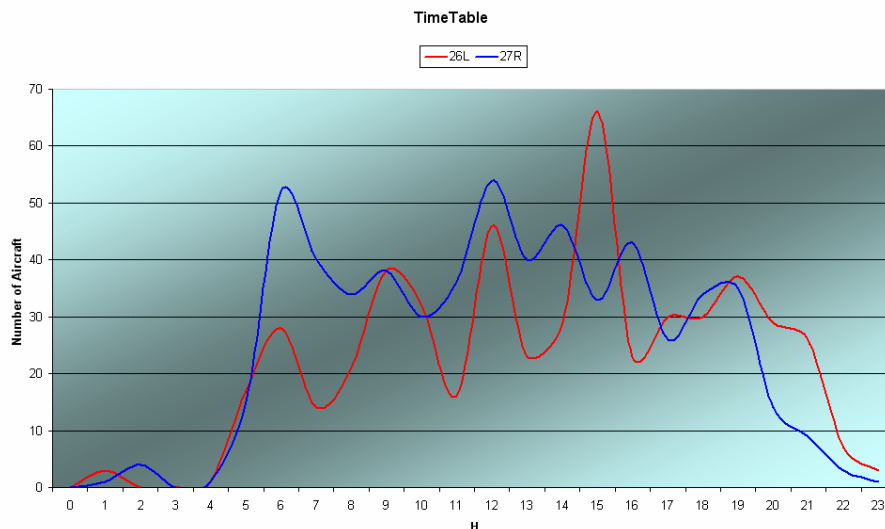


Figure 15 Time Table

For this situation we obtain a different demand for each runway, for example at 6:00 am the Time-Table shows more than 50 flights scheduled on runway 27R and less than 30 flights runway 26L, this means for 26L a traffic lower than its capacity and traffic over its saturation for 27R.

In the 26L the traffic demand is under saturation level for a long period, with a big peak at the highest demand of the day (66 flights), for 27R, traffic demand is up to the saturation level for a long period, without such high peaks.

For both runways the demand tendency is very different: for 26L the difference between peak and trough is high with a low average value, whereas there is only a little variation around a high average value for 27R.

These different situations for the two runways cause of a singular behaviour for each runway.

One more cause of the difference between the two runways is the fleet mix; in fact the average speed of the aircraft for each runway and for each procedure depends on the fleet mix.

As an example, the picture below shows the average Final Approach Speed (FAS) for each procedure of both runways, calculated for all hours of the day.

This shows that runway 26L has, for each procedure, an average FAS higher than runway 27R.

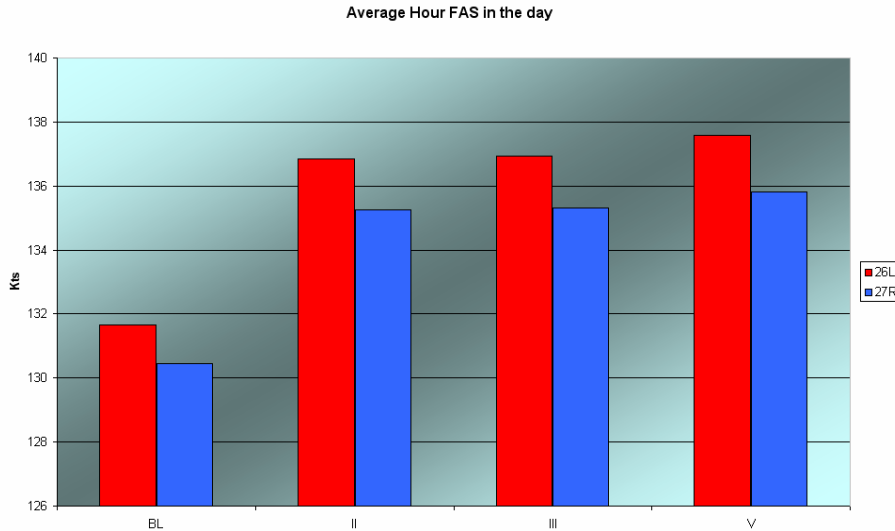


Figure 16 Average Hour FAS in the day

6.1.1. Airport throughput RWY26L

Runway throughput, for all procedures, follows the trend of time table, until 9:00, when the scheduled operations per hour reach a value close to saturation level. Here it is possible to see how the CDA procedure graphs move to the right with regard to the time table, this is indicative of delay accumulated by some flights, pushing them to a time when demand descends to a value well below saturation level; the same thing happens at 12:00.

At 15:00 the situation is very different. Here the demand goes very high above saturation level and each procedure starts to show this behaviour, but, immediately after, demand descends quickly so procedures come back to normal, having, at the end of a day, a little shift on right, with respect to the Baseline procedure, meaning an accumulated delay.

Procedure II has the minimum shift to the right compared with procedure III and procedure V.

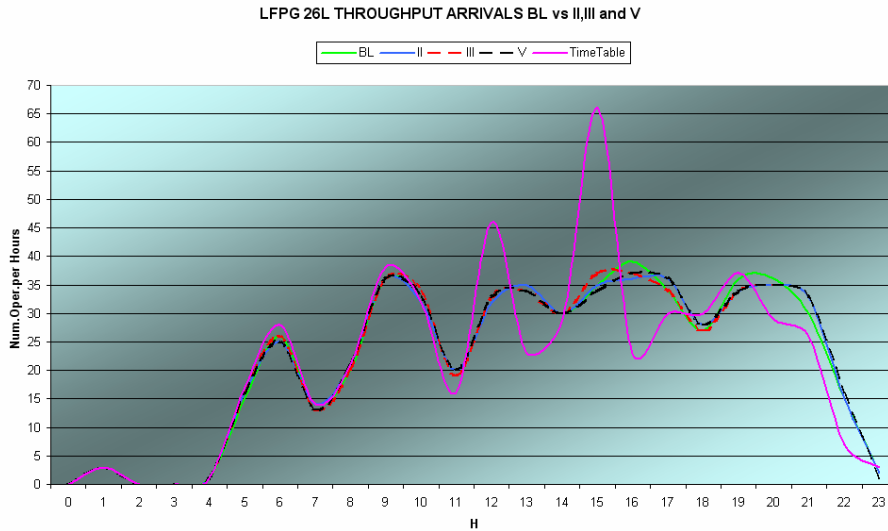


Figure 17 Throughput RWY 26L

The highest peaks for all procedures are around 16:00 with 39 operations per hour (op/h) for the baseline and 37 for procedure III and V.

Procedure III has two peaks (37 op/h), at 15:00 and 16:00.

Procedure II has the maximum values 36 op/h at 9:00 (here all procedure have the same value), at 16:00 and 17:00.

6.1.2. Airport delay RWY26L

There is little difference in Cumulative Delay between all procedures, with a continuous tendency for all procedures to increase their delay, in the following order, from the lowest to the highest: baseline, procedure II, procedure III and procedure V.

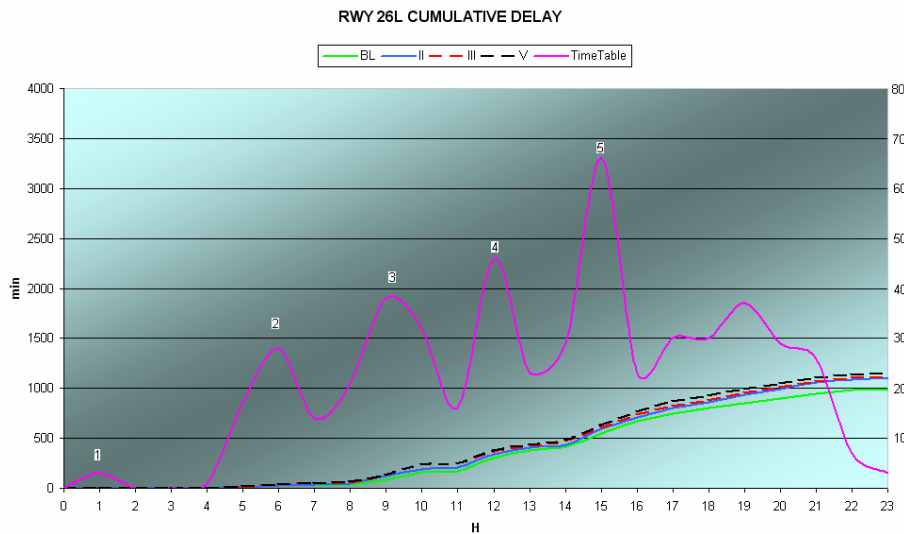


Figure 18 Cumulative Delay RWY 26L

For peaks 2 and 3 delay increases slowly, whereas there is a steeper raising when (peaks 4 and 5) demand for scheduled flights exceeds saturation level. In the graph above, it is possible to see that half of the total delay it is obtained around 15:00, where demand for scheduled flights reaches a value of 66 operations per hour.

The average delay for baseline procedure, procedure II, procedure III and procedure V, during all the day, is respectively: 1.9 min, 2.1 min, 2.14 min and 2.2 min.

6.1.3. Airport capacity RWY26L

Capacity assessment shows for runway 26L that procedure II has highest capacity (41 – 42), after the baseline, followed by procedure III (41 – 42) and procedure V (40 – 41).

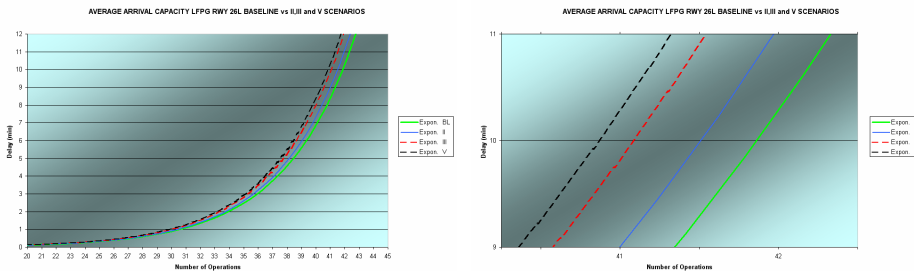


Figure 19 Capacity RWY 26L

6.1.4. Airport throughput RWY27R

On runway 27R the throughput, for all procedures, follows the demand scheduled on the time table until 5:00, where the demand goes up to saturation level.

Here it is possible to see the different reactions of the procedures; all procedures have a shift to the right compared with the baseline procedure, procedure V goes higher than procedure II and III.

After the first peak, demand goes down below the saturation level and all procedures came back to having a similar behaviour; demand goes again up and remains at a high level until 17:00. Here procedure II shows a similar behaviour of baseline procedure with lower values, procedure V and III are also similar, with higher values for procedure V, until the last peak; they have their peaks shifted to the right, compared with the baseline.

At the end of the day, when demand goes down to zero, all procedures start to descend shifted to the right compared with baseline procedure as follows: procedure II, procedure V and procedure III.

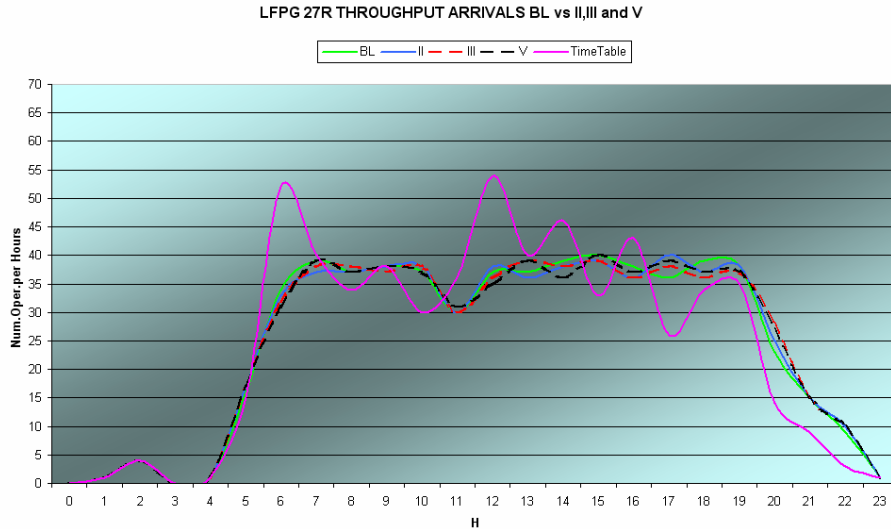


Figure 20 Throughput RWY 27R

The highest peak for all procedures is situated a couple of hours after the highest demand peak scheduled in the time table, because after this peak the demand continues to be well over the saturation level; so the NAPs reach their highest peak with delay because after their reaction to highest demand peak, they continue to have a high workload.

The highest peak of demand is located at 12:00 and for each procedure:

40 op/h at 15:00 for the baseline procedure and procedure V, 39 op/h at the same time for procedure III, which has one more peak at 13:00, and 40 op/h at 17:00 for procedure II.

6.1.5. Airport delay RWY27R

There is no delay until 5:00, when demand for scheduled flights starts to increase quickly, is it possible to see that where demand is lower than 30 op/h the cumulative delay is almost stationary.

Procedure II, in the first half of the day, gets the highest cumulative delay, where demand goes well above saturation level; after 16:00, when demand goes down to saturation level definitively, procedure II comes back to be the procedure with the least delay.

The behaviour of procedures III and V is almost the same, with a just a little more delay for procedure V at the end of the day.

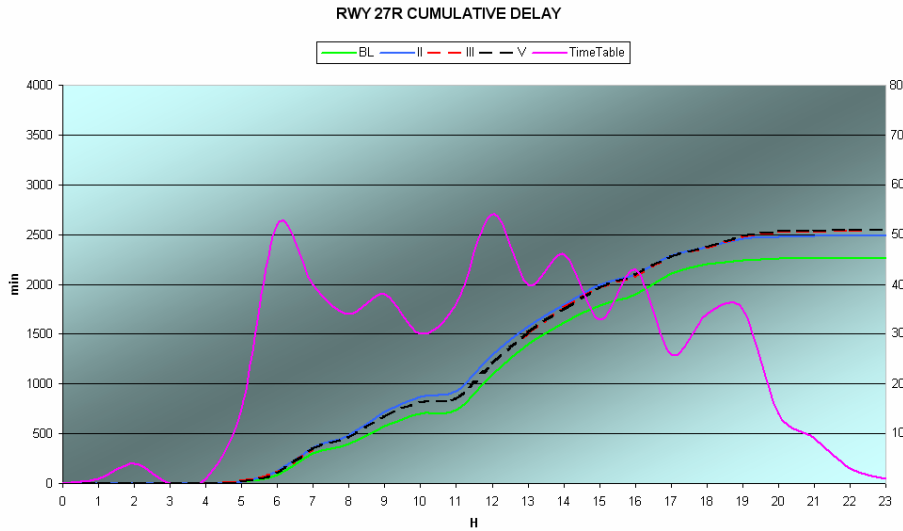


Figure 21 Cumulative Delay RWY 27R

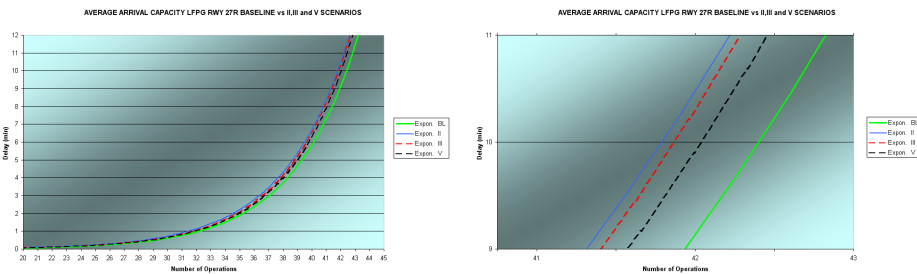
The average delays during the whole day for all procedures are the following:

baseline procedure 3.83 min, procedure II 4.24 min, procedure III 4.31 min and procedure V 4.33 min.

6.1.6. Airport capacity RWY27R

Capacity assessment for runway 27R shows that procedure V has highest capacity (42 – 42) after the baseline procedure, followed by procedure III (41 – 42) and procedure II (40 – 41).

Figure 22 Capacity RWY 27R



6.1.7. Airport throughput for the airport

For the entire airport, the throughput is a combination of the behaviour of both runways.

Until 5:00, when demand of scheduled flights goes up quickly, throughput follows the time table, after which all procedures start to follow their own behaviour.

At 6:00 (peak 2) it is possible to see how each procedure reacts to the first peak above saturation level. The baseline procedure has the highest values, for this peak, of op/h followed by procedure II and III, with similar behaviours, and procedure V.

After that, there is a trough that allows to all procedures to follow a similar tendency. It is already possible to see, at peak 3, the sequence of procedures, from right to left, baseline, procedure II, procedure V and procedure III.

During peaks 4 and 5 the airport is in condition of high workload, and here the procedures each have their own behaviour, giving, after peak 6, the following order: baseline procedure, procedure II, procedure V and procedure III.

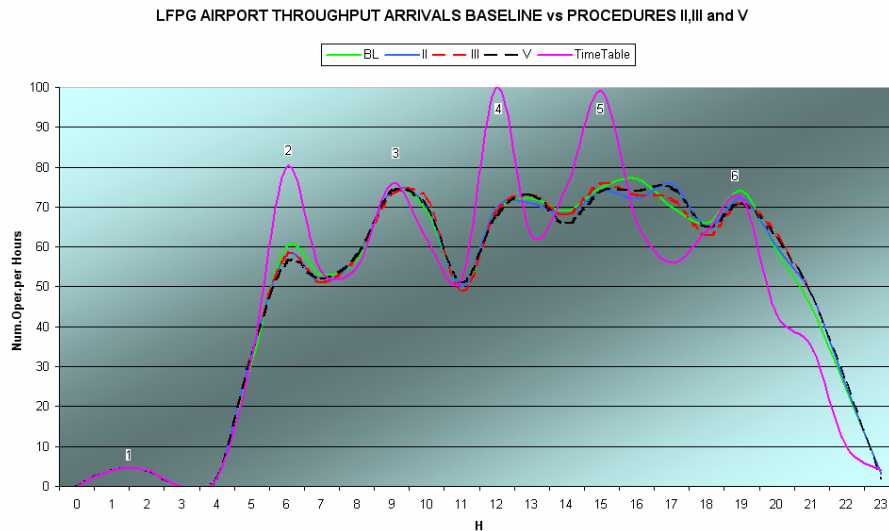


Figure 23 LFPG Throughput

The highest peaks for all procedures are around 16:00, just an hour after the second peak situated in steady condition (peak 5).

The values and times of the peaks for each procedure are:

Baseline procedure 77 op/h at 16:00, procedure II 76 op/h at 17:00, procedure III 76 op/h at 15:00 and procedure V 75op/h at 17:00.

6.1.8. Airport delay for the airport

For the whole airport, the cumulative delay is the sum of the cumulative delays of each runway.

From the graph is possible to see that the behaviour of the procedures is the same as for runway 27R because in runway 26L the cumulative delay has, for all procedures, relatively low values.

Here, as in runway 27R, procedure II has the highest value in the first half of the day, for becomes, at the end of the day, the procedure with the least cumulative delay, after the baseline.

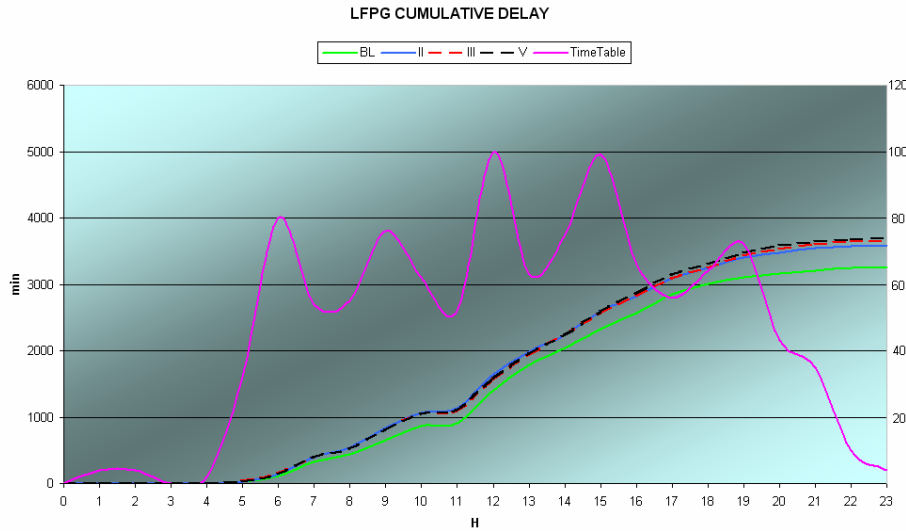


Figure 24 LFPG Cumulative Delay

The average delays during the whole day for all procedures are as follows:

baseline 2.93 min, procedure II 3.24 min, procedure III 3.29 min and procedure V 3.33 min.

6.1.9. Percentage delayed a/c

The maximum values of delay registered for each procedure are:

baseline 15.8 min, procedure II 21.62 min, procedure III 16.85 min, procedure V 18.88 min.

The table below shows relative occurrence of different delays for the different procedures

	Most.....Least			
0 – 5 min	baseline	V	III	II
5 – 10 min	II	V	III	baseline
10 – 15 min	II	III	baseline	V
15 – 20 min	V	baseline	III	II
20 - 25 min	II	---	---	---

Between 20 – 25 minutes only procedure II has experienced delay.

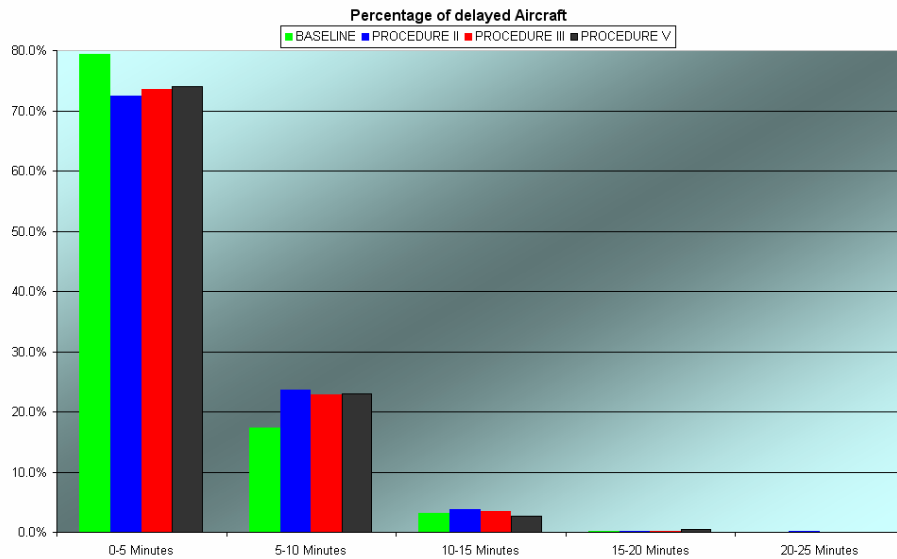


Figure 25 Percentage of Delayed Aircraft

6.1.10. Airport capacity

Capacity assessment shows that procedure II has highest capacity (80 – 82), after the baseline (81 – 83), followed by procedure III (80 – 82) and procedure V (81 – 80).

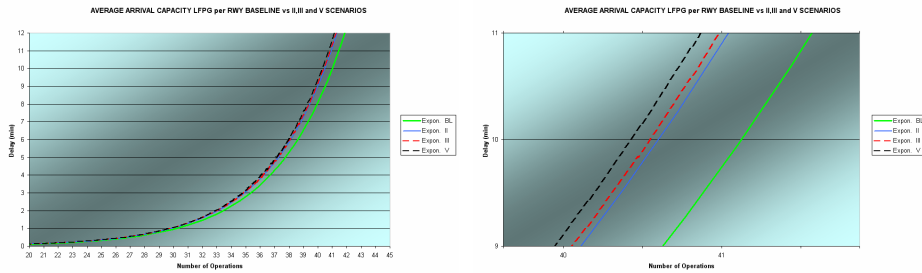


Figure 26 LFPG Capacity

6.1.11. Sequencing Actions

Compared with the baseline, as can easily be imagined, every NAP needs, in the traffic management, an increment in the number of Holdings and a reduction in fixing instructions for increase or decrease in aircraft speed. In fact all procedures are speed constrained during the NAPs, causing prior traffic management to increase holding instructions.

Each procedure starts its descent from 7000 ft at a different distance from the runway threshold. In procedure V this distance can change slightly for each different kind of aircraft that flies it, because the first segment is a descent at constant speed and not at constant angle, as is the case for procedure II and procedure III.

This distance is respectively: about 22Nm for procedure V, 26Nm for procedure III and 28Nm for procedure II.

The closer to the runway a procedure starts to descend, the greater the increasing number of holdings and the smaller the decreasing actions for Speed up/Speed down, probably because the

aircraft arrives at high speed close to the runway and the Speed up/Speed down actions are not enough to give the spacing required.

The graph below shows how procedures increase (Holding) and decrease (SpeedUp/SpeedDown) then number of correction actions: Procedure II +3%, -3%; Procedure III +5%, -4%; Procedure V +11%, -10%.

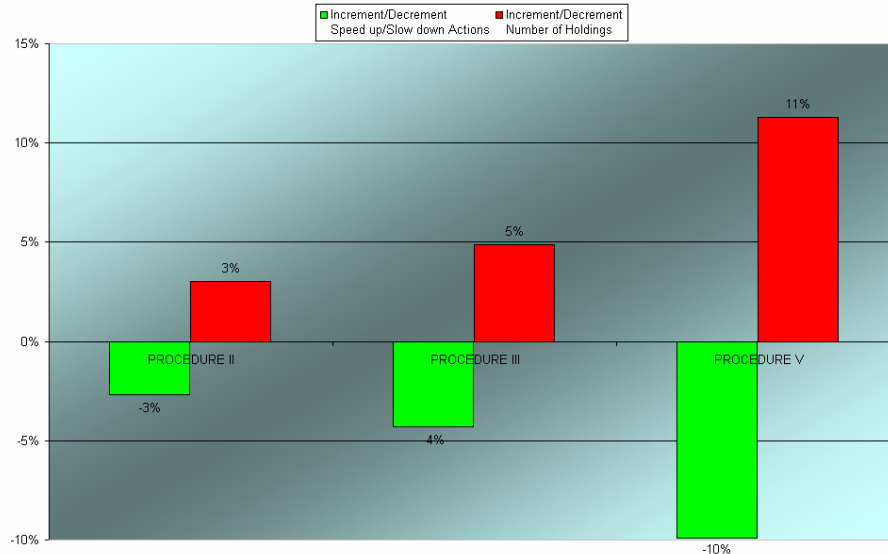


Figure 27 Variation in number of Holding and SpeedUp/SpeedDown correction

6.2. Conclusions

This report has given the results of the separate simulation exercises:

- a pre-calibration exercise for ensuring consistency between the Sourdine II partners' methods and tools so that the following simulations of the Sourdine airports may be compared. This exercise showed some major problems in the ability of the TAAM simulator to effectively simulate continuous descent approaches. These problems were later resolved by an improved version of TAAM.
- a calibration exercise for ensuring consistency between simulated output and real life using present-day data. This exercise showed the need to replace certain aircraft types which were not capable of performing the required procedures.
- the future-state simulations of three of the four Sourdine II Noise Abatement Approach Procedures.

The results of these simulations are measured in terms of throughput (the number of operations per hour with the given traffic), the average delay to an operation, and the peak capacity. The peak capacity is determined using cloned traffic and is the theoretical throughput when delay reaches 9 minutes and 11 minutes. The following table gives a summary of the results of the future-state simulations:

Procedure	26L			27R			Combined		
	Peak Throughput (ops)	Average Delay (mins)	Peak Capacity (9'-11')	Peak Throughput (ops)	Average Delay (mins)	Peak Capacity (9'-11')	Peak Throughput (ops)	Average Delay (mins)	Peak Capacity (9'-11')
Baseline	39	1.9		40	3.83		77	2.93	81-83
NAAP II	36	2.1	41-42	40	4.24	40-41	76	3.24	80-82
NAAP III	37	2.14	41-42	39	4.31	41-42	76	3.29	80-82
NAAP V	37	2.2	40-41	40	4.33	42-42	75	3.33	81-80

These results show that, while all of the Sourdine II procedures impact throughput, capacity and delay adversely, Procedure V, apart from having peak throughputs on individual runways that are no worse to those of the other procedures, and better capacity on runway 27R, systematically produces higher delays and lower capacity than the others. Its overall peak throughput is also less than the others.

Procedure II has the highest value of delay recorded for a single flight and in particular conditions, for example in runway 27R, it doesn't have the best capacity, but it is the most promising procedure for the entire CDG airport, because it has the highest airport throughput, the lowest cumulative and average delays and the maximum airport capacity of all the Sourdine II procedures.

It must, however, be said that procedure II has to start the CDA farther out than procedures III & V, so to apply this procedure the spacing issued by the controller should start earlier. This is because, at the beginning of the CDA, the distance between two aircraft has to take into account the speeds which, from this point, have to follow the designed speed profiles (for each aircraft).

The effect of procedure III is not as good as that of procedure II, but is better than that of procedure V.