

## **FINAL REPORT FOR PUBLICATION**

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**ACRONYM: OPAL**

**TITLE: Optimisation Platform for Airports, including Land-side**

**PROJECT CO-ORDINATOR: NLR**

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## 1. Table of Contents

<b>1. Table of Contents</b> .....	<b>3</b>
<b>2. Executive Summary</b> .....	<b>4</b>
<b>3. Objectives of the Project</b> .....	<b>7</b>
<b>4. Scientific and Technical Description of the Results</b> .....	<b>8</b>
4.1 WP1: Operational concept for OPAL .....	8
4.2 WP2: Design of OPAL.....	12
4.3 WP3: Building of OPAL .....	17
4.4 WP4: Validation and calibration of OPAL .....	20
4.5 WP5: Evaluation of OPAL .....	22
<b>5. List of Public Deliverables</b> .....	<b>27</b>
<b>6. Results and Conclusions</b> .....	<b>28</b>
<b>7. List of Publications, Conferences and Presentations</b> .....	<b>30</b>
<b>8. Acknowledgements</b> .....	<b>32</b>
<b>9. References</b> .....	<b>33</b>
<b>10. List of Abbreviations</b> .....	<b>35</b>

## 2. Executive Summary

The ever-increasing growth in demand showed the vulnerability of the entire air transport infrastructure: airports are becoming the prime and foremost choking points within the system. Growth in air-traffic demand is not expected to slow down. Despite a recent dip due to the incidents on September 11, 2001, air traffic demand is foreseen to increase by about 4% per year for the next 15 years [1]. To cope with this growth, airport capacity must increase. However, this will put severe pressure on maintaining current safety and noise levels. Society also forces airports to increase safety and to reduce the burden of their operations on the environment.

To increase airport capacity while maintaining current safety levels and reducing the burden on the environment, airports may change their infrastructure through the construction of new runways and terminals, and/or they may change airport processes. Such changes are likely to have a huge impact on the overall airport process (i.e., on both the airport airside and the airport landside). To study these impacts and to preclude the start of unnecessary (and sometimes irreversible) changes and a waste of resources, major airport stakeholders (e.g., airlines, air traffic service providers, and airport operators) put forward a need for some sort of tool to evaluate the overall airport process at workshops on airport capacity problems held at the European Commission (EC) in 1998.

Major airport stakeholders experienced a lack of insight in the integrated set of airport processes and the individual process interdependencies. For instance, to increase capacity one might think of increasing runway capacity by new air traffic control measures. Traditionally, only dedicated dedicated airside models were used to evaluate the effects of those measures on the airside capacity, however, the subsequent increased passenger flows within the terminal or consequences on security measures could not simultaneously be studied. Landside models, if existent, had no link whatsoever with the airside models at hand. This precluded a study of the entire airport process, and thus precluded an optimisation of the entire airport efficiency taking into account safety and noise levels.

The European Commission (Directorate General for Transport and Energy) recognised the need for a platform that will allow airport stakeholders to evaluate the efficiency of the entire airport complex. In response to this need, it funded the research project OPAL (Optimisation Platform for Airports including Landside). The major objective of the OPAL project was to provide a generic concept for the development of a decision support system for total airport performance analysis. Within the framework of this project, a user-oriented platform was being developed that allows the integration of airport modelling tools in order to model and to evaluate simultaneously airport airside and airport landside, and their interaction. This platform is called the OPAL platform. It provides the ability to integrate capacity and delay-oriented tools with others, analysing environmental, safety, and cost-benefit impacts of airport operations. Furthermore, the OPAL platform concept was applied to six major European airports: Amsterdam-Schiphol, Athens International Airport, Frankfurt, Madrid-Barajas, Palma de Mallorca, and Toulouse-Blagnac.

The OPAL project was a project in the Fifth Framework Programme of the EC. It started in May 2000 and was completed in October 2002. A consortium co-ordinated by NLR and

consisting of 16 partners from 7 countries carried out the project activities. More specifically, the consortium consisted of:

• Aeropuertos Españoles y Navegación Aérea	Aena	Spain
• Chambre de Commerce et d'Industrie de Toulouse	CCIT	France
• Consorzio Padova Ricerche	CPADOR	Italy
• Communications et Systèmes	CS	France
• Deutsche Flugsicherung	DFS	Germany
• Deutsches Zentrum für Luft- und Raumfahrt	DLR	Germany
• École Nationale de l'Aviation Civile	ENAC	France
• Holland Institute of Traffic Technology	HITT	Netherlands
• International Air Transport Association	IATA	Canada
• Iberdrola Ingeniería y Consultoria	Iberinco	Spain
• Incontrol Enterprise Dynamics	Incontrol	Netherlands
• Indra Sistemas	Indra	Spain
• Ingeniería y Economía del Transporte	INECO	Spain
• Netherlands Economics Institute	NEI	Netherlands
• National Aerospace Laboratory	NLR	Netherlands
• Research Centre of Athens University of Economics & Business/Transportation Systems & Logistics Laboratory	RCAUEB/ TRANSLOG	Greece

The OPAL project yielded a concept for the integration and a first version of such a platform (the OPAL platform). This platform:

- Connects simulators/tools:
  - Capacity and delay: MACS, MACAD, PAX/BAX, PowerSim, SLAM, SIMMOD, TAAM, and Witness-MODA;
  - Safety: TOPAZ-TAXIR and TRIPAC;
  - Environment: INM;
  - Cost-benefit: CBM.
- Operates in a heterogeneous computer environment (because the simulators/tools required different hardware platforms and operating systems);
- Operates in a distributed European computer network (because the simulators/tools are located at geographically different sites within the OPAL consortium due to, e.g., licence and proprietary issues);
- Supports secured communications (through application of the ssh protocol).

As a result, the OPAL platform can

- Enhance the ability of existing simulators/tools to co-operate;
- Provide a unified and integrated platform for modelling and evaluating total airports:
  - At different sides of an airport;
  - At different levels of detail;
  - With respect to the interaction between landside and airside.
- Examine trade-offs between different kind of problems;
- Support the choice of simulator/tool combinations for specific types of analysis and that are tested and validated for one or more airports;
- Enable the operation of simulator/tool combinations for
  - Evaluation;
  - What-if analysis;
  - Optimisation.



- Integrate new/other simulators/tools than used in the project.  
In this way, use of the OPAL platform in the early stages of the design process will minimise time, cost, and risk for the development or enhancement of an airport and its systems and operations.

During the project, the OPAL consortium collaborated with EUROCONTROL. The latter organisation has started the INCOP project in parallel to the OPAL project, aiming to integrate its CAMACA tools into the OPAL platform. After a successful integration of these tools, the suggestion of transferring the OPAL platform (under certain conditions) to EUROCONTROL for maintenance and enhancements is under investigation by both the EC and EUROCONTROL.

Finally, the results of the OPAL project will be a starting point for the Integrated Project 11 "Airport Efficiency" within the EC's Sixth Framework Programme.

### 3. Objectives of the Project

The objective of the OPAL project was to provide a generic concept for the development of a decision support facility for total airport performance analysis, and to build a first version of such a facility: the OPAL platform. To achieve these objectives, the technical activities were subdivided into five work packages (WPs), each with its own (more specific) objectives:

- **WP1: Operational concept for OPAL**  
The objective of WP1 was to provide user requirements and an operational concept for OPAL, and to define scenarios for the evaluation phase.
- **WP2: Design of OPAL**  
The objective of WP2 was to provide a specification and architecture of the OPAL platform, a design of its components (viz., model base, database, scenario manager, optimisation and diagnosis tool, and human-machine interface) and the design of simulator/tool enhancements, all based on the user requirements and operational concept from WP1.
- **WP3: Building of OPAL**  
The objective of WP3 was to build the OPAL platform according to the design from WP2, to integrate the platform's components, and to test this platform from a functional viewpoint.
- **WP4: Validation and calibration of OPAL**  
The objective of WP4 was to validate and to calibrate the OPAL platform as built in WP3.
- **WP5: Evaluation of OPAL**  
The objective of WP5 was to evaluate the OPAL platform, both from a user-acceptance viewpoint and a socio-economic impact viewpoint.

## 4. Scientific and Technical Description of the Results

As mentioned in Section 3, the OPAL project comprised five work packages. All the results of these work packages have been reported in the various project deliverables; the publicly available deliverables are listed in Section 5. In this section, an overview is presented on the research approach of, the work performed under, and the results achieved in these work packages (WPs), and hence in the project OPAL.

### 4.1 WP1: Operational concept for OPAL

The objective of WP1 (co-ordinated by NLR) was twofold. The first objective was the derivation of user requirements and the definition of an operational concept for a decision-support facility for total airport performance analysis. The second objective was to provide the definition of scenarios for the six European airports for the evaluation of the first version of this facility in WP5.

In order to achieve these objectives, a description of total airports and an inventory of state-of-the-art and state-of-practice of airport performance tools was provided. As a result WP1 consisted of the following tasks:

- Task 1.1: Description of total airports;
- Task 1.2: Inventory of performance models for airports;
- Task 1.3: Definition of operational concept;
- Task 1.4: Definition of test scenarios.

In the following subsections, the approach and results of these tasks are presented.

#### 4.1.1 Task 1.1: Description of total airports

The purpose of Task 1.1, which was co-ordinated by DLR with contributions from Aena, CCIT, IATA, Incontrol, INECO, NLR, and RCAUEB, was to provide a description of total airports in terms of processes and actors of passenger, baggage, freight and aircraft flows. The landside part of a total airport was considered to be the airport terminal(s). The airside of a total airport was considered to be the airfield and terminal manoeuvring area (TMA). As a result, the boundaries of a total airport were formed by the check-in/check-out at the landside and the TMA entry/exit at the airside.

A generic description of total airports was then provided by addressing the following questions for each of the flows:

- What processes work on the flow?
- What actors are involved in these processes?
- Where do these processes take place?

Specific descriptions were added for the airports considered in the testing and validation (viz., the airports Amsterdam-Schiphol, Athens-Spata, Frankfurt, Madrid-Barajas, Palma de Mallorca, and Toulouse-Blagnac).

Based on expertise from the participants in this task, the flows (viz., passenger, baggage, freight and aircraft flows) were assigned to participants. These participants then prepared a description of the assigned flow (and possibly for the assigned phase: arrival or departure). Furthermore, specific descriptions for each of the airports considered in the project were provided by participants involved in testing and validating the OPAL platform for this airport.



#### 4.1.2 Task 1.2: Inventory of state-of-the-art and state-of-practice

The objective of Task 1.2, which was co-ordinated by RCAUEB with contributions from Aena, CPADOR, DLR, IATA, Incontrol, INECO, and NLR, was to provide a review of the state-of-the-art and state-of-practice of analytical and simulation tools addressing the airport airside or landside. The review considered tools addressing capacity, delay, safety, security, efficiency, cost effectiveness, and environment. The goal was to identify the areas of applicability of each category of tools as well as potential gaps and overlaps arising between these, and to address issues such as data needs, modelling accuracy, speed, and user-friendliness of each model/tool.

The state-of-the-art review mainly focused on the identification and description of tools that have been proposed for airport analysis studies. The emphasis lay on understanding the properties of the tools, their structure, the area of applicability, as well as their advantages and disadvantages. The state-of-practice review focused on case studies describing the actual implementation of available tools at specific airports. Here the main objective was to identify issues related to the implementation of existing tools.

Based on the profiles of the participants in this task, tools were assigned to participants for review. For each of the tools reviewed, the participants filled in a template. This template was essential for a systematic review as it provided a set of classification criteria of tools and their subsequent classification.

Though there is a rich experience in both tools and their specific application to support strategic, operational and design decisions for airports, several problems have been identified through the comprehensive review:

- Sharp division between available airside and landside tools: currently there is no single airport analysis tool that can provide an analysis for total airports;
- Lack of integration between models/tools able to provide capacity and delay estimates and models/tools able to provide environmental and safety analysis;
- Lack of harmonised/co-ordinated measures of effectiveness describing the performance of airside and landside airport elements;
- Lack of integration of models/tools addressing cargo- and passenger-handling activities;
- Lack of harmonised computing environment needed to execute the various tools;
- Lack of data harmonisation/translation to enable data interchange for different tools.

Further, the identified voids and gaps, and the advantages and disadvantages of existing tools led to the following conclusions:

- Airport strategic decisions can be adequately addressed by analytical tools;
- Airport planning and design decision should be mainly addressed by relevant simulation tools;
- Analytical airside models/tools can be integrated with analytical landside tools in order to provide an integrated environment for total airport strategic decision making;
- Simulation airside models/tools can be integrated with simulation landside tools to provide an integrated environment for total airport operational/design analysis.

#### **4.1.3 Task 1.3: Definition of operational concept**

The objective of Task 1.3, which was co-ordinated by NLR with contributions from Aena, CCIT, CPADOR, DLR, ENAC, IATA, INECO, and RCAUEB, was to provide a definition of an operational concept. This definition was provided in terms of a system overview and user requirements. The system overview and user requirements were based on outcomes of interviews with several foreseen users of the OPAL platform.

To enable interviewees to prepare for the interviews, a document was prepared, containing an OPAL description (based on a pre-design and a high-level concept) that sketched the proposed system and contained a questionnaire. Through this document, foreseen users of the OPAL platform were interviewed. These users included AAS, ADM, AENA, EC, ENAC, EUROCONTROL, FAG, HCAA, KLM, LVNL, SEA, TLS, and UPM. Although the majority of the respondents represented airport authorities, the interviewees cover the entire spectrum of potential users of the OPAL platform.

The data from the interviews were analysed in two phases. In the first phase the answers to the questionnaire were summarised using a template. In the second phase the summaries were analysed in order to determine:

- requirements regarding the OPAL platform as a decision support system;
- requirements on types of scenarios and questions to be handled by the OPAL platform;
- requirements on entities to be included into the OPAL platform;
- interface requirements;
- database needs;
- software operational requirements;
- other general requirements.

The fulfillment of several requirements depends on the availability and capability of airport models/tools and data. Therefore, the requirements were classified into requirements that are strictly platform related and requirements that depend heavily on the availability of models/tools foreseen to be connected by and to co-operate through the platform.

The results of the interviews suggested that potential OPAL users expect that the OPAL platform should be able to provide support to assess (long and medium term strategic and operational) decisions and to perform technical design. Further, their main interest was to assess changes in airport infrastructure and procedures in terms of capacity, level-of-service, cost and revenues, environment, and/or safety.

#### **4.1.4 Task 1.4: Definition of scenarios**

The objective of Task 1.4, which was co-ordinated by DLR with contributions from Aena, ENAC, IATA, Incontrol, NEI, NLR, and RCAUEB, was to define scenarios for evaluating tool combinations through the OPAL platform for one or more of the airports considered (viz., Amsterdam-Schiphol, Athens-Spata, Frankfurt, Madrid-Barajas, Palma de Mallorca, and Toulouse-Blagnac) and to propose tools for the scenarios. The scenario descriptions gave an exemplary view on the use of the OPAL platform. The definitions of scenarios for an airport were performed by the partners who will perform the validation, calibration, or evaluation of this airport in WP4 and WP5.

For Amsterdam-Schiphol, five questions were stated:

- How to improve full deployment of airport capacity within environmental and safety limits in future scenarios?
- How to preserve a specific determined 'declared delay/capacity' with traffic growth?
- How does delay affect the operational airline cost?
- Which bottlenecks can be expected with respect to the passenger growth at landside and how to solve them?
- Which measures have to be taken when using "super heavy aircraft" (such as the A380) at landside?

To assess these questions, the tools TAAM, INM, TRIPAC, TOPAZ-TAXIR, PAX, BAX, and CBM were proposed.

For Athens-Spata, four scenarios were defined that would be assessed by the tool combination MACAD-SLAM:

- Test adequacy of facilities in view of changes (increases) in the forecasted traffic for both airside and landside facilities;
- Test adequacy of level of service provided to the passengers in view of changes (increases) in the forecasted traffic for both airside and landside operations;
- Test impact of hubbing on the airport operations for both airside and landside;
- Test impact of changes in weather conditions on the airside and landside operations.

Using the tool combination MACAD-SLAM, each of the other airports would assess one of these four scenarios as well.

For Frankfurt, the effects of large aircraft (A3XX) was to be explored. The category of this type of aircraft is not yet defined. It either is "heavy" or gets its own category "super heavy". Therefore, the use of these aircraft can have various effects on airside operations: change in separation distances, restrictions during taxiing, limited parking space at the apron, and higher turn-around times. At the landside it has primarily impact on the passenger handling. For departing passengers, a bigger waiting room at the gate is mandatory. But also facilities like check-in desks, passport control, and security screening need more capacity to allow a good level of service despite the increased number of passengers. This is also valid for arriving passengers. To explore the effects, the tools TAAM and PowerSim have been proposed.

For Madrid-Barajas, the optimisation of the stand-position distribution and use (type of traffic and companies) was to be investigated for both the landside and airside viewpoint. The airside objective was to minimise the distance and taxi times, and the number of conflicts and interactions between flights on the ground. At the landside the objective was to minimise the walking distance for passengers and to optimise the distribution of passengers treatment resources (e.g., customs, luggage hippodromes, security controls, and checking points). Given the optimum stand-position distribution and use, the resulting scenario was to be evaluated with respect to its impact on environment, safety, and cost. To evaluate the scenario, the tools TAAM, WITNESS-MODA, INM, TRIPAC, and CBM were proposed.

For Palma de Mallorca, the purpose was to determine the optimised fleet composition for the time period under study (e.g., peak hour or saturated ten minutes blocks) such that the infrastructure is used in the best possible way. Fleet composition is defined as the classification of the traffic that operates regularly at the airport, as a function of aircraft category and type, together with other features such as aircraft performance, flight rules,

and procedures followed. The optimum fleet composition was then to be evaluated with respect to noise, safety, and cost. In the Palma de Mallorca scenario, the tools SIMMOD, WITNESS-MODA, INM, TRIPAC, and CBM were proposed.

For Toulouse-Blagnac four scenarios were mentioned:

- New freight area: the purpose of this scenario was to help organise the conception of a brand new freight area on the available airport spaces with respect to both airside (e.g., number of aircraft stands and links to the tarmac) and landside (e.g., organisation of warehouses and roads).
- New noise regulations: the purpose of this scenario was to determine whether the airport can cope with the changes in noise regulations.
- Scheduled flights: the purpose of this scenario was to check whether a new flight programme can be accepted.
- New implant: the purpose of this scenario was to help define whether a global area can accept or not the buildings dedicated to a new activity at the airport.

To assess the scenarios, the tools MACAD and MACS were proposed.

## 4.2 WP2: Design of OPAL

The objective of WP2 (co-ordinated by NLR) was to design the OPAL platform, based on the results of WP1. The activities in WP2 consisted of six tasks:

- Task 2.1: Design of system architecture and interfaces;
- Task 2.2: Design of model base;
- Task 2.3: Design of database;
- Task 2.4: Design of scenario manager;
- Task 2.5: Design of optimisation and diagnostics tool;
- Task 2.6: Design of HMI.

In the following subsections, the approach and results of these tasks are presented.

### 4.2.1 Task 2.1: Design of System Architecture and Interfaces

The purpose of Task 2.1, co-ordinated by Aena with contributions from ENAC, DLR, IATA, Iberinco, Indra, and NLR, was to provide the OPAL platform specifications and architectural design. The specifications and architectural design built upon (preliminary) results from the WP1 documents and upon co-operations with the other tasks in WP2, as Task 2.1 specifies high-level requirements which are further specified in the other tasks in WP2.

From the (draft) WP1 documents, the tools and tool combinations were specified. The tools selected for incorporation into the OPAL platform were the airside models/tools:

- TAAM (Total Airspace and Airport Modeller)
- SIMMOD (Airport and Airspace Simulation Model)
- MACAD (MANTEA Airfield Capacity and Delay Model)
- INM (Integrated Noise Modeller)
- TRIPAC (Third Party Risk Analysis Package for Aircraft Accidents around Airports)
- TOPAZ-TAXIR (Traffic Organisation and Perturbation Analyzer),

the landside models/tools:

- WITNESS-MODA
- PowerSim
- SLAM (Simple Landside Aggregate Model)
- PAX/BAX (Passenger/Baggage Model),

• MACS (Macro Cargo Simulation), and a cost-benefit model (CBM). The selected tool combinations/configurations and associated airports for testing were:

- TAAM-WITNESS-MODA(-CBM) for Madrid-Barajas
- SIMMOD-WITNESS-MODA(-CBM) for Palma de Mallorca
- TAAM-PowerSim for Frankfurt
- TAAM-PAX/BAX(-CBM) for Amsterdam-Schiphol
- TAAM-INM(-CBM) for Amsterdam-Schiphol and Madrid-Barajas
- TAAM-TRIPAC(-CBM) for Amsterdam-Schiphol and Madrid-Barajas
- TAAM-TOPAZ-TAXIR(-CBM) for Amsterdam-Schiphol
- SIMMOD-INM(-CBM) for Palma de Mallorca
- SIMMOD-TRIPAC(-CBM) for Palma de Mallorca
- MACAD-SLAM for all six airports
- MACAD-MACS for Toulouse-Blagnac airport

For each selected tool, its data streams and its system requirements were specified first. This specification constituted the basis for the system design and a high-level design of the OPAL global database (to be specified further in Task 2.3), the OPAL scenario manager (to be specified further in Task 2.4), the OPAL optimisation and diagnosis tool (to be specified further in Task 2.5), and the OPAL human machine interface (to be specified further in Task 2.6). The system architecture is depicted in Figure 1.

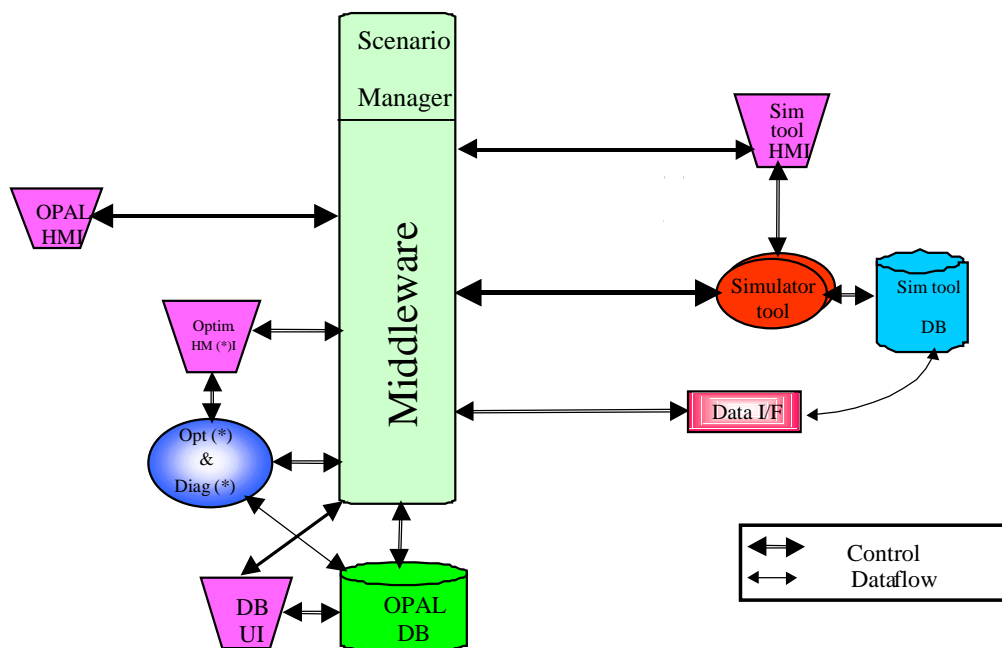


Figure 1: OPAL Architectural Design

#### 4.2.2 Task 2.2: Design of Model Base

The objective of Task 2.2, which was co-ordinated by RCAUEB with contributions from Aena, CPADOR, CS, DLR, ENAC, Incontrol, INECO, NEI, and NLR, was twofold: to determine the appropriate set of models needed to develop the model base for the OPAL platform, and to identify potential model enhancements needed to secure that the OPAL user requirements have been incorporated into this platform.

The models/tools selected have already been indicated in Section 4.2.1. Figure 2 shows the structure of the OPAL model base. This model base includes models/tools addressing issues related to capacity/delays, safety, environment, and cost-benefit. Since it is important to explore and analyse the impact and interrelationship between modules and different areas of application, several interactions between modules have been designed.

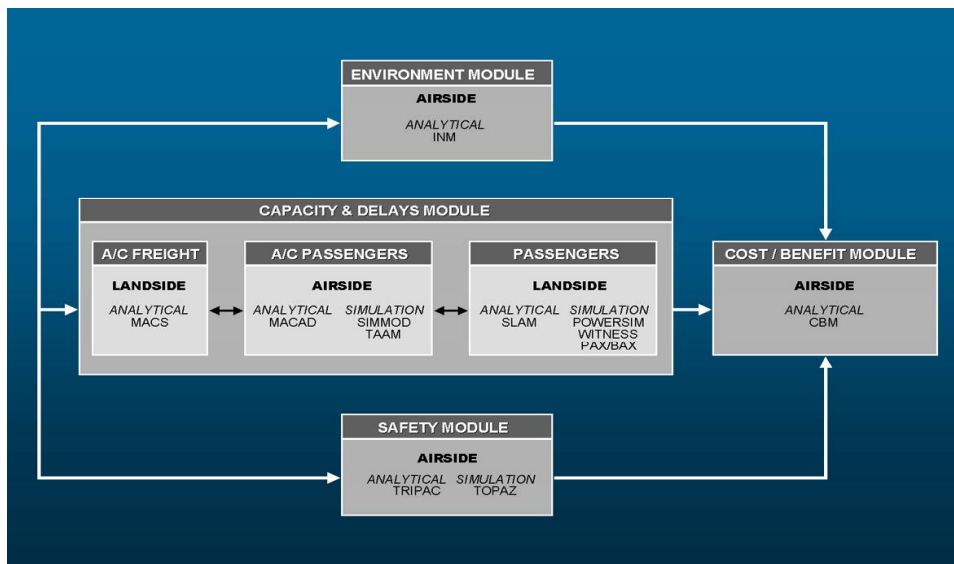


Figure 2: OPAL Model base

The identification of gaps and inefficiencies in the candidate models/tools, resulted into the decision to conduct the following model/tool enhancements or development:

- TAAM  
Aena would develop a "Ground Profiler" module that interacts with TAAM for the extraction and calculation of statistical data.
- SIMMOD  
INECO would enhance SIMMOD, adding four modules: a final approach sequencing module, an arrival stand-allocation module, a clearance time for off-block/taxi module, and a departure sequencing module. Further, Aena would develop a "Ground Profiler" that interacts with SIMMOD for the extraction and calculation of statistical data.
- MACAD  
RCAUEB would enhance MACAD with respect to apron modelling.
- TOPAZ-TAXIR  
NLR would assess the risk of runway incursions for taxiing aircraft crossing a runway using the TOPAZ methodology.

- PAX/BAX  
Incontrol would enhance PAX/BAX such that it provides additional output for the TAAM-PAX/BAX tool combination.
- WITNESS-MODA  
AENA would develop a module within WITNESS-MODA to integrate arriving and departing passengers.
- PowerSim  
DLR would use PowerSim to model the Frankfurt terminal.
- SLAM  
CPADOR would model a baggage-handling system within SLAM.
- MACS  
CS and ENAC would develop a macroscopic cargo simulation model for the airport landside.
- CBM  
NEI would develop a cost-benefit model.

#### 4.2.3 Task 2.3: Design of Database

The objective of Task 2.3, which was co-ordinated by DLR with contributions from all tool providers, was the design of the OPAL global database. This design was based upon the data streams identified and the tool combinations selected in Task 2.1. The design was expressed through entity-relationship diagrams. The purpose of the OPAL global database was to enable the exchange of data between models/tools.

To design the OPAL global database, the tool providers specified into more detail than in Task 2.1 the input and output streams of their tools, and in particular the data that may or will be exchanged through this database. These data streams were then assessed with respect to the actual data and data format. Following this assessment, data dependencies were extracted, which resulted into entity-relationship diagrams. Based on the entity-relationship diagrams and the database requirements specified in Task 2.1, a database management system was selected: MS-Access 2000.

#### 4.2.4 Task 2.4: Design of Scenario Manager

The objective of Task 2.4, which was co-ordinated by NLR with contributions from Aena and Incontrol, the design of the OPAL scenario manager. The main purpose of the scenario manager was to execute and monitor the test scenarios with the OPAL tool combinations. The activities in this task consisted of a description of the functionality of the OPAL scenario manager, the design of the OPAL middleware, the design of the OPAL workflows, and the design of the OPAL convergence/divergence analyser tool.

The OPAL scenario manager consisted of 3 interrelated parts:

- OPAL middleware
- OPAL graphical user interface
- OPAL workflows

The OPAL middleware is the interconnecting core of the OPAL platform. The OPAL graphical user interface presents the contents of the OPAL platform to the user. The OPAL workflows structure the contents of the OPAL platform.

The OPAL middleware has the following main functionality and capabilities:

- Specification/encapsulation of local/remote OPAL tools;
- Grouping of input/output data files into input/output data containers (directories);
- Interconnecting of local/remote OPAL tools and input/output data containers into workflows;
- Grouping of workflows and/or local/remote OPAL tools into folders (directories);
- Automatic/manual execution of workflows with local/remote OPAL tools;
- Automatic/manual activation of local/remote OPAL tools;
- Automatic/manual defaulting of options/arguments/parameters of local/remote OPAL tools;
- Automatic/manual transfer of input/output data files between local/remote hosts;
- Automatic/manual filtering of input/output data files between input/output data containers;
- Automatic/manual conversion of input/output data files between formats

The OPAL graphical user interface enables the browsing of all kinds of objects as icons in windows and the operations on these objects. The OPAL workflows are schemes of interconnected tools and data containers (i.e., a directed graph of icons). These workflows are an essential part for the mutual integration of the OPAL tools within the OPAL platform and for the execution and monitoring of the test scenarios with the OPAL tool combinations. The SPINeware middleware technology was selected as the OPAL middleware. SPINeware has been developed by NLR for NEC.

Further, to monitor successive runs of an OPAL airside tool and an OPAL landside tool within an OPAL tool combination for a certain OPAL test scenario, a convergence/divergence analysis tool was designed.

#### **4.2.5 Task 2.5: Design of Optimisation and Diagnostics Tool**

The objective of Task 2.5, which was co-ordinated by Aena with contributions from Iberinco and NLR, was to specify and design the OPAL optimisation and diagnostics tool. The aim of the optimisation tool was to enable the user to explore a set of alternatives. The aim of the diagnostics tool was to assess the integration feasibility between airside and landside tools.

Three procedures were considered in order to provide optimisation capabilities to the OPAL platform:

- Combinatorial graphical analyser exploring and classifying a set of airport configurations;
- One-dimensional optimiser seeking the optimum value of a selected parameter within a prespecified range;
- Two-dimensional optimiser seeking an optimum of two selected parameters within a prespecified range.

The most important purpose of the diagnostics tool is to identify relationships between the variables and events involved in the simulation, through tracing and displaying those variables and events to the user. This tool is useful to inspect the information integrity and to show the results in an easy way.

#### **4.2.6 Task 2.6: Design of HMI**

The objective of Task 2.6, which was co-ordinated by Aena with contributions from Iberinco, was to design the OPAL Human Machine Interface (HMI). This HMI should make the OPAL



platform easy and intuitive to handle, i.e., make the OPAL platform user friendly. The OPAL HMI was defined to consist of all elements of the OPAL platform where the user can exchange information with the OPAL platform.

The first step in the design of the OPAL HMI was to identify and classify all the elements of the platform where the user can exchange information. As the platform would (re-)use the HMIs of the individual tools that are connected to the OPAL platform as much as possible, this task focussed mainly on the OPAL HMIs for the access to the platform and for the optimisation and diagnostics tool, using the facilities provided by the OPAL middleware (i.e., SPINEware).

The main functions of the OPAL HMI are:

- presentation of the OPAL platform and providing guidelines to the user for the use of the platform;
- user login and validations;
- providing information and instructions about the use and features of the modules identified in Task 2.2;
- selection of module and tool combination.

The main functions of the OPAL optimisation and diagnostics tool HMI are:

- statement of optimisation problem;
- presentation of optimisation and diagnostics results.

### **4.3 WP3: Building of OPAL**

The objective of WP3 (co-ordinated by DLR) was to build the OPAL platform, according to the design in WP2. More precisely, it comprised of implementing the components designed in WP2 and the integration and functional testing of the OPAL platform:

- Task 3.1: Implementation of model base;
- Task 3.2: Implementation of database;
- Task 3.3: Implementation of scenario manager;
- Task 3.4: Implementation of optimisation and diagnostics tool;
- Task 3.5: Implementation of HMI;
- Task 3.6: Integration and functional testing.

In the following subsections, the approach and results of these tasks are presented.

#### **4.3.1 Task 3.1: Implementation of Model Base**

The objective of Task 3.1, co-ordinated by RCAUEB with contributions from Aena, CPADOR, CS, DFS, DLR, ENAC, Incontrol, INECO, NEI, and NLR, was to implement the simulator/tool enhancements/developments specified in the Task 2.2 and to design and implement the interfaces between the OPAL simulators/tools and the OPAL global database. The design of these interfaces was based on the OPAL global database design in Task 2.3, and the implementation was based on this design and the implementation of the OPAL global database (cf. Task 3.2). More precisely,

- CBM  
NEI designed and implemented CBM, including the interface with the OPAL global database.

- INM  
NLR designed and implemented the interface between the INM and the OPAL global database. To use INM in combination with TAAM, a TAAM .inp file has to be converted. As part of an NLR project, such a converter has been developed. To enable the use of this converter, NLR has implemented an interface between this converter and the OPAL global database.
- MACAD  
RCAUEB designed and implemented enhancements of MACAD. These enhancements concerned a new user interface, and an improved scenario generation and management.
- MACS  
CS and ENAC designed and implemented MACS.
- PAX/BAX  
Incontrol has designed and implemented the interface between the terminal passengers and baggage model PAX/BAX and the OPAL global database.
- PowerSim  
DLR has modelled the flows for arriving, departing, and transfer passengers in PowerSim for Frankfurt Airport. In addition, DLR designed and implemented the interface between PowerSim and the OPAL global database.
- SIMMOD  
Aena and INECO implemented enhancements of SIMMOD. Aena added a ground profiler module to SIMMOD. INECO added a final approach sequencing module, an arrival stand-allocation module, a clearance time for off-block/taxi module, and a departure-sequencing module. Moreover, INECO has designed and implemented the interface between SIMMOD and the OPAL database.
- SLAM  
CPADOR has implemented the enhancements of SLAM. The enhancements concerned the modelling of a baggage-handling system, and an improvement allowing a better data exchange and operations in a network environment. CPADOR provided the OPAL consortium access to the SLAM manual and a running version of SLAM through [www.math.unipd.it/opal](http://www.math.unipd.it/opal).
- TAAM  
DFS designed and implemented the interface between TAAM and the OPAL global database. Aena implemented a ground profiler module for TAAM.
- TOPAZ-TAXIR  
NLR has modelled a runway incursion model TAXIR in TOPAZ-TAXIR, and designed and implemented the interface between TOPAZ-TAXIR and the OPAL global database.
- TRIPAC  
NLR has designed and implemented the interface between TRIPAC and the OPAL global database.
- Witness-MODA  
Aena designed and implemented the enhancement of Witness-MODA: a module to integrate arriving and departing passengers. Furthermore, Aena designed and implemented the interface between Witness-MODA and the OPAL database.

In addition to the implementations, the participants in Task 3.1 provided a requirements traceability matrix and installation and user guides.

#### **4.3.2 Task 3.2: Implementation of Database**

The objective of Task 3.2, co-ordinated by DLR, was to implement the OPAL global database according to the design in Task 2.3. DLR implemented this database in MS-Access 2000. During the (design and) implementation of the interfaces between the OPAL simulators/tools and the OPAL global database, modifications to the database design and implementation were required. Also, requests from other OPAL components resulted in modifications to the OPAL global database. Further, during the testing of the interfaces by the integration team (cf. Task 3.6) additional modifications to the OPAL global database were required. As a result, DLR has updated the OPAL database (design and) implementation in various stages.

#### **4.3.3 Task 3.3: Implementation of Scenario Manager**

The objective of Task 3.3, co-ordinated by NLR, was to implement the scenario manager for OPAL. The scenario manager is based on the capabilities and functionality of the SPINeware middleware. Through NLR, consortium partners who required the installation of SPINeware individually signed licence agreements with NEC. After signing this licence agreement, NLR distributed the SPINeware software (version 3.5), including the installation and user guide, to these partners.

Since the delivery NLR provided support to the partners installing, configuring, and using SPINeware. Furthermore, through requests and specifications resulting from Task 3.6 (related to secure communication in particular), NLR prepared modifications and scripts for a tailored use of SPINeware.

In addition to the distribution of SPINeware, NLR implemented the convergence/divergence tool according to the design in Task 2.4, and provided the basics for the workflows (which were further specified by the integration team in Task 3.6).

#### **4.3.4 Task 3.4: Implementation of Optimisation and Diagnostics Tool**

The objective of Task 3.4, co-ordinated by Aena with contributions from Iberinco, was the implementation of the optimisation and diagnosis tool, according to the design in Task 2.5. Iberinco, together with AENA, performed this implementation and provided a user manual.

#### **4.3.5 Task 3.5: Implementation of HMI**

The objective of Task 3.5, co-ordinated by Aena with contributions from Iberinco, was the implementation of the human-machine interface (HMI), according to the design in Task 2.6. Iberinco, together with AENA, implemented this interface and prepared a user manual.

#### **4.3.6 Task 3.6: Integration and functional testing**

The objective of Task 3.6 was to perform the integration and functional testing of the OPAL platform such that this platform functions correctly from a technical viewpoint. This task was co-ordinated by Aena with the support of Indra (responsible for the local integration) and CS (responsible for the remote integration) and with contributions to the local and remote integration from ENAC and IATA and all simulators/tool providers.

As indicated, the activities in Task 3.6 were subdivided into 2 main categories:

1. Local integration
2. Remote integration

The local integration concerned the monitoring of the implementation activities in the other tasks in WP3 and the testing the implementations (i.e., enhancements, interfaces, convergence/divergence tool, optimisation and diagnosis tool, and HMI). In addition, the local integration concerned the further specification of the workflows from Task 3.3 in SPINeware and their testing. For each of the tool combinations considered in the OPAL project, a separate workflow is created. This workflow controls (for the tool combination under consideration) the complete execution of the local/remote tools and OPAL components involved. Together with the (successfully tested) OPAL components, the workflows constitute the OPAL platform. As part of the local integration, Indra prepared a CD-ROM with the OPAL components and an installation and user manual for the OPAL platform.

The remote integration concerned connection tests between pairs of OPAL partners. These tests comprised two tests: establishing a stand-alone secure (ssh) connection from one partner to the other and establishing an ssh connection from one partner to the other through SPINeware (enabling the former to browse through the directory of the machine of the latter). A prerequisite for performing the remote integration tests was the installation and configuration of a new version of cygwin (in case the partner involved is using a Windows machine), of Openssh (to enable secure communication between sites), and of SPINeware. CS and AENA both prepared guidelines for the installation and configuration of cygwin and Openssh. NLR provided supporting scripts related to the proper use of SPINeware under the new cygwin and secure communication. As a result of the remote integration, successful tests have been performed between:

- Aena and DLR
- Aena and NLR
- CS and NLR
- DFS and DLR
- DFS and NLR
- from Aena to CPADOR
- from CPADOR to RCAUEB
- from NLR to RCAUEB

In addition, as part of the collaboration between the OPAL project and EUROCONTROL's project INCOP (Integration of CAMACA in OPAL), successful tests have been performed between Aena and EUROCONTROL and between NLR and EUROCONTROL, through a joint effort by Aena, Indra, NLR, and EUROCONTROL. Furthermore, workflows have successfully executed from Aena using tools at NLR and DLR, and from EUROCONTROL using tools at Aena and NLR.

#### **4.4 WP4: Validation and calibration of OPAL**

The objective of WP4, co-ordinated by Aena, was to validate and calibrate the OPAL platform. It consisted of seven tasks:

- Task 4.1: Definition of validation and calibration methodology;
- Task 4.2: Validation and calibration of OPAL for Frankfurt;
- Task 4.3: Validation and calibration of OPAL for Amsterdam-Schiphol;
- Task 4.4: Validation and calibration of OPAL for Madrid-Barajas;
- Task 4.5: Validation and calibration of OPAL for Palma de Mallorca;
- Task 4.6: Validation and calibration of OPAL for Athens-Spata;
- Task 4.7: Validation and calibration of OPAL for Toulouse-Blagnac.

In the following subsections, the approach and results of these tasks are presented.

#### **4.4.1 Task 4.1: Definition of Validation and Calibration Methodology**

The objective of Task 4.1, which was co-ordinated by Aena with contributions from IATA and RCAUEB, was the preparation of a validation and calibration methodology for the OPAL platform. In this preparation advantage was taken from the projects CONVERGE and MAEVA.

The validation and calibration methodology described the way the OPAL platform was to be validated and calibrated. The validation should ensure that the results obtained through the OPAL platform will not be degraded compared to the situation without the OPAL platform. The calibration should ensure that the results obtained through the OPAL platform will have the highest accuracy possible. Each partner was to perform the validation and calibration for its implementations, except for the optimisation and diagnostics tool. The validation and calibration of this latter tool was assigned to different partners. In addition, for the validation, general indicators were defined. The partners performing the validation were to specify and tailor these to their situation.

#### **4.4.2 Tasks 4.2-4.7: Validation and Calibration of OPAL for six airports**

The objective of Tasks 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 was the validation and calibration of the OPAL platform using scenarios for the airports Amsterdam-Schiphol, Athens-Spata, Frankfurt, Madrid-Barajas, Palma de Mallorca, and Toulouse-Blagnac. The validation concerned the assessment of the performance of the OPAL platform against the user requirements and expectations as identified in Task 1.3. This meant verifying whether the platform worked properly with respect to the user requirements and whether it guaranteed expected and coherent data. Furthermore, in the validation it was checked whether the OPAL platform has been implemented according to the design specifications in WP2. In the calibration the accuracy and validity of the parameters and output of the simulators/tools were checked against real operational data.

The validation and calibration activities were performed with the local OPAL platform (and in parallel to the remote integration tests). The following OPAL components were validated and calibrated:

- Human-machine interface (HMI)  
The validation of the OPAL HMI concerned the verification that the HMI worked properly, permitting access to the OPAL platform and the selection of studies to be executed, and facilitating an easy-to-manage communication of the user with the platform. This validation was performed by all partners.
- Interfaces  
The validation of the interfaces between simulators/tools and the OPAL global database concerned the verification that the interfaces converted data properly into the adequate format and did not degrade the results. The organisations responsible for the implementation of these interfaces were also responsible for the validation and calibration.
- Global database  
The validation of the OPAL global database comprised of checking and guaranteeing that this database managed the data for the various OPAL components and the simulators/tools in the appropriate way. DLR performed this validation.

- Scenario manager  
The validation of the scenario manager comprised of two tasks:
  - Validation of the workflows  
The validation of the workflows consisted of checking that the implemented workflows ran without faults, activated the selected OPAL components and simulators/tools in the appropriate sequence and timing, and performed the data transport properly. The leaders of Tasks 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 (viz., DLR, NLR, Aena, INECO, RCAUEB, and CS, respectively) were responsible for this validation.
  - Validation and calibration of the convergence/divergence tool  
The validation and calibration of the convergence/divergence tool comprised of checking whether this tool provided proper advises for a given scenario. HITT performed this validation and calibration.
- Optimisation and diagnosis tool  
The validation and calibration of the optimisation and diagnosis tool was divided into four sub-activities:
  - Validation and calibration of the ranking optimisation  
The validation and calibration of the ranking optimisation concerned the verification that this tool properly ranked the results of a number of prespecified alternatives. NLR performed this validation and calibration.
  - Validation and calibration of the one-parameter optimisation  
The validation and calibration of the one-parameter optimisation concerned the verification that this tool determined the optimum parameter value within a prespecified range for a selected parameter. Aena performed this validation and calibration.
  - Validation and calibration of the two-parameter optimisation  
The validation and calibration of the two-parameter optimisation concerned the verification that this tool determined the optimum parameter value within a prespecified range for two selected parameters (one landside and one airside parameter) simultaneously. Aena performed this validation and calibration.
  - Validation and calibration of the diagnosis tool  
The validation and calibration of the diagnostics tool concerned to check that the results obtained through the OPAL platform were identical to those obtained without the OPAL platform. INECO performed this validation and calibration.
- Model enhancements  
Simulators/tools enhanced or developed within the project OPAL were individually validated and/or calibrated. These tools were CBM, MACAD, MACS, SIMMOD, SLAM, TAAM, TOPAZ-TAXIR, and Witness-MODA. The OPAL consortium partners responsible for the enhancements/developments performed this validation and/or calibration.

All OPAL components were successfully validated and calibrated, except the two-dimensional optimisation. For the two-dimensional optimisation, the optimisation problem could be properly defined and stored into the OPAL global database, but the interfaces of the simulators/tools involved in the optimisation did not provide all relevant data.

#### **4.5 WP5: Evaluation of OPAL**

The objective of WP5 (co-ordinated by RCAUEB) was to evaluate the OPAL platform for six European airports, using the test scenarios defined in Task 1.4. It consisted of eight tasks:

- Task 5.1: Definition of evaluation methodology;
- Task 5.2: Evaluation of OPAL for Frankfurt;
- Task 5.2: Evaluation of OPAL for Amsterdam-Schiphol;
- Task 5.2: Evaluation of OPAL for Madrid-Barajas;
- Task 5.2: Evaluation of OPAL for Palma de Mallorca;
- Task 5.2: Evaluation of OPAL for Athens-Spata;
- Task 5.2: Evaluation of OPAL for Toulouse-Blagnac;
- Task 5.8: General assessment.

In the following subsections, the approach and results of these tasks are presented.

#### 4.5.1 Task 5.1: Definition of Evaluation Methodology

The task (RCAUEB) defined together with Aena an evaluation methodology. In this methodology, the OPAL platform was evaluated for each of the six airports (viz., Amsterdam-Schiphol, Athens-Spata, Frankfurt, Madrid-Barajas, Palma de Mallorca, and Toulouse-Blagnac) on two evaluation criteria: user acceptance and friendliness, and socio-economic impacts. In addition, these evaluation criteria and their results were further evaluated as part of the general assessment.

The objective of the user acceptance and friendliness was to elicit users' attitudes to and perception of application(s) and the OPAL platform modules/functionality based on questionnaire surveys and interviews. The set of indicators for measuring user acceptance and friendliness is presented in Table 1.

ID	INDICATORS	DEFINITION	TYPE OF MEASUREMENT
I <sub>U1</sub>	Ease of creating scenarios	It measures the ease of setting-up scenarios by using the platform interface	Qualitative
I <sub>U2</sub>	Ease of modifying scenarios	It measures the ease of changing scenarios or particular elements thereof by using the platform interface	Qualitative
I <sub>U3</sub>	Average speed for setting up a scenario	It measures the time efficiency of creating a scenario	Qualitative
I <sub>U4</sub>	Ease of accessing the global database	It measures the ease of accessing and retrieving/ storing common data to the global database	Qualitative
I <sub>U5</sub>	Ease of using the scenario manager	It measures the ease of effectively using and navigating with the scenario manager	Qualitative
I <sub>U6</sub>	Ease of using the diagnostic/optimisation tool	It measures the ease of using the diagnostics/ optimisation tool	Qualitative
I <sub>U7</sub>	Provision of alternative options to users	It measures the ease of performing a particular task by using alternative system options / procedures	Qualitative
I <sub>U8</sub>	Flexibility	It measures the navigation flexibility of the user within the platform	Qualitative
I <sub>U9</sub>	Ease of simultaneously analysing alternative scenarios	It measures the ease of simultaneously analysing alternative scenarios	Qualitative
I <sub>U10</sub>	Overall presentation quality	It measures the presentation quality of the platform HMI	Qualitative
I <sub>U11</sub>	Ease of understanding the model results	It measures the ease of understanding the results provided by a particular platform run	Qualitative
I <sub>U12</sub>	Degree of training for effectively using the system	It measures the degree of training for effectively using the system and interpreting its results	Qualitative

Table 1: Indicators for measuring user acceptance and friendliness.

The objective of the socio-economic impact was to provide an estimation of the effectiveness or benefits derived from the use of the OPAL platform, as well as to explore the reliability/usefulness of the results provided by the platform with respect to the ability to

reflect reality in terms of airport operations. The corresponding set of indicators is presented in Table 2.

ID	INDICATORS	DEFINITION	TYPE OF MEASUREMENT
Is1	Quality of info provided with respect to noise contours estimation	It measures the quality of the results provided with respect to the estimation of the noise contours.	Qualitative
Is2	Quality of info provided with respect to total airport capacity	It measures the quality of the results provided with respect to the estimation of the total airport capacity.	Qualitative
Is3	Quality of info provided with respect to total airport delays	It measures the quality of the results provided with respect to the estimation of the total airport delays (i.e., airside, landside).	Qualitative
Is4	Quality of info provided with respect to the level of service of airport operations	It measures the quality of the results provided with respect to the level of serviced generated by the total airport operations.	Qualitative
Is5	Quality of info provided with respect to the true causes of total airport delays	It measures the quality of the results provided with respect to the identification of the true causes of airport delays (i.e., airside, landside).	Qualitative
Is6	Quality of info provided with respect to the utilisation of airport infrastructure	It measures the quality of the results provided with respect to the assessment of the utilisation of airport infrastructure (i.e., airside, landside).	Qualitative
Is7	Quality of info provided with respect to safety assessment	It measures the quality of the results provided with respect to the safety assessment of the airport operations.	Qualitative
Is8	Quality of info provided with respect to the quantification of costs and benefits stem from airport operations	It measures the quality of the results provided with respect to the quantification of the costs and benefits generated by airport operations.	Qualitative

Table 2: Indicators for measuring socio-economic impacts.

The qualitative assessment scale for both indicators is presented in Table 3.

Scale	Definition
5	<i>Very Good Performance</i>
4	<i>Good Performance</i>
3	<i>Average Performance</i>
2	<i>Poor Performance</i>
1	<i>Very Poor Performance</i>

Table 3: Qualitative assessment scale.

#### 4.5.2 Tasks 5.2-5.7: Evaluation of OPAL for airports

In the Tasks 5.2, 5.3, 5.4, 5.5, 5.6 and 5.7, the OPAL platform was evaluated for the airports Frankfurt, Amsterdam-Schiphol, Madrid-Barajas, Palma de Mallorca, Athens-Spata, and Toulouse-Blagnac, respectively. For the two evaluation criteria (as mentioned in Section 4.5.1) the selected tool combinations and scenarios in Task 1.4 were used. In addition, the MACAD-SLAM combination was used for each airport, as part of the horizontal socio-economic assessment.



#### 4.5.3 Task 5.8: General assessment

The two specific objectives of Task 5.8 were to identify the main strong and weak points of the OPAL platform based on the users' feedback and to identify its impact. The general idea was that there is a before and after situation where a high user participation in the production process is a key element. To this end, OPAL partners were requested to fill in the user acceptance and friendliness questionnaire for the "before" situation, using the same set of qualitative indicators.

In addition to utilising the individual assessments from Tasks 5.2-5.7, a general assessment questionnaire was developed by IATA and NLR. In general terms, the impact of a new mode of production falls into two categories. The first category relates to the ability to achieve goals, which was not necessarily the case before. It's referred to as *efficiency*. The second category refers to the ability to do more with possibly less. It's referred to as *productivity or effectiveness*.

- Questions 1, 2 and 3 are related to the ability of the OPAL platform to improve efficiency:
  1. Does OPAL fill a gap to achieve specific demand/capacity and operational objectives that would not have been achieved otherwise (please specify)?
  2. Does OPAL provide access to tools and/or methodology not accessible otherwise?
  3. Is availability of input data a limitation specific to OPAL or is it general problem to any study?
- Questions 4 and 5 provide a qualitative feedback on both effectiveness and efficiency:
  4. Does OPAL provide more and better information to the decision maker?
  5. Will using OPAL give you the opportunity to conduct studies more often or more studies?

The following concluding observations were elicited through the OPAL general assessment activities:

- Most OPAL partners involved in developing and using the platform indicate a strong productivity improvement when it comes to create, modify and setting scenarios.
- The partners reported to be very satisfied with accessing the global database, using the scenario manager, using the diagnostic/optimisation tool and with the overall presentation quality.
- The optimisation capability is definitively a significant improvement.
- It is not clear if OPAL can provide access to tools and methodologies not accessible before except although some tools (like CBM, MACS, MACAD, and SLAM) were developed or improved as part of the project. Most studies would be conducted anyway but would have required more time and resources.
- There is only limited improvement regarding the ease of performing a task by using alternative system options/procedures. The potential time saving associated with OPAL can be important but users consistently reported the learning of SPINeware requires significant time and effort, which should be considered when determining the overall time saved.
- Almost all users mentioned no change in the ease of understanding the model results. This result was expected.
- Data gathering remains a critical and difficult task.
- OPAL does not improve meeting planning objectives but facilitates their achievement.

- The partners consistently responded with a "Good Performance" rating with regards to OPAL's socio-economic potential with the exception of Is8, which was rated as "Average". However, it should be noted that one partner's rating for Is5 was "Poor".

The observations summarised above come from knowledgeable users involved in the development of the platform. The generalisation of the conclusions may not apply to all potential users. Further, there is an inherent "blackbox syndrome" when it comes to models in general, and OPAL is no exception. OPAL, if anything, confirms the need for relevant expertise and experience when conducting planning studies. There is the potential risk of an expert or consultant specialised in a particular airport system becoming involved in analysing interrelated systems because the platform provides additional outputs and possibilities. The right expertise and the right tools remain the key factors of a successful study. Finally, large organisations conducting studies on a regular basis and/or with significant resources are likely to benefit from using an OPAL type platform. It is not clear if medium or small organisations will benefit from investing in learning how to use the platform.

## 5. List of Public Deliverables

Table 4 provides an overview of the project deliverables. For each deliverable, this table indicates:

- deliverable's identification (Doc.ID)
- task corresponding to the deliverable
- organisation responsible for the deliverable
- deliverable's title
- date and reference number of the deliverable

Doc.ID	Responsible		Title	Reference
	Task	Organisation		
D1.1	1.1	DLR	Description of Total Airports	[2]
D1.2	1.2	RCAUEB	Inventory of Performance Models for Airports	[3]
D1.3	1.3	NLR	Definition of Operational Concept: System Overview and User Requirements	[4]
D1.4	1.4	DLR	Definition of Test Scenarios	[5]
D2.1	2.1	Aena	Platform Specification and Architectural Design	[6]
D2.2	2.2	RCAUEB	Design of Model Base	[7]
D2.3	2.3	DLR	Database Design	[8]
D2.4	2.4	NLR	Scenario Manager Design	[9]
D2.5	2.5	Aena	Optimisation and Diagnosis Tool Design	[10]
D2.6	2.6	Aena	HMI Design	[11]
D3.1	3.1	RCAUEB	Implementation of Model Base	[12]
D3.2/ D3.3	3.2/3.3	DLR & NLR	Test Report on Database and Scenario Manager	[13]
D3.4	3.4	Aena	Optimisation and Diagnosis Tool User Manual	[14]
D3.5	3.5	Aena	HMI User Manual	[15]
D3.6-1	3.6	Aena	Software Installation Guide	[16]
D3.6-2	3.6	Aena	First Steps with OPAL Platform	[17]
D4.1	4.1	Aena	Validation and Calibration Methodology	[18]
D4.2-4.7	4.2-4.7	DLR, NLR, Aena, RCAUEB, CS	Validation and Calibration of Report	[19]
D5.1-5.8	5.1-5.8	RCAUEB, DLR, NLR, Aena, ENAC	Evaluation of OPAL Platform	[20]

Table 4: List of public deliverables

## 6. Results and Conclusions

Complying with the objectives of the OPAL project, the two main results are:

1. A concept for an integrated computational platform for total airport performance analysis;
2. A first version of a computational platform for total airport performance analysis (called the OPAL platform) according to this concept, which was demonstrated for 6 major European airports: Amsterdam-Schiphol, Athens-Spata, Frankfurt, Madrid-Barajas, Palma de Mallorca and Toulouse-Blagnac.

The concept for the computational platform is characterised by the following technical specifications:

- The platform connects a variety of existing airport modelling tools in a distributed and heterogeneous computer environment; (the OPAL platform connects the tools CBM, INM, MACAD, MACS, Pax/Bax, PowerSim, SIMMOD, SLAM, TAAM, TOPAZ-TAXIR, TRIPAC, and Witness-MODA)
- The platform uses a dedicated database for data exchange between tools (i.e., output data of one tool that is used as input data of another tool is stored in a dedicated database by the former tool; the latter tool retrieves these data from this database);
- The platform supports secured communications;
- The platform is expandable by new / other tools than those used in the OPAL platform (the OPAL platform has demonstrated this through the integration of EUROCONTROL's CAMACA tool).

The implementation of the OPAL platform indicated:

- All applicable tool combinations have been successfully integrated and connected in the OPAL platform;
- The proper functioning of the particular tool combinations has been documented and the estimated results provided reasonable valid evidence (average or above average performance in most socio-economic indicators) for all airports and the specified scenario configurations. All applicable tool combinations examined have proved to properly function through the OPAL platform and accurately reflect reality in terms of their output / results, albeit by accepting some "irreducible minimum" of deviations from reality that are attributed to the inherent complexity in fully reflecting the actual airport operations and airport / scenario configurations.

As a result, the OPAL platform will be able to run scenarios pertaining capacity and delays by total airport operations, and to integrate these results with tools for assessing safety, environment and cost-benefit. Herewith, the platform will be able to support airport strategic and operational planning decisions that will guide future airport enhancements and developments and boosting the efficiency of total airport operations.

Furthermore, from a users' perspective, the main conclusions of the project are closely related to the observations that were elicited through the OPAL general assessment (in Task 5.8):

- Most OPAL partners involved in developing and using the platform indicate a strong productivity improvement when it comes to create, modify and setting scenarios.
- The partners reported to be very satisfied with accessing the global database, using the scenario manager, using the diagnostic/optimisation tool and with the overall presentation quality.

- The optimisation capability is definitively a significant improvement.
- It is not clear if OPAL can provide access to tools and methodologies not accessible before except although some tools (like CBM, MACS, MACAD, and SLAM) were developed or improved as part of the project. Most studies would be conducted anyway but would have required more time and resources.
- There is only limited improvement regarding the ease of performing a task by using alternative system options/procedures. The potential time saving associated with OPAL can be important but users consistently reported the learning of SPINEware requires significant time and effort, which should be considered when determining the overall time saved.
- Almost all users mentioned no change in the ease of understanding the model results. This result was expected because the OPAL platform was not intended or even could not enhance the ease of understanding the tools' results but rather the friendliness in using the tools through the platform.
- Data gathering remains a critical and difficult task.
- OPAL does not improve meeting planning objectives but facilitates their achievement.
- The partners almost unanimously rated the OPAL platform with a "Good Performance" evaluation score.

During the conducting of the project activities, two important observations were made, which may be considered as lessons learned:

- Integration of tools in a distributed computer environment is a complex task, requiring dedicated solutions for participating sites. Sufficient time and effort should be allocated to this task. Due to the dedication of the partners involved, the extension of the project duration, and the allocation of extra effort, this complex task was successfully completed.
- Calibration and evaluation of the platform required the availability of (accurate) data. The gathering of these data revealed to be a difficult task. For instance, some data was not directly available, some data was confidential, some data was difficult to understand, airport staff was not much involved or was overwhelmed by the amount of data. Moreover, no one within the OPAL consortium could enforce the collection of missing data. In future projects, it is suggested that the data required is already available at the start of the project or to have a work package (or task) dedicated to the collection of data.

Within the context of the Sixth Framework Programme (viz. Integrated Project 11 "Airport Efficiency"), results and lessons learned of the OPAL project can be used, limitations of the current platform can be alleviated, and improvements of the OPAL platform can be initiated.

## 7. List of Publications, Conferences and Presentations

The OPAL project and/or OPAL products have been presented:

- European SIMMOD User Group (Milan, October 5-6, 2000) by DLR;
- Workshop “Integrating Airports into Traffic of the Region” (DLR, Braunschweig, November 2000) by DLR;
- EUROCONTROL’s Airport Capacity Modelling Task Force, 5<sup>th</sup> meeting (EUROCONTROL, Brussels – December 20, 2000) by NLR;
- Aeronautics Days 2001 (Hamburg, January 29-31, 2001) by NLR;
- European SIMMOD User Group (Lanzarote, April 25-26, 2001) by Aena;
- Symposium “Simulation in ATM”, (Delft, June 2001) by CPADOR;
- Annual Conference of the Italian Operations Research Society (Cagliari, September 2001) by CPADOR;
- SPINeware Information Event (NLR, Amsterdam – September 12, 2001) by NLR;
- European SIMMOD User Group (Toulouse, October 25-26, 2001) by ENAC;
- Transport Research Board (Washington D.C., January 13-17, 2002) by RCAUEB;
- EUROCONTROL’s Airport Operations Team, 9<sup>th</sup> meeting (EUROCONTROL, Brussels – January 31, 2002) by NLR;
- Second Aeronautical Systems Workshop (Madrid) by INECO;
- EC’s Fifth Framework Project “ATC-Wake”, kick-off meeting (NLR, Amsterdam, July 10, 2002) by NLR;
- ICT Kenniscongres (The Hague, September 5-6, 2002) by NLR;
- AEA Technology (NLR, Amsterdam, September, 2002) by NLR;
- European Research 2002 (Brussels, November 11-13, 2002) by NLR;
- Transport Research Board (Washington D.C., January 12-16, 2003) by RCAUEB;
- ATC Maastricht 2003 (Maastricht, February 18-20, 2003) by NLR;
- Fifth EUROCONTROL/FAA ATM R&D Seminar (Budapest, June 23-27, 2003) by NLR;
- AIAA/ICAS International Air and Space Symposium and Exhibition: The Next 100 Years (Dayton, July 14-17, 2003) by NLR.

The OPAL project and/or OPAL products have been published:

- OPAL brochure.
- OPAL posters at ATC Maastricht 2001, Aeronautics Days 2001, ATC Maastricht 2002, European Research 2002, and ATC Maastricht 2003.
- M.J.A. van Eenige (NLR),  
“OPAL: Optimisation Platform for Airports, including Landside”,  
*International Airport Review* 6(3), pp. 59, 61 and 62, September 2002.
- J. Gille (NEI) and D. Mans (NEI),  
“OPAL: Optimisation Platform for Airports including Landside”,  
in ROTA (NEI’s quarterly publication; in Dutch) 2002.
- Student papers at RCAUEB.
- “Laurea” theses at CPADOR.
- Diploma thesis at DLR.
- S. Stroeve (NLR), H. Blom (NLR), and M. van der Park (NLR),  
“Multi-Agent Situation Awareness Error Evaluation in Accident Risk Modelling”,  
FAA/Eurocontrol ATM 2003.



- A. Rutten (NLR), H. Ten Have (NLR), and M. Van Eenige (NLR)  
“Integrated Airport Analysis, The Next Generation Decision Support Tools for Airport Stakeholders”, AIAA Paper 2003-2794, AIAA/ICAS International Air and Space Symposium and Exposition: The Next 100 Years.

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## 9. References

### 9.1 Supporting documents

- [1] European Commission (2002), *A Single European Sky: Broadening Horizons for Air Travel*.

### 9.2 Public deliverables

- [2] T. Mühlhausen (DLR),  
"OPAL: Description of Total Airports",  
Version 1.1, May 28, 2003.
- [3] K.G. Zografos (RCAUEB),  
"OPAL: Inventory of Performance Models for Airports",  
Version 1.0, October 31, 2003.
- [4] J.M. van den Akker (NLR), M.J.A. van Eenige (NLR), K.G. Zografos (RCAUEB), and Y. Portillo (INECO),  
"OPAL: Definition of Operational Concept: System Overview and User Requirements",  
Version 0.4, July 9, 2003.
- [5] T. Mühlhausen (DLR), A.J.C. Roeloffs (NLR), R. Arnaldo Valdes (AENA), Y. Portillo (INECO), K.G. Zografos (RCAUEB), and F. Mora-Camino (ENAC),  
"OPAL: Definition of Test Scenarios",  
Version 1.1, May 28, 2003.
- [6] J.A. Herreria Garcia (AENA), J.B. Raja Julve (AENA), and C.G.M. Welman (NLR),  
"OPAL: OPAL Platform Specification and Architectural Design",  
Version 1.1, July 9, 2003.
- [7] K.G. Zografos (RCAUEB),  
"OPAL: Design of Model Base"  
Version 1.1, July 9, 2003.
- [8] A. Keller (DLR) and T. Mühlhausen (DLR),  
"OPAL: OPAL Database Design",  
Version 2.52b, July 9, 2003.
- [9] M.J.A. van Eenige (NLR) and C.G.M. Welman (NLR),  
"OPAL: Scenario Manager Design",  
Version 1.1, July 17, 2003.
- [10] J.A. Herreria Garcia (AENA), J.B. Raja Julve (AENA), L.J. Alvarez Anton (Iberinco), V. Giner (Iberinco), and A. Guzman (Iberinco),  
"OPAL: Optimisation and Diagnosis Tool Design",  
Version 1.2, July 9, 2003.

- [11] J.A. Herreria Garcia (Aena), J.B. Raja Julve (Aena), L.J. Alvarez Anton (Iberinco), V. Giner (Iberinco), and A. Guzman (Iberinco),  
"OPAL: HMI Design",  
Version 1.1, July 9, 2003.
- [12] K.G. Zografos (RCAUEB),  
"OPAL: Implementation of Model Base",  
Version 1.1, July 17, 2003.
- [13] P.T. de Boer (NLR), M.J.A. van Eenige (NLR), L. Floc'hic (CS), and T. Mülhausen (DLR),  
"OPAL: Test Report on OPAL Global Database and Scenario Manager",  
Version 1.1, July 31, 2003.
- [14] J.B. Raja Julve (Aena), J.A. Herreria Garcia (Aena), A. Gúzman (Iberinco), C. Alvarez (Iberinco), and L.J. Alvarez Anton (Iberinco),  
"OPAL: Optimisation and Diagnosis Tool User Manual",  
Version 1.2, July 9, 2003.
- [15] J.A. Herreria Garcia (Aena), J.B. Raja Julve (Aena), M. Mendoza (Iberinco), M. López (Iberinco), and L.J. Alvarez Anton (Iberinco),  
"OPAL: HMI User Manual",  
Version 1.1, July 9, 2003.
- [16] M.A. Luna (Indra) and B. Trincado (Indra),  
"OPAL: Software Installation Guide",  
Version 1.1, July 9, 2003.
- [17] M.A. Luna (Indra) and B. Trincado (Indra),  
"OPAL: First Steps with OPAL Platform",  
Version 1.1, July 9, 2003.
- [18] R. Arnaldo Valdes (Aena), J.A. Herreria Garcia (Aena), J.B. Raja Julve (Aena), K.G. Zografos (RCAUEB), and C. Mirfin (IATA),  
"OPAL: Validation and Calibration Methodology",  
Version 1.1, July 9, 2003.
- [19] Aena, CPADOR, CS, DFS, DLR, ENAC, HITT, Incontrol, INECO, NEI, NLR, and RCAUEB,  
"OPAL: Validation and Calibration Report",  
Version 1.1, July 31, 2003.
- [20] RCAUEB, Aena, CCIT, CPADOR, DLR, ENAC, IATA, Incontrol, INECO, NEI, and NLR,  
"OPAL: Evaluation of OPAL Platform",  
Version 1.1, July 31, 2003.

## 10. List of Abbreviations

AAS	Amsterdam Airport Schiphol
AATT	Advanced Air Transportation Technologies
ACAM	Airport Capacity Modelling
ADM	Aéroports de Montréal
AENA	Aeropuertos Españoles y Navegacion Aérea
AOT	Airport Operations Team
ATC	Air Traffic Control
ATM	Air Traffic Management
CAMACA	Commonly Agreed Methodology for Airside Capacity Assessment
CBM	Cost Benefit Model
CCIT	Chambre de Commerce et d'Industrie de Toulouse
CPADOR	Consorzio Padova Ricerche
CS	Communications & Systems
DFS	Deutsche Flugsicherung
DLR	Deutsches Zentrum fuer Luft- und Raumfahrt
EC	European Commission
ENAC	Ecole Nationale de l'Aviation Civile
ESA	External Safety Analyser
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAG	Flughafen Frankfurt/Main A.G.
HCAA	Hellenic Civil Aviation Authority
HITT	Holland Institute of Traffic Technology
HMI	Human Machine Interface
IATA	International Air Transport Association
INM	Integrated Noise Modeller
IBERINCO	Iberdrola Ingenieria y Consultoria
INECO	Ingenieria y Economia del Transporte
KLM	Royal Dutch Airlines
LVNL	Air Traffic Control the Netherlands
MACAD	MANTEA Airfield and Delay Model
MACS	Macro Cargo Simulation
MAEVA	Master ATM European Validation Plan
MANTEA	Management of Surface Traffic in European Airports
NEI	Netherlands Economic Institute
NLR	National Aerospace Laboratory
OPAL	Optimisation Platform for Airports, including Land-side
RCAUEB	Research Centre of the Athens University of Technology
SEA	Società Esercizi Aeroportuari S.p.A.
SIMMOD	Airport and Airspace Simulation Model
SLAM	Simple Landside Aggregate Model
TAAM	Total Airspace and Airport Modeller
TLS	Toulouse Airport
TMA	Terminal Manoeuvring Area
TOPAZ	Traffic Organization and Perturbation Analyzer
TRANSLOG	Transportation Systems & Logistics Laboratory



TRIPAC

Third Party Risk Analysis Package for Aircraft Accidents around  
Airports

UPM

Polytechnic University Madrid

WP

Work Package