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EC Project Officer	EC – DG-TREN	Mr. H. Vu Duc	

Table of Contents

(28 pages in total)

List of Abbreviations

ACI	Airports Council International
Aena	Aeropuertos Españoles y Navegación Aérea
AIA	Athens International Airport
APRON	Aviation Policy Information Resources based on Observatory Networks
ARC	Airport Research Center
A-SMGCS	Advance Surface Movement, Guidance and Control System
ASTER	Aviation Safety Targets for Effective Regulation
ATM	Air Traffic Management
AUEB	Athens University of Economics and Business
BETA	Operational Benefit Evaluation by Testing an A-SMGCS
CAATS	Co-operative Approach to Air Traffic Services
CFR	Consorzio Ferrara Ricerche
DG	Directorate-General
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EC	European Commission
ECORYS	ECORYS Nederland
EMMA	European Airport Movement Management by A-SMGCS
E-OCVM	European Operational Concept Validation Methodology
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
HITT	Holland Institute of Traffic Technology
IATA	International Air Transport Association
Incontrol	Incontrol Management Consultants
INECO	Ingenieria y Economia del Transporte
Isdefe	Ingenieria de Sistemas para la Defensa de España
J2EE	Java 2 Platform Enterprise Edition
LEONARDO	Linking Existing On Ground, Arrival and Departure Operations
MAEVA	Master ATM Validation Plan
NLR	National Aerospace Laboratory NLR
ONERA	Office National d'Études et de Recherche Aérospatiales
OPAL	Optimisation Platform for Airports, including Landside
OPTAS	Optimisation of Airport Systems
Polar	Polar Consultores
SARS	Severe Acute Respiratory Syndrome
SICTA	Sistemi Innovativi per il Controllo del Traffico Aereo
SPADE(-2)	Supporting Platform for Airport Decision-Making and Efficiency Analysis (-Phase 2)
SWOT	Strengths-Weaknesses-Opportunities-Threats
TAPE	Total Airport Performance and Evaluation
THENA	Thematic Network on Airport Activities
TRANSLOG	Transportation Systems and Logistics Laboratory
TU Delft	Delft University of Technology
TREN	Energy and Transport
UC	Use Case
UML	Unified Modelling Language

1 Project execution

1.1 Background

Among all different transport modes, air transport has shown by far the largest traffic increase and growth potential during the last two decades. Despite the recent events with the negative impacts on the air transport industry (e.g., the depressed global economy, the terrorist attack of September 11, 2001, the Iraqi Wars, and SARS), analysts generally agree and recent traffic figures provide evidence that the industry starts to recover and air traffic growth rates are likely to return to their previous levels in the medium term. ACI Europe forecasts that international air passenger traffic will increase by an average of 3.6 % per year between 2002 and 2020. Moreover, with the enlargement of the European Union (EU) and the greater travel distances involved, air transport will play an even more important role in the integration of Europe.

Based on the anticipated demand figures, the traffic growth envisaged for the medium to long term future in EU Member States have to be mostly accommodated by a relatively small number of primary hub airports. In parallel, the reorganisation of the European sky under the dictates of the Single European Sky initiative and SESAR initiative will inevitably lead to an expansion in airspace capacity, which should be accompanied by increased capacity on the ground in order to maximise the benefits of the creation of a common air traffic management system in Europe. A direct consequence of the growing demand and the resulting mismatch between demand and supply of air transport and airport services is the increase of congestion problems both in the air and on the ground with considerable externalities and negative consequences reflected on the level of service offered to the travelling public, the efficiency of airport operations, the quality of the surrounding environment, and the safety of the entire air transport system.

The increasing demand and associated externalities, in conjunction with technical, physical and political constraints in providing sufficient capacity, have stimulated vigorous policy discussions toward examining and assessing the traffic implications on various airport performance metrics with focus on capacity and delay, level of service, environmental impacts, safety and security. Stakeholders and policy makers involved in or affected by the airport decision making process are asked to make decisions, draw policy directions, and operate in a quite complicated environmental, institutional, and operational setting. They often face challenging decision making questions with strong interdependencies and often conflicting objectives (trade-offs).

The decision making process and implementation for dealing with the decision making questions involve the deployment of technical expertise or decision support in (cf. Figure 1):

- Knowledge of the problem domain and scope;
- Knowledge of (selecting and using) tools capable of supporting the particular decisions;
- Interpretation of tool results in the particular decision making context; and
- Availability of appropriate data fulfilling the particular decision making and tool requirements.

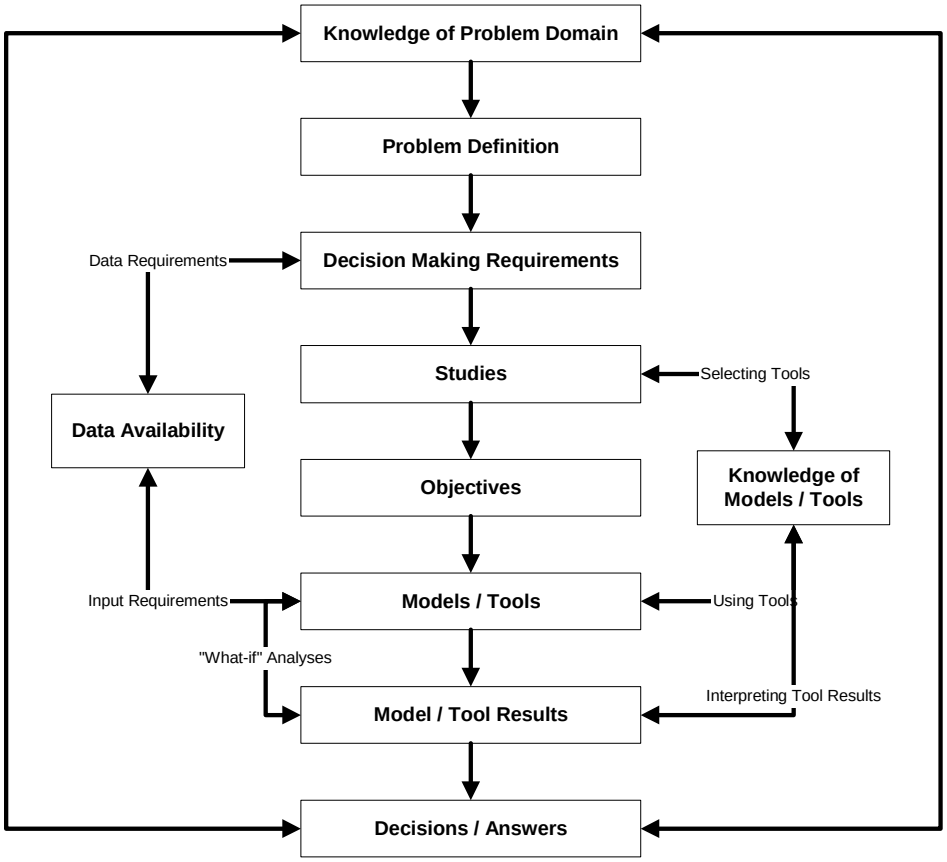

***Figure 1**: Airport Decision-Making Process*

1.2 Objectives

In response to the decision making requirements, the objective of the SPADE-2 Project is to design (if and where necessary - in addition to use cases already designed during Phase 1), implement, test and evaluate appropriate use cases that will be seamlessly integrated in a user-friendly computational platform (i.e., decision-support system) for airport stakeholders and policy makers. This system will provide support in airport (both airside and terminal) design, development and planning, allowing integrated impact and trade-off analyses for a variety of performance measures (e.g., capacity, delay, and level of service, environment, and safety). Use cases are a wizard-type use of an integrated set of tools assisting airport-domain experts in addressing widely arising airport planning, development or design questions (what-if) without requiring familiarity with the tools themselves.

The SPADE-2 Project addresses "Airport Efficiency" (within the Sixth Framework Programme of the European Commission). It is Phase 2 out of two phases. Phase 1 (and previous phase) dealt with the development of a complete design of the decision-support system and the implementation of an early prototype of the system. By means of this prototype, a visual example of the system to potential users was provided. Phase 2 concerns the actual implementation, testing and validation of the system.

1.3 State-of-the-art

A number of research projects in the airport domain have been funded by the European Commission during the last few years. These projects have four major research directions: i) airport capacity & efficiency optimisation, ii) validation and evaluation of ATM concepts, iii) development of safety and security standards, rules, and best practices, and iv) technology development in terms of airside, airspace, terminal, and ground equipment (cf. Figure 2). Among the major and most relevant projects in this field, the following can be listed:

- TAPE: The "Total Airport Performance and Evaluation" project was funded by the European Commission (DG VII). Its objective was the development and validation of a decision support system for airport performance evaluation and strategic planning.
- OPTAS A + B: The main objectives of the "Optimisation of Airport Systems A+B" projects funded by the European Commission (DG VII) projects were: i) to evaluate a suite of airside and terminal simulation tools to conduct a set of case studies to evaluate the potential capacity impacts of a range of initiatives likely to be introduced at European airports in the future, and ii) to develop a fast runtime, high level modelling tool which integrates the airside and terminal components of an airport.
- OPAL: The objective of the "Optimisation Platform for Airports, including Landside" project, funded by the European Commission (DG TREN), was to develop an integrated, distributed simulation platform for modelling, evaluating and optimising airport airside and terminal operations, independently or in conjunction.
- LEONARDO: The fundamental objective of the "Linking Existing ON ground, Arrival and Departure Operations" project, funded by the European Commission (DG TREN), was to demonstrate the feasibility of integrating existing arrival, departure and ground management tools for air transport operation. This project aimed at the integration of concepts and technologies allowing not only the sharing of information between the arrival, departure and ground movement tools, but also co-ordination, taking into account requests and constraints from their "neighbours" tools.
- ASTER: The major objective of the "Aviation Safety Targets for Effective Regulation" project, funded by the European Commission (DG TREN) was to develop a method and tools to define target levels of safety for the total air transport system and to support the identification of optimal safety improvement measures (through regulation) to achieve the target level of safety.
- MAEVA: The project titled "A Master ATM European Validation Plan", funded by the European Commission (DG TREN), aimed to define an overall validation strategy for the pre-EATMS (pre European ATM System) for the 5th Framework Programme validation projects, generating a validation master plan.
- CAATS: The project titled "Cooperative Approach to Air Traffic Services", funded by the European Commission (DG TREN), aims to define a co-ordinated, co-operative European approach to ATM research and technical support in the domains of safety, human factors and validation for ATM projects within the 6th Framework Programme.
- BETA: The main objective of the "Operational Benefit Evaluation by Testing an A-SMGCS" project, funded by the European Commission (DG TREN), was threefold: i) the implementation of mature A-SMGCS (Advanced Surface Movement Guidance and Control System) elements and the creation of industrial rules for integration, ii) the generation of operational procedures adapted to the new technology potential, and iii) the user operational benefit validation.
- EMMA: The objective of the "European Airport Movement Management by A-SMGCS" project, funded by the European Commission (DG TREN) in continuation of the BETA project, is the development, demonstration, and evaluation of a surface movement guidance and control system for airports.
- THENA: The main objective of the "Thematic Network on Airport Activities" project, which is funded by the European Commission (DG TREN), is to create and develop an environment of

co-ordination and collaboration, in order to increase the visibility and transparency of airport related research activities, as well as to identify new research needs and possibilities.

- APRON: The objective of the "Aviation Policy information Resources based on Observatory Networks" project, funded by the European Commission (DG TREN), is threefold: i) to identify and validate the requirements of the policy formulation process, ii) to integrate and harmonise the existing information collected from the various individual sources, and iii) to establish a physical communication network (airport observatory) that will enable the exchange of data between airport and air transport stakeholders.
- SPADE: The "Supporting Platform for Airport Decision-making and Efficiency Analysis" Project is the precursor of the SPADE-2 Project, and has been funded by the European Commission (DG-TREN) with the aim to identify user requirements, use cases and detailed design specifications for an integrated computational platform that will be able to support decisions related to airport development, planning and design allowing an integrated impact analysis with respect to a variety of measures of effectiveness (e.g., capacity, delay, level-of-service, safety, security, noise, and cost-benefit).

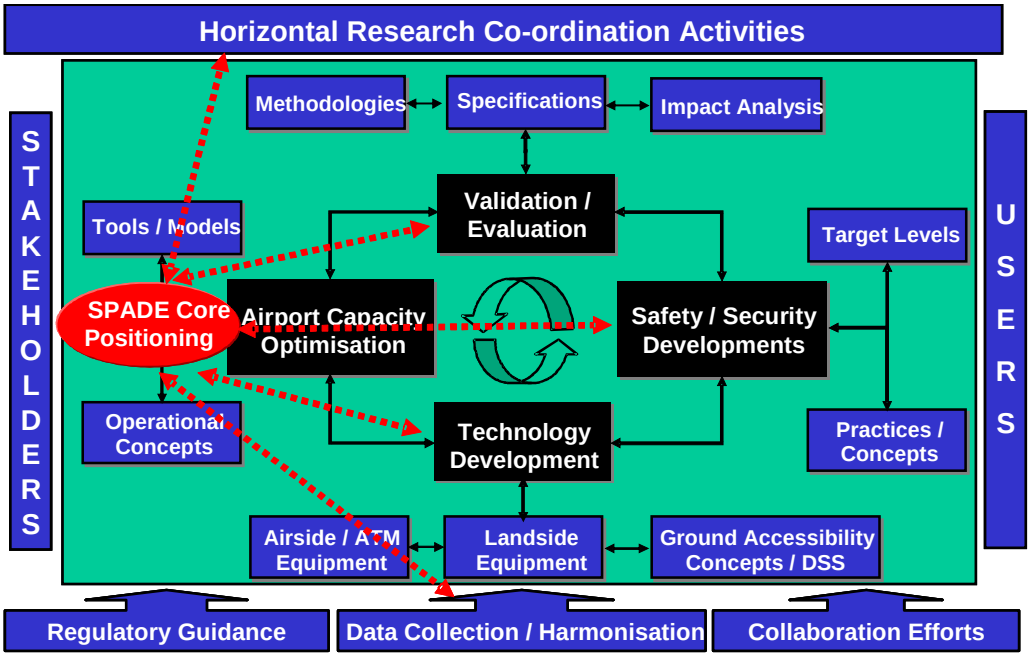

***Figure 2**: State-of-the-Art Review ("Research Map" in the Airport Domain in Europe)*

The above listed research projects mainly address modelling issues (e.g., TAPE, OPTAS, LEONARDO, OPAL, SPADE), validation / evaluation issues (e.g., MAEVA, CAATS), safety and security issues (e.g., ASTER, CAATS), and technology development issues (e.g., BETA, EMMA). Furthermore, a number of horizontal research activities (e.g., APRON, THENA, and CAATS) have been conducted with the purpose of co-ordinating research activities and integrating research results and related airport data on a collaborative environment in the sense of an airport observatory network. The SPADE-2 Project capitalises on work performed within the framework of the aforementioned research projects. In addition, SPADE-2 works closely together with on-going research projects by exploiting results and data that have been (will be) produced by these projects in all related directions (i.e., safety, security, validation / evaluation, technology development, horizontal and co-ordinated research activities). In that respect, although the core research activities

and focus of SPADE-2 are positioned under the category of airport capacity optimisation and modelling, it will develop research synergies and will fully consider the following aspects (cf. Figure 2):

1. Specifications and methodologies for validation / evaluation analysis;
2. Safety and security standards that have been determined through previous and on going research work;
3. Regulatory / policy constraints and issues;
4. Collected and harmonised airport data and results of studies performed through horizontal research activities in the airport domain.

1.4 Approach

As indicated the SPADE System is based on the concept of use cases (cf. Figure 3). In the context of the SPADE-2 Project, a use case is a “wizard-type”, integrated use of a set of tools assisting airport-domain experts in addressing a widely arising airport development, planning or design problem without requiring familiarity with the tools themselves. The wizard thus provides a pre-structured modelling environment which embeds the computational intelligence and familiarity of tool experts. The ultimate objective of use cases is to help airport-domain experts analyse the various airport performance trade-offs involved in each case (e.g., capacity, delay, level-of-service, safety, security, environmental impacts, and cost-efficiency) and to provide appropriate decision support. This concept enables the user to perform the analysis under consideration through "pre-structured" and built-in, "wizard-type" navigation aids in a single run by shielding the user from the complicated model and tool world: enabling him or her to focus on the real question to be addressed. The system will contain a specific set of use cases.

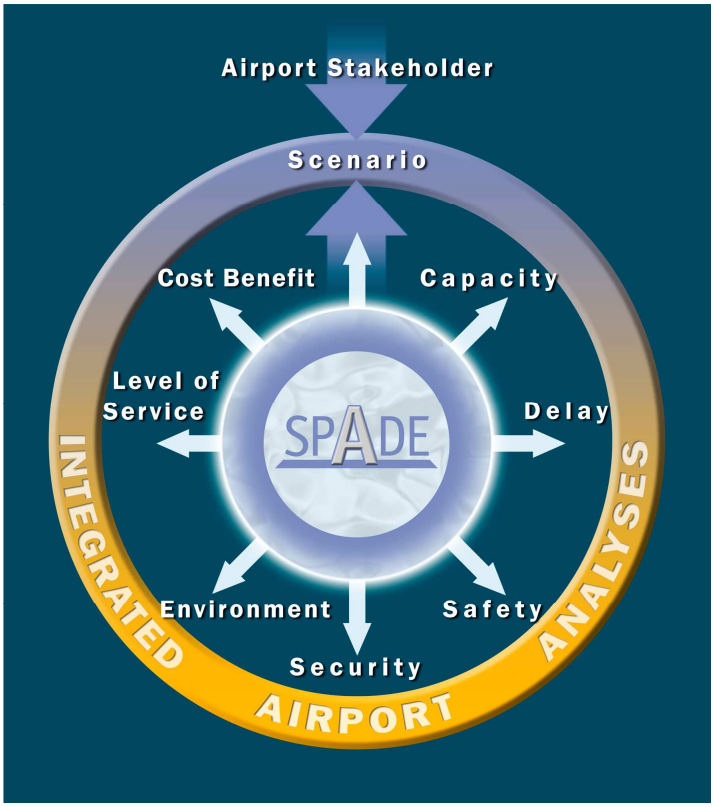

***Figure 3**: SPADE concept*

The activities in the SPADE-2 Project follow the standard lifecycle and consist of 5 major activities:

1. Preparation: The results and feedback of the SPADE Project (i.e., Phase 1) are assessed to update and detail the activities to be performed in the SPADE-2 Project.
2. Implementation and testing of system components. The system generic components (i.e., the components that are generic to the system and that may be used by different use cases) are implemented and tested.
3. Implementation, testing and integration of use cases. Each of the use cases is implemented and tested: its input and output interface, and its computational components. Furthermore, the implemented and tested use cases are seamlessly integrated into the SPADE System.
4. Validation. Any areas where the design and implementation of the use cases and the overall system do not properly support the provision of the functionality specified and the use case requirements are identified, and any correction is carried out.
5. Field exploitation and dissemination. This activity concerns an operational assessment of the system by airport stakeholders, and the determination of future use and commercial exploitation. Also two User Group Meetings and a World-wide Conference (on airport performance assessment) are organised.

Section 1.7 provides more details of the approach and the associated activities.

1.5 Results

The main results of the SPADE-2 Project are a user-friendly, fully tested (with regard to integration, validation against requirements, and usability and operational assessment) decision-support system for airport development, planning and design, and a set of use cases that are seamlessly integrated into this system. The system will enable airport stakeholders and policy makers to perform integrated impact analyses in the various levels of decision making through pre-structured paths and built-in, "wizard-type" navigation aids.

The results are elaborated in Section 1.7. With these results the SPADE-2 Project has accomplished its objectives.

1.6 Consortium

The activities in the SPADE-2 Project were conducted by a consortium consisting of 17 organisations from 7 different counties, which was co-ordinated by NLR. These organisations are listed in the table below.

Participant number	Participant name	Participant short name	Country
1	Nationaal Lucht- en Ruimtevaartlaboratorium (National Aerospace Laboratory NLR) Anthony Fokkerweg 2 1059 CM Amsterdam The Netherlands Main technical point-of-contact: Mr. Michel van Eenige	NLR	The Netherlands
2	Aeropuertos Españoles y Navegacíon Aérea Josefa Varcarcel 30 28027 Madrid Spain Main technical point-of-contact: Mr. Frederic Ham	AENA	Spain

3	Research Centre of the Athens University of Economics and Business - Transportation Systems and Logistics Laboratory Evelpidon 47A & Lefkados 33 11362 Athens Greece Main technical point-of-contact: Prof. Kostas Zografos	AUEB-RC/ TRANSLOG	Greece
4	Deutsches Zentrum für Luft- und Raumfahrt Lilienthalplatz 7 38108 Braunschweig Germany Main technical point-of-contact: Mr. Rainer Kiehne	DLR	Germany
5	International Air Transport Association 800 Place Victoria H4Z 1M1 Montreal Canada Main technical point-of-contact: Mr. Alex D'Amico	IATA	Canada
6	Amsterdam Airport Schiphol Evert van de Beekstraat 202 1118 ZG Schiphol The Netherlands Main technical point-of-contact: Ms. Joyce Groot	AAS	The Netherlands
7	Athens International Airport Administration Building 017 19019 Spata Greece Main technical point-of-contact: Ms. Christina Attesli	AIA	Greece
8	Airport Research Center Bismarckstrasse 61 52066 Aachen Germany Main technical point-of-contact: Mr. Ken Roeher	ARC	Germany
9	ECORYS Nederland Watermanweg 44 3067 GG Rotterdam The Netherlands Main technical point-of-contact: Mr. Dick Mans	ECORYS	The Netherlands
10	Incontrol Management Consultants Papendorpseweg 77 3528 BJ Utrecht The Netherlands Main technical point-of-contact: Mr. Simon van der Weij	Incontrol	The Netherlands
11	Ingenieria y Economia del Transporte Avenida del Partenón 4 28042 Madrid Spain Main technical point-of-contact: Mr. Jaime Garcia Saez	INECO	Spain

12	Ingenieria de Sistemas para la Defensa de España Edison 4, 28006 Madrid Spain Main technical point-of-contact: Mr. Vicente Bordon Galan	Isdefe	Spain
13	Office National d' Études et de Recherche Aérospatiales Avenue Edouard Belin 2 31055 Toulouse France Main technical point-of-contact: Mr. Sebastien Aubry	ONERA	France
14	Consorzio Ferrara Ricerche Via Savonarola 9 44100 Ferrara Italy Main technical point-of-contact: Prof. Giovanni Andreatta	CFR	Italy
15	Polar Consultores Condesa de Venadito, 1 28027 Madrid Spain Main technical point-of-contact: Mr. Enrique Castillo	Polar	Spain
16	Sistemi Innovativi per il Controllo del Traffico Aereo Viale Fulco Ruffo di Calabria c/o Aeroporto di Capodichino 80144 Naples Italy Main technical point-of-contact: Mr. Luigi Brucculeri	SICTA	Italy
17	Delft University of Technology Jaffalaan 5 2628 BX Delft The Netherlands Main technical point-of-contact: Mr. Paul Roling	TU Delft	The Netherlands

1.7 Activities performed and results achieved

As mentioned in Section 1.4, the activities in the SPADE-2 Project have been subdivided into five main activities:

1. Preparation;
2. Implementation of system components;
3. Implementation and integration of use cases;
4. Validation;
5. Field exploitation and dissemination.

The associated activities conducted and the results obtained are described in the next subsections.

1.7.1 Preparation

The first step in the actual implementation and validation of the SPADE System concerned the detailed specification of the work to be performed in the SPADE-2 Project based on the results and outcomes from the SPADE Project. To this end the following activities were performed:

- Review of use cases and update of descriptions
  In the SPADE Project 14 use cases have been described and categorised as either "strategic" (supporting medium to long-term decisions with analytical, high-level tools) or "operational" (supporting short to medium-term decisions with detailed simulation tools); see Table 1.

	ID SPADE	Title
Strategic use cases	Strat1	Expanding airport landside infrastructure
	Strat2	Airside infrastructure development
	Strat3	Airport capacity management
	Strat5	Sharp Traffic Increase
	Strat7	(a) Airport capacity vs. infrastructure elements (b) Airport bottleneck analysis
Operational use cases	Oper1	Fleet characteristics impact on airport operations
	Oper2	(Re-)allocation of flights
	Oper3	Impact of new airport equipment and procedures on airport operations
	Oper4	Analyse impact of new procedures
	Oper6	Airport capacity determination
	Oper7	New security devices and/or procedures
	Oper8	Taxiing methodology
	Oper9	Airport capacity vs. airside factors
	Oper11	Trade-off airport capacity versus environmental capacity and/or airport performance

Table 1: *List of use cases from SPADE Project*

Each of these use cases was reviewed and assessed. Special attention was paid to the completeness of the use case descriptions, specification and design, and to the overlap between different use cases in order to assess, for instance, whether use cases should be combined. The result of this assessment is summarised in Table 2.

New ID	Old ID(s)	Title
UC1	Strat1 Strat3 Strat5	Airport capacity management
UC2	Strat2	Match capacity and demand (sustainable)
UC3	Strat7a Strat7b Oper9	Integrated airport analysis
UC4	Oper1	Fleet characteristics impact on airport operations
UC5	Oper2 Oper7	Airport capacity utilisation (detailed)
UC6	Oper6	Airport capacity determination
UC7	Oper11	Airport capacity versus environmental capacity and/or airport performance
UC8	Oper8	Taxiing methodology
UC9	Oper3 Oper4	Impact of new equipment and/or procedures

Table 2: *Final list of use cases for implementation in SPADE-2 Project*

- Review of system architecture and use case design
  The SPADE System architecture and the use case designs were reviewed, and some open issues were identified, which had to be addressed in the implementation of the SPADE System and its use cases.

- Review of tools
  The list of tools associated with each of the use cases was reviewed, including their availability within the SPADE-2 Consortium. Table 3 lists the tools per use case.

Use Case	Tools
UC1	FLASH, MACAD, SLAM, INM, TRIPAC, CBM
UC2	ABS, INM, TRIPAC, CBM
UC3	SIMMOD, INM, LuciadATCPlayback
UC4	TRAFGEN, ESTOP, RAMS PLUS, TAAM, INM, CBM, CAST
UC5	SAMANTA, TAAM, CBM
UC6	TRAFGEN, ESTOP, TAAM, CAST
UC7	TRAFGEN, TAAM, SIMMOD, SAMANTA, INM, TRIPAC, CBM
UC8	TRAFGEN, ESTOP, TAAM, CAST
UC9	TAAM, SAMANTA, INM, TRIPAC, CBM

Table 3: *List of tools per use case*

- Review of feedback and lessons learnt
  The feedback obtained from key stakeholders during the SPADE workshops in Brussels and Malaga as well as through visits to airports was reviewed. One of the most important feedbacks concerned the terminology used, resulting in the development of a SPADE-2 Glossary.

1.7.2 Implementation

The next step in the development of the SPADE System was the implementation of system components and the implementation (and integration into this system) of use cases.

1.7.2.1 Implementation of system components

In the SPADE Project, the SPADE System was designed; see Figure 4. Based on this design the SPADE-2 Consortium implemented the various system components:

- Input component;
- Computational component;
- Output component;
- Data model and database (including database and model interfaces).

After their implementation, the individual connections of the system components were tested first:

- Input and output component to computational component;
- Database to computational component;
- Computational component to model interface.

Next, the system components were connected and tested. In particular end-to-end tests were performed, which spanned more than two components. This resulted in a properly functioning framework / core of the SPADE System, on top of which the use cases have been implemented and in which the use cases have been integrated.

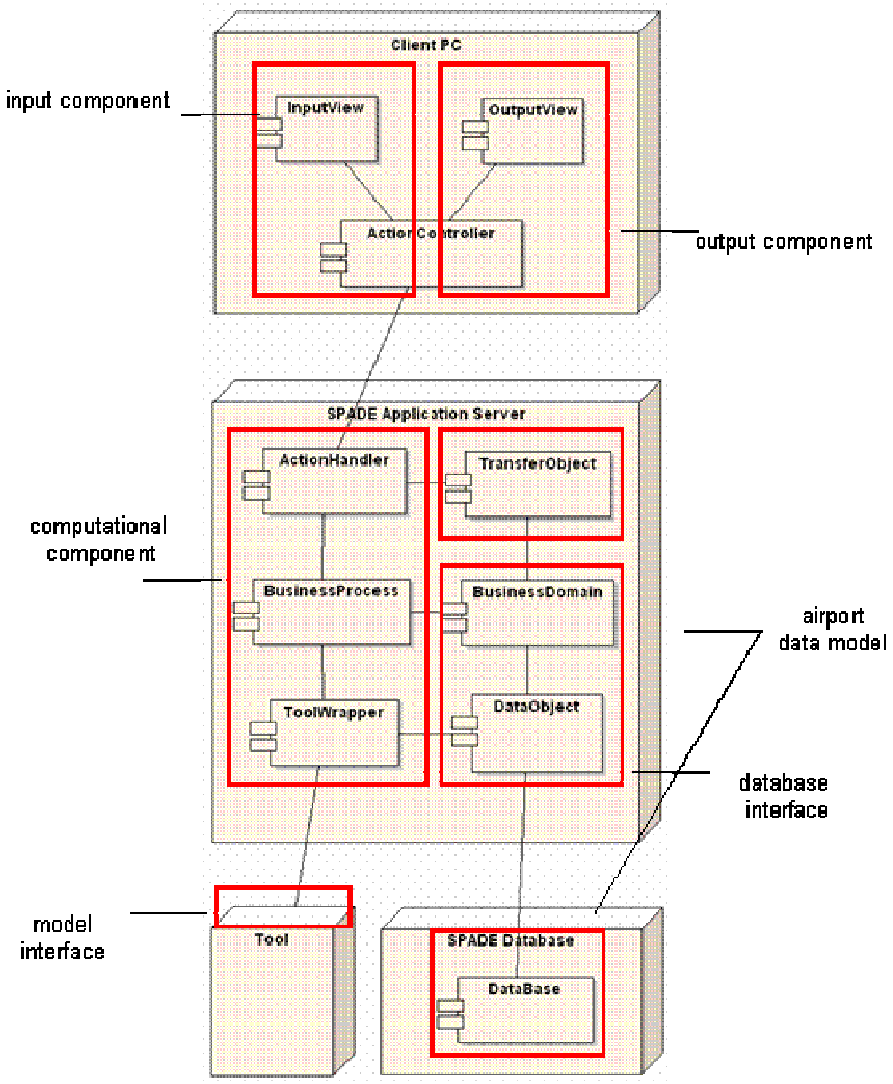

Figure 4: *SPADE System design and its generic components*

1.7.2.2 Implementation of use cases

Using the implemented system components, the nine use cases were implemented:

- UC1: Airport capacity management
  The objective of UC1 is to assess the impact of changes in airport infrastructure (e.g., expansion of runway system, apron area or check-in counters), operational procedures (e.g., security procedures, service times/disciplines or separation minima), and/or traffic volume or distribution (e.g., fleet characteristics, passengers' characteristics, traffic peaking or traffic growth). It addresses performance indicators such as capacity, delay, level-of-service, noise, third-party risk, and cost-benefits. UC1 integrates the following tools:
  - FLASH: flight schedule generator;
  - MACAD: airport capacity and delay tool;
  - SLAM: terminal capacity, delay, and level-of-service tool;
  - INM: noise around airport model;
  - TRIPAC: third-party risk model;
  - CBM: cost-benefit model.

- UC2: Match capacity and demand
  The objective of UC2 is to provide a generic analysis for airport strategic planning problems: what is the airport's baseline performance, what is the effect on airport performance for a business as usual strategy, what is the effect on airport performance after expanding the runway system, or what is the effect on airport performance after the implementation of a demand management strategy? UC2 addresses performance indicators such as capacity, delay, noise, third-party risk, and cost-benefits. It integrates the following tools:
  - ABS-FSG: flight schedule generator;
  - ABS-ACD: airport capacity and delay model;
  - INM: noise around airport model;
  - TRIPAC: third-party risk model;
  - CBM: cost-benefit model.
- UC3: Airport airside analysis
  The objective of UC3 is to assess the effects of changes in infrastructure/procedures from an airport airside perspective in order to highlight the airport zones that will be more congested or generate the largest delays. UC3 enables the analysis of a single airport layout and how traffic increase affects performance, and the comparison of how traffic increase affects two alternative airport infrastructures and/or procedures. It addresses performance indicators such as capacity, flow, demand, delay, noise, and safety (in terms of bottlenecks). UC3 integrates the following tools:
  - SIMMOD: fast-time airport airside simulator;
  - INM: noise around airport model;
  - LuciadATCPlayback visualisation tool for aircraft movements.
- UC4: Fleet characteristics impact on airport operations
  The objective of UC4 is to assess how potential changes in fleet characteristics (e.g., aircraft type, city pair, or flight schedule) will affect airport operations in terms of capacity (airside), efficiency, noise, and cost-benefits. UC4 integrates the following tools:
  - TRAFGEN: traffic generator;
  - ESTOP: runway-occupancy estimator;
  - TAAM: fast-time airport airside simulator (as alternative to RAMS PLUS);
  - RAMS PLUS: fast-time airport airside simulator (as alternative to TAAM);
  - INM: noise around airport model;
  - CBM: cost-benefit model;
  - CAST: visualisation tool for aircraft movements.
- UC5: Airport capacity utilisation
  The objective of UC5 is to analyse impacts of changes in external factors (e.g., airline alliances or new Schengen countries) and/or minor changes in terminal infrastructure (e.g., security or check-in procedures) or allocation rules (e.g., check-in and stands), with regard to capacity, passenger/baggage throughput, and cost-benefits. UC5 integrates the following tools:
  - Samanta: fast-time airport terminal simulator;
  - TAAM: fast-time airport airside simulator;
  - CBM: cost-benefit model.
- UC6: Airport capacity determination
  The objective of UC6 is to assess the impact of changes in traffic, or operational usage of airside elements (e.g., runway configuration, taxiing speeds, or separations) or change in weather (e.g., wind speed and direction, visibility, or temperature). UC6 addresses performance indicators such as capacity, delay, and level-of-service. It integrates the following tools:
  - TRAFGEN: traffic generator;
  - ESTOP runway-occupancy estimator;
  - TAAM: fast-time airport airside simulator;
  - CAST: visualisation tool for aircraft movements.

- UC7: Airport capacity versus environmental capacity and/or airport performance
  The objective of UC7 is to analyse the impact of airport optimisation (in terms of capacity or noise) on airport performance: what is the maximum environmental (noise) capacity of the airport, what is the impact of a noise optimised slight schedule, what is the impact of adding flights, what is the maximum airside capacity of the airport, or what is the impact of an airside optimised flight schedule? UC7 addresses performance indicators such as capacity (airside and terminal), level-of-service, noise, third-party risk, and cost-benefits. It integrates the following tools:
  - TRAFGEN: traffic generator;
  - TAAM: fast-time airport airside simulator (as alternative to SIMMOD);
  - SIMMOD: fast-time airport airside simulator (as alternative to TAAM);
  - Samanta: fast-time airport terminal simulator;
  - INM: noise around airport model;
  - TRIPAC: third-party risk model;
  - CBM: cost-benefit model.
- UC8: Taxiing methodology
  The objective of UC8 is to use taxiing methodology to optimise airport performance (e.g., modifying traffic, operational use, and/or weather conditions) with regard to capacity, delay, safety (number of conflicts), and efficiency (global quality factor). UC8 integrates the following tools:
  - TRAFGEN: traffic generator;
  - ESTOP: runway occupancy estimator;
  - TAAM: fast-time airport airside simulator;
  - CAST: visualisation tool for aircraft movements.
- UC9: Impact of new procedures and/or equipment
  The objective of UC9 is to assess the impact of implementing new procedures and airport equipment on investment cost, return on investment, and operational benefits, with regard to capacity (airside and terminal), delay, level-of-service, noise, third-party risk, and cost-benefits. For instance, what is the impact of changes in night regime, separation minima, or aircraft turn-around time. UC9 integrates the following tools:
  - TAAM: fast-time airport airside simulator;
  - Samanta: fast-time airport terminal simulator;
  - INM: noise around airport model;
  - TRIPAC: third-party risk model;
  - CBM: cost-benefit model.

After the implementation and testing of use cases, each use case was integrated into the SPADE System, resulting in a SPADE System with properly functioning use cases.

1.7.3 Validation

After the implementation of the SPADE System with its nine use cases, the system was subject to validation. The aim of the validation was to assess whether the implemented system and its associated use cases were capable of supporting the functionalities specified and the use case requirements elicited in the SPADE Project. The validation process was based on E-OCVM.

Each use case has been validated individually and through/within the system, comprising two types of activities:

- Validation of the use case and system against use case-specific and system requirements in order to assess whether the system and its use cases have been built right.
- Usability assessment in order to assess whether the right system has been built. To this end the SUMI questionnaire was used together with some other specific questions on usability.

In cases where it was concluded that the implementation of the SPADE system and its use cases did not adequately support the specified functionalities or did not adequately met the requirements, the implementation was modified and enhanced accordingly.

1.7.4 Field exploitation and dissemination

Two major dissemination activities have been performed within the SPADE-2 Project. The first one concerned field trials, in which potential users performed an operational assessment of the SPADE System. The second one concerned the organisation of two User Group Meetings and a World-wide Conference.

1.7.4.1 Field trials

The SPADE-2 Project organised field trials in which potential users performed an operational assessment of the SPADE System as the final step in its validation process. After some training they actually used the SPADE System to perform studies of their interest. Each use case was subject to these field trials. The list below provides an overview of the organisations that were involved in performing these trials (the so-called use case field trial champion).

Use case	Use Case Field Trial Champion
UC1	AIA
UC2	NLR
UC3	Naples Airport
UC4	Malaga Airport
UC5	Amsterdam Airport Schiphol
UC6	Malaga Airport and Santander Airport
UC7	Amsterdam Airport Schiphol
UC8	Malaga Airport and South-Tenerife Airport
UC9	Amsterdam Airport Schiphol

In general the use case field trial champions appreciated the SPADE System, in particular with regard to the interface and the wizard-style workflow, facilitating the use of tools that were previously difficult to use. Further, they provided valuable advices for improvements to specific use cases.

1.7.4.2 User Group Meetings and World-wide Conference

The SPADE-2 Project organised two User Group Meetings and a World-wide Conference.

1.7.4.2.1 User Group Meetings

The SPADE-2 Consortium considered the establishment of a User Group as an appropriate means to perform dissemination activities within the SPADE-2 Project. This group consisted of airports and airport stakeholders. The members of this group were invited to the two User Group Meetings organised. The first one took place at Athens International Airport (AIA) on June 18, 2009, whereas the second one was held on November 6, 2009 at Las Palmas de Gran Canaria, just after the SPADE World-wide Conference (see Section 1.7.4.2.2).

- **First User Group Meeting**
  The agenda of the first User Group Meeting (held at AIA on June 18, 2009) was:

Description	Responsible
Welcome and introduction	NLR
Presentation: SPADE-2 Overview	NLR
Presentation: Overview of SPADE Use Cases	AUEB-RC/TRANSLOG
Presentation/Demonstration: Use Case on Airport Capacity Management	AUEB-RC/TRANSLOG

Facilitated discussion and feedback from participants	Aena
Presentation/Demonstration: Use Case on Trade-off Airport Capacity and Environmental Capacity	NLR
Facilitated discussion and feedback from participants	Aena
Presentation: Exploitation	Aena
Wrap-up	NLR

In addition to consortium members, the following members of the User Group participated in this Meeting:

Company
Amsterdam Airport Schiphol
Athens International Airport
EC
Frankfurt Airport
IATA
Milan-Malpensa Airport
MIT
Oslo Airport

In the User Group Meeting the attendees proposed several recommendations. Some of them could be considered within the scope of the SPADE-2 Project, whereas others were considered for follow-up activities and projects.

- **Second User Group Meeting**
  The agenda of the second User Group Meeting (held in Las Palmas on November 6, 2009) was:

Description	Responsible
Presentation: SPADE-2 Project ✈ Introduction ✈ Overview of the main project outcomes ✈ Overview of comments and recommendations from the previous User Group Meeting	NLR
Presentation: Importance of a tool such as SPADE-2 for the creation or modification of Airport Master Plans	Polar
Presentation: SPADE-2 Future Expansion / Enhancement Opportunities	INECO
Presentation: Exploitation Results	Isdefe
Exhibition: SPADE-2 Use Cases	SPADE-2 Consortium
Wrap-up	NLR

In addition to consortium members, the following members of the User Group participated in this Meeting:

COMPANY / PROJECT
Aena
Amsterdam Airport Schiphol
Frankfurt Airport
IATA
Linkoping University
Milan-Malpensa Airport
Munich International Airport

The recommendations provided by the attendees focused on potential improvements and expansions for consideration in follow-up activities and projects.

1.7.4.2.2 World-wide Conference

In addition to the two User Group Meetings the SPADE-2 Project organised a World-wide Conference on airport performance assessment, which was held in Las Palmas de Gran Canaria on November 4-5, 2009. The presentations of international speakers from Europe and the Unites States of America were organised in two sessions and completed by a round-table discussion on the main issues which were raised during the two sessions.

More precisely, the agenda of the SPADE World-wide Conference was:

Day 1: November 4, 2009

Welcome session

- Welcome by the Chairman of the Organising Committee – Michel van Eenige (SPADE-2 Project Manager – NLR)
- Welcome by the European Commission- Hoang Vu Duc (Project Officer)

Session 1: Performance Assessment: A Policy Perspective
Chairman: Hoang Vu Duc (Project Officer - European Commission)

- The influence of evolving policy goals on airport performance assessment – Richard Marchi (Senior VP of ACI – North America)
- Airport in the SESAR context – Alejandro Egido (SESAR WP6 Leader – Aena)
- Airport Development Policy – Speaker: Colin Spear (IATA)
- Airport in the framework of the EU policy – Speaker: Hoang Vu Duc (Project Officer – European Commission)

Day 2: November 5, 2009

Session 2: Total Airport Performance Assessment: State-of-the-Art
Chairman: Prof. Konstantinos G. Zografos (AUEB-RC/TRANSLOG)

- Measuring the total economic impact of delays – Professor Mark Hansen (University of California, Berkeley)
- The SPADE-2 Decision Support System for Integrated Airport Performance Assessment – Michel van Eenige (SPADE-2 Project Manager – NLR) and Prof. Konstantinos G. Zografos (AUEB-RC/ TRANSLOG)
- An analysis of congestion of inbound air traffic – Professor Paolo Dell'Olmo (University of Rome "La Sapienza")
- Assessment of airport performance using analytic, fast-time and human-in-the-loop simulation – Professor Antonio Trani (Virginia Polytechnic Institute and State University)

Session 3: Airport Congestion Management & Delays: State-of-Practice
Chairman: Michel van Eenige (SPADE-2 Project Manager – NLR)

- Recent airport congestion management initiatives in the United States – Professor Michael Ball (University of Maryland)
- A comparison of US and Europe airport delay drivers – David Knorr and Philippe Enaud (FAA and EUROCONTROL PRU)

- Extensions of the level of service concepts at airports for planned traffic – Professor Johannes Reichmuth (RWTH Aachen University)
- Forecasting airport delays – Dr. David Chin (FAA)
- Definition and measure of KPIs to monitor airside airport performance in Europe – José Luis Garcia Chico (CRIDA/Aena)

Round-Table Discussion
Moderator: Professor Giovanni Andreatta (University of Padova)
Discussants:
- Hoang Vu Duc (Project Officer – European Commission)
- Prof. Bruno Desart (EUROCONTROL)
- Colin Spear (IATA)
- Manuel Dorado (Aena)

1.8 Intentions for use and impact

The main intention for use of the SPADE-2 Project is that airport stakeholders and policy makers (e.g., airports and EC) will use the SPADE System to provide support to their decision-making questions. To this end, the SPADE-2 Consortium used (intermediate) results to interest them in the SPADE System, hereby further customising the system to their needs (e.g., needs related to the types of questions to be addressed and to the user interaction). This interest was and will be raised by presentations by the SPADE-2 Consortium at various forums; for instance:

- interactions with related projects (e.g., with AGAPE, AIMS, CAATS-2 and SESAR, and through ATM Projects Meeting) and with EUROCONTROL;
- participation in conferences and exhibitions, e.g.,:
  - Aeronautics Days 2006;
  - 21st European Conference on Operational Research "OR for Better Management of Sustainable Development";
  - IFAC Symposium on Control in Transportation Systems;
  - 25th Congress of the International Council of the Aeronautical Sciences;
  - 26th Congress of the International Council of the Aeronautical Sciences
  - 86th Transportation Research Board Annual Conference;
  - 87th Transportation Research Board Annual Conference;
  - 88th Transportation Research Board Annual Conference;
  - Transport Advisory Group - The Netherlands;
  - Airports 2020 Conference & Exhibition;
  - European ATM Innovation;
  - Fourth DGLM Workshop on State-of-the-art in ATM, Civil Aviation and Maritime Affairs (DGLM), Dutch Ministry of Transport, Public Affairs and Water Management;
  - EPISODE 3 / CAATS II Joint Dissemination Event.
- papers:
  - proceedings of ICAS2006;
- organisation of SPADE User Group Meetings:
  - SPADE User Group Meeting in Athens;
  - SPADE User Group Meeting in Las Palmas.
- organisation of SPADE World-wide Conference:
  - Airport assessment conference in Las Palmas.
- visits to airports:
  - Amsterdam Airport Schiphol;
  - Berlin-Brandenburg International Airport;

- Malaga Airport;
- Naples Airport;
- Santander Airport;
- South-Tenerife Airport.

Also a SPADE-2 brochure and the public SPADE(-2) web-site contributed to raising general awareness of the SPADE-2 Project and its intentions. All publicly available information and results of the SPADE-2 Project can be accessed through the public project website (http://spade.nlr.nl).

The major argument to interest airports and stakeholders in the SPADE System is its strong and positive impact on two major key strategic aspects:

1. The improvement of the airport decision-making process quality through an integrated and systematic impact analysis, e.g., of capacity, delay, noise, and security.
2. The homogenisation and rationalisation of this process at a European level through addressing a standard set of questions or use cases related to airports. What changes from airport to airport are, of course, the airport data as well as a relatively limited number of assumptions that underlie the analysis.

In addition to these key strategic aspects, the SPADE-2 Project also responds to societal needs. For instance, the SPADE System

- Contributes to solving one of the major problems airport stakeholders face in working with information and software supporting tools: their complexity. The SPADE system exhibits the capability of supporting airport-modelling decisions and identifying potential sources of inefficiency of airport operations. In effect, improved airport efficiency will reduce delays and the resulted "out-of-pocket" cost suffered by the various airport users, while it will indirectly improve employment and working conditions of the airport and air traffic management personnel. As a matter of fact, an improvement in the airport operations (e.g., reduction of delays, demand smoothing, and reduction of congestion) will be, in turn, reflected on the working conditions in terms of the workload and anxiety related to airport personnel involved especially in critical safety activities.
- Contributes to improving external safety of air transport by a capability of performing specific external safety analysis for particular airports (i.e., assessing the safety level within airport borders and the residential area around the airport). External safety considerations are not widely taking into consideration yet, but these considerations may draw the increasing attention of policy makers and aviation stakeholders as part of monitoring the fulfilment of air transport safety standards in general.
- Provides the capability of specifying noise exposure of the area around the airport. This feature of the system enables the user to assess the impacts of alternative enhancements and modifications of the airport infrastructure and the operational procedures that are currently in effect, with the aim to reduce the residents' disturbance due to the noise exposure produced by aircraft operations.

Both the aforementioned policy issues and social aspects are considered to be major concerns of the European Community and they have received high priority for consideration among the objectives of past and on-going RTD (Research and Technological Development) projects. Nevertheless, a next step of the SPADE System is to cover environmental aspects in order to meet the increasing need for (more) environmental-friendly air transport (e.g., developments towards emission trading).

At a more global level, the SPADE system considers and contributes to the social objectives and needs of the European Community, and supports the establishment and promotion of the EU

policies, as these have been set by the "White Paper on European transport policy for 2010: time to decide" and other relevant regulations or proposals for regulatory establishments / amendments. Moreover, the SPADE system allows addressing policy issues and regulatory aspects under the wide spectrum of the quality of life and the level of service provided to passengers, the noise policy and energy requirements, as well as the employment and working conditions. In summary, the expected SPADE contribution to the policy objectives and societal needs of the European Community are presented in the Table 4.

Areas of Policy & Social Interest	**SPADE Contribution**
External safety / Security aspects and implications on airport operations	+++
Environmental concerns (with regard to noise)	+++
Airport capacity management (delays' reduction)	+++
Airport demand management (slot management)	++
Airport infrastructure / investment planning	++
Airport pricing / charging system	+
Airport operational practices / concepts	++
Air Traffic Management	+
Collaboration of airport stakeholders	++
Dissemination of research outcomes	+++
Commercial exploitation of results	++
Development of educational / training activities	+++
Formulation of industry regulation	+
Consumer / passenger protection	+

***Table 4**: Expected SPADE Contributions to the Policy Objectives and Societal Needs of the European Community. (The symbols (+), (++), and (+++) indicate the degree / importance of potential SPADE contribution in the particular areas of policy and social interest.)*

The SPADE Programme also contributes to the state-of-the-art (as described in Section 1.3) by addressing the open research issues and problems:

- Lack of seamless integration between existing tools able to provide airport studies (e.g., capacity, delays, external safety, and noise). The OPAL platform provides the ability to integrate capacity and delay-oriented models with others analysing the noise, external safety, and cost-benefit impacts of airport operations. However, tools are only partially integrated with respect to selected configurations of tools, which were practically modified to be able to interchange / communicate common data requirements. This, in turn, means that tools should be iteratively run by the user (not an automatic "back-office" procedure where the user only defines / selects a study (and possibly provides input data) and where the system takes care of all necessary computations and data transfers, after which the user in turn can select / inspect the information he / she needs), while the tool results are reported in a fragmented manner without capabilities of performing "trade-off" analyses. The SPADE concept of use cases is a research approach that produced a system for studying in a well-structured manner typical types of questions faced by decision makers and assessing trade-offs between airport performance metrics. The SPADE Programme developed a harmonised computing environment and interface that will not require prior knowledge / expertise on the individual tools and their specific functionality, data sets and modelling approach, through built-in use cases.
- Lack of data / input harmonisation to enable interchangeability between integrated models. Within the OPAL project, a superset of the data requirements of the various integrated models was developed; albeit with considerable duplication, redundancies, and without a consensus on the description / modelling of the airport processes. The SPADE Programme capitalised on work

performed within the APRON project, and it used as much as possible standardised and harmonised data and indicators.

- Lack of harmonised / co-ordinated measures of effectiveness describing the performance of the airside and landside airport elements. Similarly, the SPADE Programme exploited the given synergies with the APRON project to set and adopt a standardised reporting system for the various performance metrics that are provided through the SPADE Programme.
- Existing tools can successfully address all decision making levels and provide decision support to various airport studies, but they practically exhibit limited applicability and usefulness to high-level decision making in airport planning and design, on the grounds that they require in-depth technical knowledge and expertise for using them. In practice, the decision maker is interested in obtaining an insight and examining alternative (even approximate) solutions and “what-if” scenarios into particular strategic problems. Existing tools require substantial familiarity and prior knowledge to tackle with their use, build scenarios addressing the study objectives, and prepare the appropriate data sets pertaining to the given study and scenario. In effect, the capability of the tools to support strategic decision making is limited since they actually fail to deal with the study of essential trade-offs faced by the airport decision makers. The OPAL platform provided a proof of the concept of tool integration, but the issue of a user-friendly, decision support system for a practitioner (as compared to an academician) to assess strategic issues is still pending. This objective and challenging opportunity is tackled by the SPADE Programme through the identification of the set of use cases that have been implemented in order to provide answers to widely arising questions / problems.

Finally, the airport community relies heavily on standards. All technology, procedures and operations are at least standardised and harmonised locally. However, the European dimension of problems faced by airports implies that technology, procedures and operations have to be standardised and harmonised as a minimum at European level. The SPADE Programme applied widely spread, commonly recognised, and proven standards and methodologies, guaranteeing a wide applicability of the SPADE results within Europe. Further, this programme impulsed the improvement and solution to problems on standardisation and harmonisation, as faced by airport stakeholders in their decision-making process, through:

- The development of standardised, commonly understood, and well-structured framework for describing and modelling the processes of the entire airport complex (with respect to different flows, actors, and airport elements covered) in order to systematically describe and document the airport system.
- The development of harmonised / co-ordinated measures of effectiveness describing the performance of the airside and landside airport elements.
- The development of data / input harmonisation so that a common database can be interchangeably used between integrated models.

In addition, the SPADE system can contribute to a standardisation of the airport decision-making process within Europe as the commonly accepted platform for airport decision-support at strategic and tactical / operational level.

1.9 Conclusions

The SPADE-2 Project accomplished its objectives, resulting in a user-friendly, fully tested (with regard to integration, validation against requirements, and usability and operational assessment) decision-support system for airport development, planning and design, and a set of use cases that are seamlessly integrated into this system. The system will enable airport stakeholders and policy makers to perform integrated impact analyses in the various levels of decision making through pre-structured paths and built-in, "wizard-type" navigation aids (without requiring any knowledge of or experience in the underlying simulation or analytical tools).

The SPADE-2 Consortium informed airports and airport stakeholders on the SPADE approach, system, and (intermediate) results. In particular, the SPADE-2 Consortium held field trials and organised two User Group Meetings and a World-wide Conference, which confirmed the importance of the subject (i.e., integration of tools for obtaining an overall *total* airport view and providing support in trade-offs) and yielded constructive and valuable feedback and suggestions for improvements and enhancements of the SPADE approach, system and use of this system.

2 Dissemination and use

In addition to the dissemination activities presented in Section 1.7.4, the following exploitation activities have been conducted in the SPADE-2 Project:

- Definition of SPADE functionalities and their competitive advantages for potential users: to ensure a proper understanding by the different kinds of organisations (e.g., consultants, EC, airport management organisations, and airport service providers), but also by the actors with different decision-making authority within these organisations, that can take advantage of the SPADE System. This activity resulted in a set of marketing material (e.g., presentations and brochures), which provides a description of the functionalities and competitive advantages of the SPADE System and its use cases.
- SWOT analysis. This activity resulted in an overview of the various strengths of, weaknesses of, opportunities for and threats for the SPADE System.
- Market analysis. This activity resulted in an analysis of the potential market for the SPADE System.
- Definition of business models. This activity resulted in the definition of several preliminary business models for the exploitation of the SPADE System.

2.1 Presentations and publications

The SPADE Project has disseminated and published its (intermediate) results at various occasions and through various means:

- SPADE website: `http://spade.nlr.nl`;
- SPADE leaflet;
- SPADE-2 User Group Meetings:
  - Athens (June 18, 2009);
  - Las Palmas (November 6, 2009).
- SPADE-2 Presentation:
  - Aeronautics Days 2006 (Vienna, June 19-21, 2006);
  - 21st European Conference on Operational Research “OR for Better Management of Sustainable Development” (Reykjavik, July 2-5, 2006);
  - IFAC Symposium on Control in Transportation Systems (Delft, August 29-31, 2006);
  - 25th Congress of the International Council of the Aeronautical Sciences (Hamburg, September 3-8, 2006);
  - "ATM Projects Meeting" (Brussels, January 9-10, 2007);
  - 86th Transportation Research Board Annual Conference (Washington, January 21-25, 2007);
  - Transport Advisory Group - The Netherlands in Amsterdam (April 12, 2007);
  - "ATM Projects Meeting" (Brussels, November 14, 2008);
  - 87th Transportation Research Board (TRB) Annual Meeting (Washington, January 13-17, 2008);
  - Conference at TRB AV060 Committee (Airspace and Airfield Capacity and Delays) during Transportation Research Board Annual Meeting (Washington, January 15, 2008);
  - Fourth DGLM Workshop on State-of-the-art in ATM, Civil Aviation and Maritime Affairs (DGLM), Dutch Ministry of Transport, Public Affairs and Water Management (The Hague, December 18, 2008);
  - 88th Transportation Research Board (TRB) Annual Meeting (January 11-15, 2009);
  - Conference in NEXTOR (U.S. National Center of Excellence for Aviation Operations Research), TRB AV060 Committee on Airspace and Airfield Capacity and Delays, international conferences (e.g., 12th Air Transport Research Society 2008 Conference).

- SPADE-2 Paper:
  - Proceedings of 25th Congress of the International Council of the Aeronautical in Hamburg Sciences (September 3-8, 2006);
  - Proceedings of 86th Transportation Research Board (TRB) Annual Conference in Washington (January 21-25, 2007);
  - Proceedings of 21st European Conference on Operational Research "OR for Better Management of Sustainable Development" in Reykjavik (July 2-5, 2006);
  - Scientific paper (Journal to be specified);
  - Greek news letter.
- SPADE-2 Participation:
  - "Airports 2020 Conference & Exhibition - Airport Design and Development 2020" (Munich, October 10, 2007);
  - European ATM Innovation (Southampton, January 15-18, 2008);
  - 26th Congress of the International Council of the Aeronautical Sciences (Anchorage, September 14-19, 2008);
  - EPISODE 3 / CAATS II Joint Dissemination Event (Brussels, October 13-14, 2009);
- SPADE-2 Interviews:
  - by CAATS-2 Project;
  - by AIMS Project;
  - by AGAPE Project.
- SPADE-2 Assessment:
  - Interoperability with EUROCONTROL's PACS.