Nationaal Lucht- en Ruimtevaartlaboratorium

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Executive summary

SPADE - Supporting Platform for Airport Decision-making and Efficiency Analysis

Problem area

Due to the expected growth and high demands (e.g. safe, cheap, comfortable, and environment-friendly) in air traffic, the decision making process is getting more complex for airlines, airports, and air traffic service providers. This process is supported by models. These models are normally focussed on a specific domain and do not allow trade-off analysis between conflicting requirements.

Description of work

To overcome these limitations, the EC research project SPADE (Supporting Platform for Airport Decision making and Efficiency analysis) develops an integrated platform. Applying the concept of use cases, this platform will connect different models to allow the analysis of complex airport related questions through “pre-structured modeling paths”, built-in, “wizard-type” navigation.

Results and conclusions

In a first step, a workshop with airport managers and air traffic control experts was conducted. The result of this workshop was a catalogue of use-cases, which show typical questions in this domain.

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Author(s)
J. Kaiser
K.G. Zografos
H.H. Hesselink
M.J.A. van Eenige
G. Torres
Y.A.J.R. van de Vijver

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Nationaal Lucht- en Ruimtevaartlaboratorium, National Aerospace Laboratory NLR

Anthony Fokkerweg 2, 1059 CM Amsterdam,
P.O. Box 90502, 1006 BM Amsterdam, The Netherlands
Telephone +31 20 511 31 13, Fax +31 20 511 32 10, Web site: www.nlr.nl

Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

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SPADE - Supporting Platform for Airport Decision-making and Efficiency Analysis

J. Kaiser[1], K.G. Zografos[2], H.H. Hesselink, M.J.A. van Eenige, G. Torres[3] and Y.A.J.R. van de Vijver

[1] German Aerospace Center DLR

[2] Athens University of Economics and Business

[3] Aeropuertos Espanoles y Navigacion Aerea AENA

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Abstract

Due to the expected growth and high demands (e.g. safe, cheap, comfortable and environment-friendly) in air traffic, the decision making process is getting more complex for airlines, airports, and air traffic service providers. This process is supported by models. These models are normally focussed on a specific domain and do not allow trade-off analysis between conflicting requirements. To overcome these limitations, the EC research project SPADE (Supporting Platform for Airport Decision making and Efficiency analysis) develops an integrated platform. Applying the concept of use cases, this platform will connect different models to allow the analysis of complex airport related questions through "pre-structured modelling paths", built-in, "wizard-type" navigation. In a first step a workshop with airport managers and air traffic control experts was conducted. The result of this workshop was a catalogue of use-cases, which show typical questions in this domain.

Contents

Introduction

It is expected that the air traffic demand will increase within the European Union with an average rate of 3.7 % per annum (latest forecast from EUROCONTROL) for the period 2002-2010; cf. Figure 1. This considerable increase together with the limited ground resources will result in an unbalanced situation and will lead to increasing delays within the air transportation system. These facts make the decision making for airport operators more complex and challenging. Domains like security, efficiency, level of service, and environment have to be considered in this context but they are frequently contradictory to each other. Due to this complexity the decision making processes needs to be supported by the deployment of models [2].

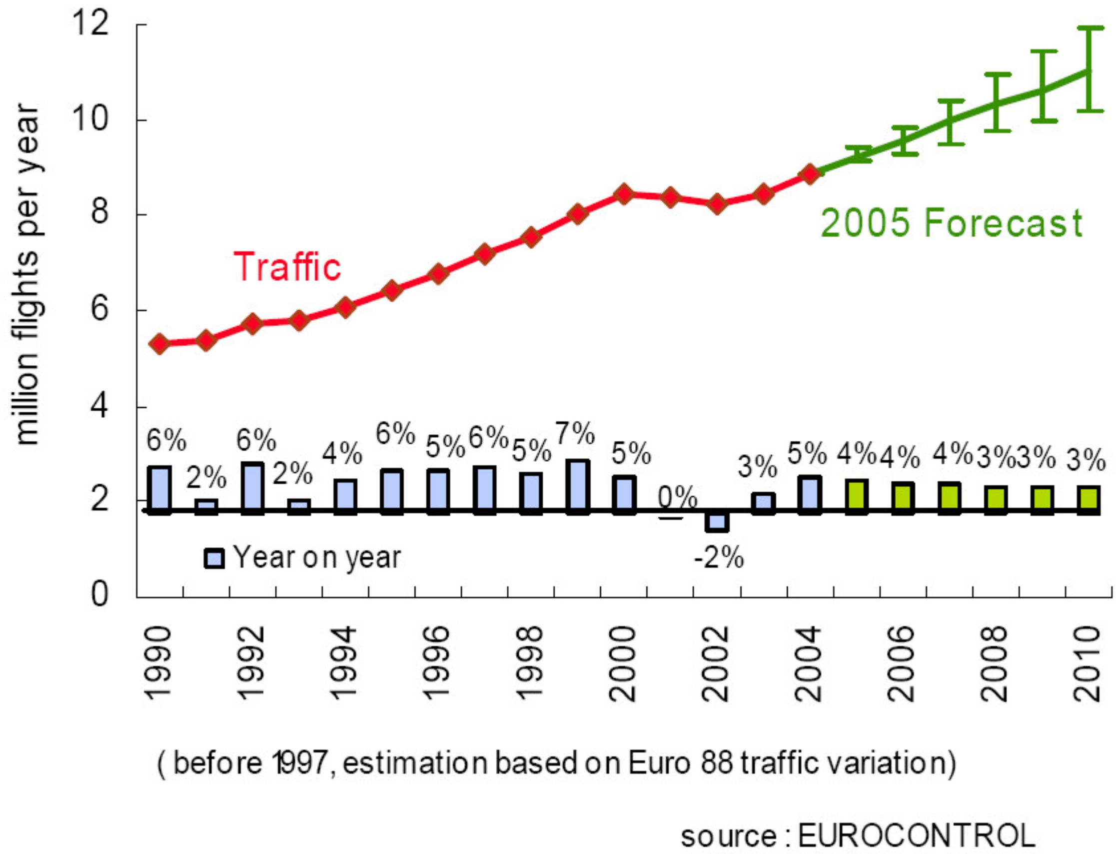

Figure 1: Mid term forecast for Europe [1]

At present, the majority of the existing models focus on a specific problem domain – airside or landside of the airport, passenger movements, baggage flow, or environmental aspects. These models cannot or only partially support the required complex decisions [3]. These considerations led to the initiation of a research project by the European Commission called

OPAL (Optimisation Platform for Airports including Landside). The approach of this project was to connect several existing models to a common platform. This has opened users the possibility to model an airport in a comprehensive manner. Based on the knowledge gained from OPAL [3] the project SPADE was initiated. The objective is the development of a common platform which is easy to handle for the analysis of critical problems in the airport context [2].

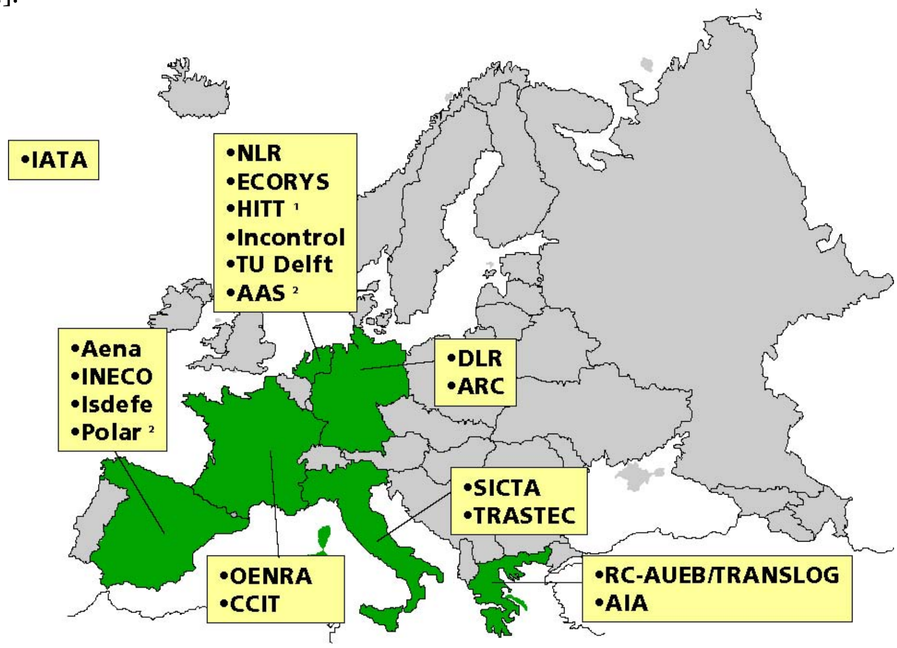

Figure 2: SPADE partners. ([1] partner in the first project phase; [2] partner in the second project phase)

The following section describes questions that are usually evaluated by airport managers and air traffic control experts with the help of supporting tools. Afterwards the realisation into a supporting platform for airport decision processes is explained. In the third section a description of the pre-prototype for the demonstration of the functionality is given. At last a perspective of the possibilities that users have with the availability of such a platform is illustrated.

1 Use Cases with particular interest for Airport operators and air traffic service providers

The objective of the project SPADE is to develop a decision-support system for decision makers in the air transport domain. This system is henceforth called SPADE platform. A first step in the project was the survey of airport operators, air traffic service providers, and airlines to specify the requirements for such a system. The results were consolidated in a workshop together with potential users. Based on this survey, specific use cases which represent typical problems in the strategic or operational / tactical domain were developed. Here, operational domains have a time horizon from a few days up to several months. [7] [8]

1.1 Strategic Use Cases

In this section all elicited strategic use cases are described. Strategic use cases represent questions with a long time horizon. Often the strategic application level involves the use of macroscopic simulation/analytical tools, allowing faster processing times, and what-if analysis of, for example, various infrastructure designs of an airport.

1.1.1 Expanding the airport landside infrastructure

If an airport has to cope with overused landside facilities different options need to be analysed to overcome this problem. With this use case it would be possible to analyse these options to dispose of bottlenecks. A typical approach is to investigate the different investments in existing and/or new landside infrastructure to increase the existing capacity. The user wants to compare the costs of the different options on the one hand with the effects of the different options on the airport performance on the other hand. These effects are the handling capacity of the airport in terms of number of passengers and cargo, waiting times, etc. With this use case it is possible to analyse options only on the landside - like the introduction of new baggage handling systems - or also combined options - like the extension of piers.

A typical user for this use case is someone from the national government, airport management or a real estate investor. The typical time horizon for this use case is 15 - 20 years.

1.1.2 Airside Infrastructure Development

This use case deal with extension of airside infrastructure of an airport like the building of a new runway and considers several criteria:

- Environmental impact versus capacity increase;
- Quality (level of service) versus capacity;
- Quality (level of service) versus costs;

- Postponing the investment in order to save money versus improving the probability of meeting the demand (or reducing the risk of not meeting the demand);
- Whether the investment will be profitable or not. The time horizon for this problem is 30 years.

1.1.3 Airport Capacity Management

Airport operators at every major European airport are practically faced with specification of the “declared airport capacity”. With this use case effects will be analysed which result from changes of the declared capacity. For this, airport operators must examine what this change means for delay, level of service, noise, and safety.
Typical users are airport operators, Civil Aviation Authority, and/or National Slot-coordinators. The time horizon is from one year to a few years.

1.1.4 Sharp Traffic Increase

The objective of this use case is to assess the infrastructure needs and demand management measures required in order to cope with sharp traffic increases. In the scope of this use case a “sharp traffic increase” is understood from two different perspectives.

1. There could be an abrupt increase in the total number of movements from one period to another with a rate over 10 %.
2. There could be traffic peaks during some particular hours within a day. This situation can be observed on hubs primarily.

Due to the different time frames in this analysis, a wide time horizon from 1 to 25 years is covered.

1.1.5 Infrastructure Elements and impacts on Airport Capacity

The use case refers to the landside context of airport applications and assesses the airport capacity taking into account all the infrastructure elements. The capacity assessment is carried out in an integrated way, taking also into account efficiency (air, ground and total delays), safety (ground conflicts, runway crossings) and environmental (noise impact) aspects. The time horizon for this use case is from 6 to 18 months.

1.1.6 Airport Bottlenecks Analysis

The use case refers to the groundside context of airport applications and assesses the airport bottlenecks under high throughput along the groundside components in terms of delays and the related delay sources. Identifying the airport zones that are more congested or generate the highest delays, it highlights the groundside hot-spots on which infrastructure and/or operational changes have to be made with the highest priority. The starting point could be the current scenario and once the bottlenecks are recognised, a “what-if” analysis can be performed in order to identify the more suitable actions to reduce congestion at the hotspots. For instance, changes regarding stands, taxiways, links, and entry/exit points can be taken in account. Users here are airport operators and air traffic service providers. The time horizon for this use case is from 6 to 18 months.

1.2 Operational Use Cases

In this section operational use cases are described. They represent questions with a shorter time horizon. The operational level would typically not involve evaluating the impact of a major airport infrastructure change, but could involve the evaluation of new departure/arrival procedures, using the existing infrastructure in a different way to accommodate changing demand.

1.2.1 Fleet Characteristics Impact on Airport Operations

This use case analyses the impact of possible changes in the fleet characteristics (aircraft type, city pair, airline, flight schedule etc.) on airport operations, especially in terms of airside and landside capacity, efficiency, environmental impact, and cost/benefit analysis for a given scenario. Different aspects of the operation are addressed in an easy way with this use case. Knowing how the characteristics of the fleet - changing continuously on an hourly, daily and seasonal basis - affect airport operations ensures a suitable tactical approach to get the maximum benefit from a given infrastructure. For an airport (and companies working at airports) it is important to have sufficient capacity and resources available at the right time and place in order to handle flights, passengers, and baggage in an efficient and smooth way. The airport has to decide about:

- resource allocation (where and when are personnel, desks, reclaim belts, gates, and other resources required, and how many capacity sources are required);
- changes in the planning (gate allocation, taxi paths, reclaim belt allocation, etc.);
- alternative routing (if a flight schedule generates high (peak) volumes, it could be necessary to determine alternative routes for certain flows).

The typical time-horizon for this Use Case is twofold:

- Operational (short term): decisions taken on hourly, daily and weekly basis;
- Tactical (medium term): decision taken for the next season or on a 3-6 months basis.

1.2.2 Re-allocation of flights

Objective of this use-case is to assess the consequences of flight allocations to the check-in desks/areas and gates. A different allocation has an impact on passenger flows between check-in and gates, including passport control desks, security lanes, lounges, shops, etc. Compare the flows with the available capacity, assess delays, etc. Flight allocations and allocation rules can be changed due to:

- political changes (e.g. more Schengen countries);
- changes in airline alliances;
- introduction of new airlines (e.g., low cost);
- opening of new terminal infrastructure (e.g. new pier or new terminal building);
- aircraft delays (gate changes);
- operational decisions.

The typical user is a tactical or operational planner, who is responsible for providing sufficient capacity to airport users (handlers and airlines) and for a smooth passenger (or baggage) process, and could indicate any capacity shortage and propose investments to improve capacity.

1.2.3 Impact of new Airport Equipment and Procedures

To cope with traffic increase at airports, new equipment has to be validated before operational deployment. This general use case analyses the impact of such new equipment or procedures on airport operations, including airside and landside aspects. Examples for candidate new equipment are A-SMGCS (Advanced Surface Movement Guidance and Control System) for guidance and control of movements or CDM (Collaborative Decision Making) and other new equipment for situation assessment. A new procedure can be e.g. an enhanced gate allocation protocol (airside) or a baggage routing protocol. The time horizon is from one day to 6 months.

1.2.4 Analyse the Impact of new Procedures

This use case is used to analyse the effects of new procedures on the operations of an airport. An example of a new procedure is a more strict night constraint. The effects of two or more night restrictions can be compared to see the difference in costs and environmental effects (mainly noise). Another example is reduced separation minima. Accepting smaller distances between aircraft, while maintaining the same safety level, can increase the capacity of an airport. The user could then analyse the trade-off between the increasing operational complexity versus the increased capacity of the airport. The time horizon is 1 year or more.

1.2.5 Airport Capacity Determination

The use case refers to airport airside applications and assesses various impacts on airport capacity in order to determine the nominal capacity for the airport and to see how contingencies can change this capacity. When evaluating capacity at airports and their elements (e.g., runways, taxiways, aprons) two main questions arise:

- How is capacity defined?
- How can airport capacity be measured by means of simulation or model based tools?

Airport capacity can be defined as the number of flights that can be handled by an airport element (e.g., runway, apron, etc.) in a time unit (hour, day, and year). But capacity can also be assessed as the level of service provided by an airport:

- Maintained capacity: maximum hourly capacity to be assumed continuously.
- Peak capacity: maximum hourly capacity that could be assumed for an exceptional hour, but that cannot be assumed continuously.
- Daily capacity: maximum number of flights that can be handled without degrading the level of service (delay levels, etc.)

This use case presents two ways of calculating airport capacity; each one of them intended for a different timeframe or purpose:

- Abstract capacity (per day) implies the definition of certain admissibility limits for a given day of operations. Simulations are then performed on an average day with different traffic increments and different levels of traffic handled. The evolution of service parameters (delays, ground conflicts, etc.) is monitored. Abstract capacity is the traffic level (per day) where one analysed parameter reaches its admissible level.
- Saturation capacity is the maximum traffic level that can be handled by the airport no matter what the service parameters are (unfeasible delay levels are assumed) and correspond to the maximum number of movements that are possible with a particular airport infrastructure. It provides the upper limit of the airport capacity. This way of calculating airport capacity is well described in the literature and is currently known as airport saturation capacity which provides the maximum possible number of movements per hour. It is based on the simulations of an airport model operating with a continuous traffic demand (higher than its capacity). Therefore, there will be always an aircraft waiting or available for either landing or take-off during the study period. The results of these simulations provide the maximum theoretical airport capacity for a given infrastructure taken into account the particular operational procedures as well as the traffic mix and runway dependencies.

The time horizon can be between many weeks and 10 years.

1.2.6 New security devices and/or procedures

In this use case the user wants to find out what the effects of the introduction of another security system, other security measures, or a new check-in system are. The user is interested in the effects on security levels and also in the effects on the operational practices at the airport. New check-in systems using biometrics can provide a fast check-in facility for business travellers, or a very secure way of checking-in passengers. Biometrics refers to computerised technologies to check a person’s identity. Finger printing, facial recognition, hand geometry, iris recognition, retina recognition, and speech recognition are all examples of such systems. The introduction of another security system and/or other security measures will on the one hand lead to increased security levels, but can on the other hand have negative operational impacts like capacity problems, long queues, etc. For this use case the time horizon is 6 months or more.

1.2.7 Taxiing Methodology

With this use case it is possible to analyse different airport layouts (apron, taxiway system, and runway system) resp. new operational procedures and to find the most favourable aspects of each of the options. Taxiing Methodology would assist in making a decision about the operational usage of an apron scheduled or in analysing different layouts posed for building of a new airport.

1.2.8 Airside factors and impacts on Airport Capacity

The use case refers to the airside context and airport ground movement applications and will assess the airport capacity taking into account changes in ATC procedures:

- Changes in current procedures (Standard Procedures);
- Introduction of new procedures (Noise Abatement Procedures, GNSS Based Procedures, etc.);
- Operational changes (reduced separation on approach).

The capacity assessment is carried out in an integrated way, taking also into account efficiency (travel time and air delays, taxiing time and ground delays), environmental aspects (noise footprints), safety (key indicator), and level of service related to an assigned delay threshold. The typical time horizon is between 6 and 18 months.

1.2.9 Trade-off Airport Capacity vs. Environmental Capacity and/or Airport Performance

The user can run this use case to analyse the impact of increasing the capacity of a specific airport. The user can compare the increase of airport capacity with the effects on the airport performance and/or the environment. A typical user for this use case is someone dealing with airport management or flight management. A typical time horizon for this use case is 1 year or more.

2 Integration of use cases in a simulation platform

The use cases listed in Section 1 have been implemented in a software design with the "Unified Process" methodology based on UML (Unified Modelling Language) [4] [6].
The whole SPADE platform is based on the following 4 modules. These components are common for all use cases.

2.1 Input Component

This component is the interface between user and SPADE platform. With this interface the user has the ability to select the desired use case and required parameters. All inputs define a scenario. The results can be compared with results of alternative scenarios. Dependent on the scope of analysis it will be possible to select a range and level of detail for the desired output. The information which is necessary for a scenario can be divided into three categories:

- Traffic information:

The most important element in this category is the flight schedule. A traffic generator is implemented for easy usage. This generator creates a flight schedule based on information like traffic-mix (e.g. percentage of aircraft types) or increase of traffic with regard to a reference flight plan.

- Airport Layout:

The modelling of airport layout (runways, taxiways, apron, and parking positions) is mostly a very complex and ambitious task. It is highly dependent on the simulation/analytical tool's format and specifications. Many of these models require a high degree of experience to implement a complete layout. For that reason the envisaged way to generate an airport model from the scratch is to use the particular tool interface by a domain expert user. Once the airport layout has been created it will be imported into the SPADE platform to be used in the desired study. Minor modifications could be done through the Input Component in this airport layout.

- Operational information:

This concerns information like arrival and departure routes, strategies for using parking positions, assignment of airport resources, etc. Depending on the Use Case, this information will be predefined (the user has to select the most appropriate one) or not (the user has to enter data through the Input Component). Besides these main inputs, additional information might be necessary, dependent on the use case.

2.2 Output Component

The output component of the platform and its functionalities allow to produce and post-process output data in order to realize a comparative assessment of the airport system in terms of different points of view:

- Capacity,
- Safety,
- Environment,
- Efficiency,
- Quality of service, and
- Economical aspects.

2.3 Computational Component

The computational component is responsible for performing the sequence of actions necessary to execute a use case study. It specifies for each use case the tools that have to be executed and the order in which these tools have to be executed (tools scheduling). The specification of the computational component has to ensure that all data needed by each tool is available either from the airport data model, the use case input, or as output from another tool within the current execution. The time flow is illustrated in Figure 3.

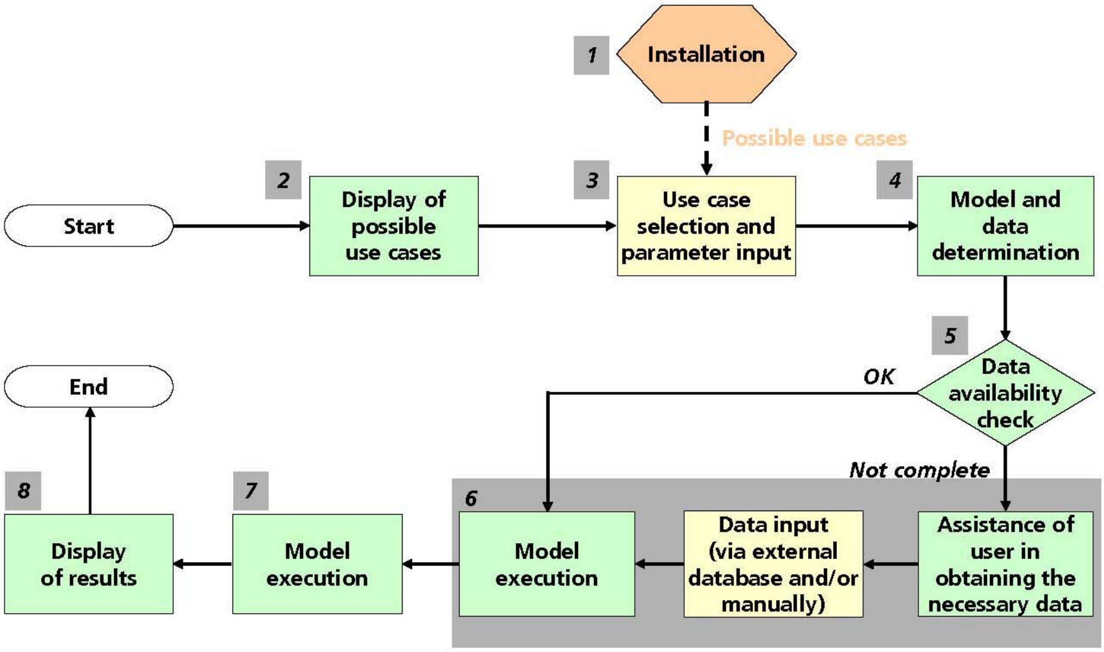

Figure 3: Time flow diagram of the SPADE platform

The steps in the time flow are:

1. Installation of software, the executable use cases on the system are determined through the available models.
2. By use of the platform these use cases are shown to the user after the program start
3. The user selects the corresponding use case for his problem domain
4. The platform determines the requirements on model and input data
5. The data stored in the data model will be checked for completeness
6. In the cases for that all necessary data is available, the platform will start the models. In the other case the user will be assisted by the input of data from external data sources or in a manual way
7. The model results will be prepared
8. The use case will be finished with the display of the results

2.4 Airport Data Model

The airport data model stores all necessary data to run the different use cases. Both all input and all output data are covered. To have a good compatibility of this model with external data sources, analogies in the data format with the EUROCONTROL AIXM (Aeronautical Information Exchange Model) [5] will be used. However, not all necessary data (e.g. flight schedule) for the SPADE platform are stored in the EUROCONTROL model. Therefore, the airport data model will contain data definitions which are specific for SPADE.

3 Pre-prototype

A major and important outcome of the first project phase was the development of two pre-prototypes. These demonstrate the feasibility, functionality, and usability of the applied approach.
For this, one operational and one strategic use case have been selected.
The pre-prototypes fulfil the steps of the envisaged platform:

- User gains access
- User selects use cases
- User defines questions (see Figure 4)
- SPADE platform perform computation
- SPADE platform presents integrated results (see Figure 5)

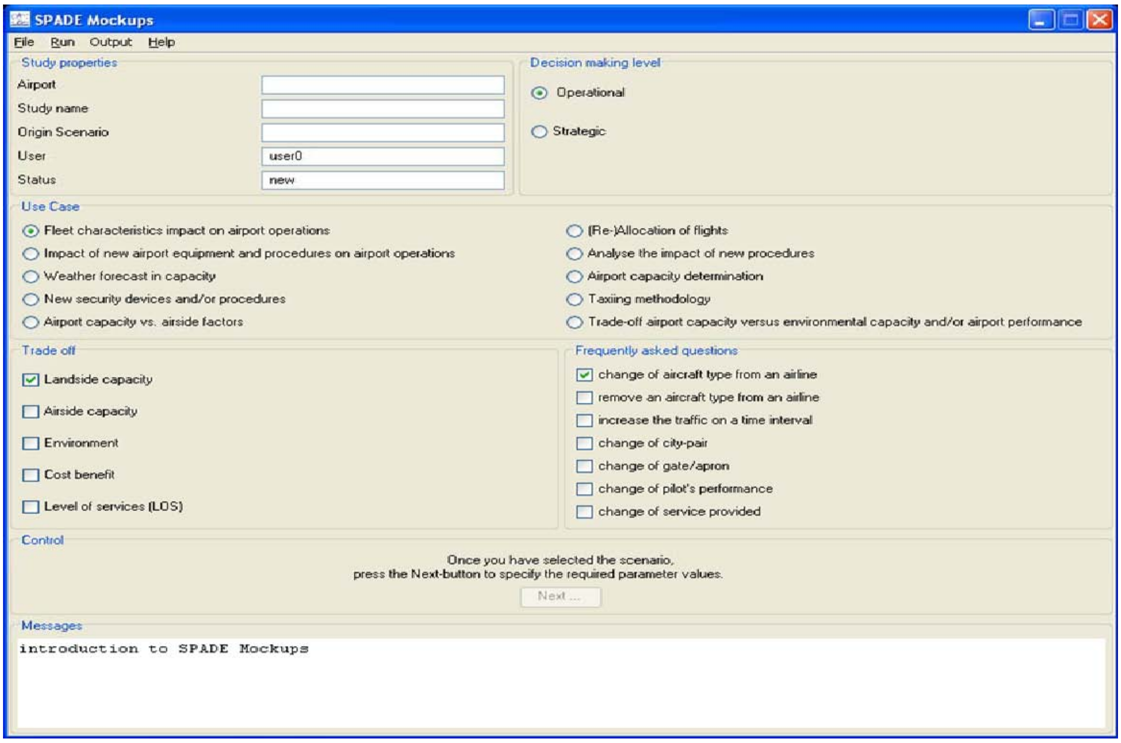

Figure 4: SPADE HMI

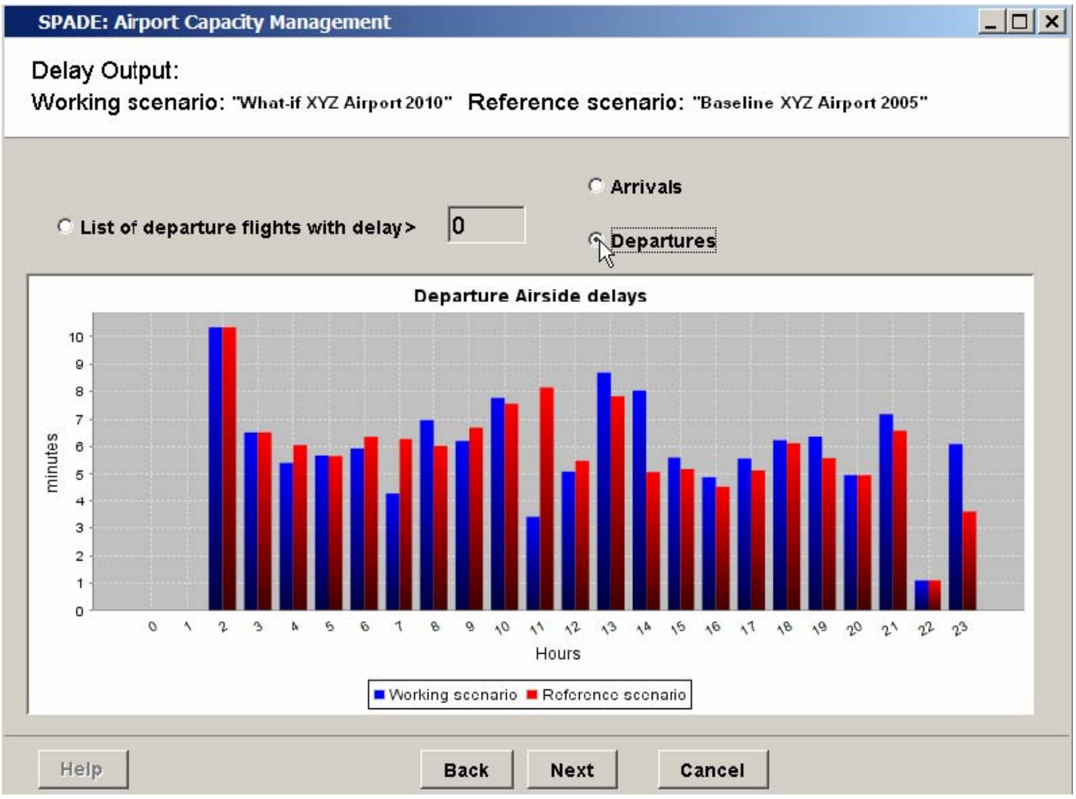

Figure 5: Example of SPADE HMI comparative output display

4 Perspective

The use cases, components, and pre-prototypes described in this paper were developed in the first project phase of SPADE funded by European Commission 6th Framework Programme based on the “Unified Process”. The second phase of the project is planned to start within 2006. Tasks of this second phase include implementing, testing, and evaluating the entire SPADE platform. With the availability of the SPADE platform a gap will be closed in the existing model world. In the future decision makers will be in a position to model complex and jointly networked processes supported by SPADE. The platform aims to provide a solid basis for effective decision making.

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