EC DG VII
Transport Programme
(4.3.1/41)

Contract : AI-96-SC.1054

DAVINCI

Departure and ArriVal INtegrated Management System for Cooperative Improvement of Airport Traffic Flow

DAVINCI FINAL REPORT

Document Version Log

Version #	Issue Date	Section Affected	Relevant Information
0.1	16/07/99	All	Creation
0.2	29/07/99	All	Comments from the partners
0.3	29/09/99	4.	Refinement pursuant to EC Request (meeting 09/09/1999).
1.0	30/09/99	None	Format change. Approval by the partners

Document Distribution

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Review and Approval of the Document

Organisation Responsible for Review	Reference of comment documents	Date
All Partners & Quality Manager		30/09/99
Organisation Responsible for Approval	**Name of person approving the document**	**Date**
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Partnership

The consortium which carried out the DAVINCI Project consisted of six contractors and five associated contractors from seven countries, as follows:

Isdefe (Spain), Coordinator
Universidad Politécnica de Madrid (Spain), Associated Contractor to Isdefe
Syseca Belgium, Contractor
Sofréavia (France), Contractor
Thomson-CSF Airsys (France), at contract signature, now Airsys ATM S.A., Associated Contractor to Sofréavia
Siemens AG (Germany), Contractor
National Air Traffic Services (UK), Contractor
NLR (Netherlands), Associated Contractor to NATS
DERA (UK), Associated Contractor to NATS
EDISOFT (Portugal), Contractor
INESC (Portugal), Associated Contractor to EDISOFT

Executive Summary

The main objective of the Departure and Arrival Integrated Management System for Co-operative Improvement of Airport Traffic Flow (DAVINCI) project, sponsored by Directorate General VII of the European Commission was to define and demonstrate the feasibility of integrating and/or co-ordinating the various components of existing or future airport traffic management systems. This objective is based on the premise that improved data sharing and further co-ordination/integration at airports will reduce airport delays and increase airport capacity for any given physical infrastructure.

This document is the final report of the DAVINCI project. It presents the objectives of the project and the means used to achieve the objectives. It provides a detailed scientific and technical description of the project, by each of the four DAVINCI phases: Assessment of Current Situation, Solution, Development of Demonstrator and Demonstration and Evaluation.

Briefly, the DAVINCI project surveyed current airport operations to establish the extent of existing co-operative activity. Decision-making processes were analysed in order to identify the underlying user requirements. Based on this analysis, several operational scenarios were defined to illustrate the range co-operative problems in European airport management. A method was defined to aim at reducing the impact of these problems, including both operational and technical elements, that consisted of co-operative management and data sharing by the planners involved in airport management.

A generic functional and architectural model of an airport co-operative management system was designed. A demonstrator was developed to evaluate representative aspects of a co-operative management system as defined by these models. A validation strategy was developed for the co-operative management system, which was used to perform a limited evaluation of the operation of the demonstrator.

Finally, the document presents several conclusions reached from the DAVINCI project, presenting both findings and conclusions of the demonstration conducted, overall conclusions and recommended lines of action for future work. The overall conclusion reached is that the DAVINCI project has made a start in improving traffic management at airports by proposing flexible, tool-independent co-operation among the planning tools used in airport operation. Although the specific results obtained by the DAVINCI Demonstrator are not as significant as was initially expected, they are positive overall and point the way to future work in the field of improving airport management.

1. Objectives of the Project

Many different systems exist across Europe, at both the national and local levels, for managing airport functions. These systems, which include those for airport stand allocation, airline/airport ramp management, air traffic control (ATC), ground movement control, and arrival and departure scheduling or sequencing systems, can be called collectively Airport Traffic Management Systems (APTMS). In addition to these current systems, several specific automated tools are under development to support functions such as arrival scheduling, departure scheduling, and surface movement guidance and control.

Although airports, airlines and ATC service providers try to optimise the efficiency of their individual APTMS systems, little effort is directed toward real integration of these systems so as to maximise the performance of the overall airport system. This lack of integration prevents optimum use being made of available capacity at airports and in terminal area airspace. It further reduces the efficiency of the tactical Air Traffic Flow Management (ATFM) system and 4-D planning. In order to solve this problem, the co-ordination requirements of each individual APTMS system need to be analysed, so as to establish procedures and define an open system architecture for the progressive integration of current and future systems.

The main objective of the Departure and Arrival Integrated Management System for Co-operative Improvement of Airport Traffic Flow (DAVINCI) project was to define and demonstrate the feasibility of integrating and/or co-ordinating the various components of existing or future APTMS systems. This objective was based on the premise that improved data sharing and further co-ordination/integration at airports will reduce airport delays and increase airport capacity for any given physical infrastructure.

2. Means Used to Achieve the Objectives

The objective of the DAVINCI Project, as stated in the preceding section, was achieved by:

?? Determining and analysing user needs for efficient integration and co-ordination of airport management functions.
?? Defining and specifying techniques to describe the system model, the integration/co-ordination process and the decision-making process.
?? Designing and describing a proposed method for integrating and co-ordinating airport management functions, based on existing and foreseen automated tools.
?? Analysing and describing the decision-making process and identifying various options for allocating decisions.
?? Specifying and designing an open architecture to support the designed integration and co-ordination method.
?? Developing and operating a demonstrator.
?? Analysing and evaluating the results of the demonstration conducted on the demonstrator.

3. Scientific and Technical Description of the Project

The work performed during the DAVINCI project was structured in four phases: (a) Assessment of Current Situation; (b) Solution; (c) Development of Demonstrator; and (d) Demonstration and Evaluation. The work done and major results achieved in each of these phases are presented in the following subsections.

3.1. Phase I: Assessment of Current Situation

The first phase of the DAVINCI project identified, analysed and summarised the existing problems, constraints and degree of co-ordination in the co-operative management of airport traffic. The following work was done in this phase:

?? Systematic survey of related projects and on-going activities in Europe and individual countries, to catalogue the operational procedures, requirements and systems for APTM.
?? Analysis of automated tools and systems, identifying common interfaces and functionalities, major constraints and limitations, and operational procedures. The tools and systems were identified on the basis of general surveys of over 20 European airports and more detailed surveys of six selected airports: Amsterdam/Schipol, Brussels, Frankfurt, Lisbon, London/Gatwick and Paris/Charles De Gaulle.
?? Summary and assessment of user needs and requirements.
?? Organisational analysis of real-time decision-making processes and the allocation of decision-making amongst airports, airlines, ATC and others, identifying organisational boundaries and system interfaces.
?? Identification, classification and selection of three generic operational scenarios for a co-operative management system, to be used for the demonstration.

The data gathering from existing sources, airport survey process, summary and assessment of user needs and requirements, analysis of decision-making processes and definition of generic scenarios will each be discussed in greater detail in the following subsections.

3.1.1. Data-Gathering from Existing Sources

The first step in the DAVINCI project was to catalogue the operational procedures, requirements and systems for APTM documented in existing reports, databases and other sources. In addition, pre-existing European projects and initiatives relevant to the scope of DAVINCI were identified, reviewed and synthesised. This information was recorded in a standard "Systems Information Description" format.

This work led to the identification of 43 systems, tools or projects that were thought to have relevance to DAVINCI. "Systems Information Descriptions" were completed for 37 of these. These systems, tools and projects were then analysed to determine the areas of APTM covered by each. Table 3-1 analyses the systems identified from documentary sources; Table 3-2 analyses the projects/initiatives and Table 3-3 analyses the relevant papers.

NAME	APPROACH	LANDING	TAXIING	PARKING	GROUND OPS	TAKE OFF	DEPARTURE
AMOSS	†	†	†	†	†	†	†
ARAMIS	†						
ARRCOS	†	†	†				
CORE PLUS	†	†	†	†	†	†	†
Comparatiave Prolem Solving between Airline Operations Control & ATC Traffic Flow Management	†						†
COMPASS	†						
DEPCOS						†	†
FAST UK	†						
FAST USA	†						
IDAHO	†	†	†	†	†	†	†
MAESTRO	†	†					
OBCCOS					†		
Reource Allocation	†	†	†	†	†	†	†
SIIGAER	†	†	†	†	†	†	†
TACO	†						
TARMAC			†	†	†		
Wake Vortex Warning System	†	†					
4-d Planner	†						
TOTAL 18	15	8	7	6	7	8	7

Table 3-1 Systems Identified from Documentary Sources

NAME	APPROACH	LANDING	TAXIING	PARKING	GROUND OPS	TAKE OFF	DEPARTURE
ADORA	+						
AIRPORT G	+		+	+			
ATHOS		+	+	+	+	+	+
CADS	+						+
DAFUSA		+	+	+	+	+	+
DEFAMM		+	+	+	+	+	+
ECAC APATSI	+	+					
FACTOR	+	+	+	+	+	+	+
MANTEA			+	+	+	+	+
NOAA	+						
RHEA	+	+	+			+	+
TAPE	+	+	+	+	+	+	+
VAPORETO	+	+	+	+	+	+	+
TOTAL 13	**8**	**8**	**9**	**8**	**7**	**8**	**9**

Table 3-2 Projects/Initiatives Identified from Documentary Sources

NAME	APPROACH	LANDING	TAXIING	PARKING	GROUND OPS	TAKE OFF	DEPARTURE
Airport Capacity Enhancement by Planning of Optimal Runway Occupancies.			+			+	
EAGLES Need for a European Air Ground Laboratory for Efficient System Integration.	+	+	+	+	+	+	+
Information System for Airport Handling Operations.	+	+	+	+	+	+	+
Investigation of Ground Access Mode Choice for Departing Passengers.							+
Modelling & Analysis of an Airport Departure Process.							+
Satisfying Airport Operational Requirements Using Seamless GNSS Techniques, Procedures and Processing.	+	+	+	+	+	+	+
TOTAL **6**	**3**	**3**	**4**	**3**	**3**	**4**	**5**

Table 3-3 Relevant Papers, etc. Identified from Documentary Sources

In addition to the identification of systems, this part of the work also identified six stages in the "life cycle" of an aircraft during its for arrivals passage through an airport: (a) approach control, (b) for departures arrival control; (c) ground movement control; (d) ground handling; (e) ground movement control; and (f) departure. The diagram in Figure 3-1 shows this sequence of stages and the various processes identified within each stage.

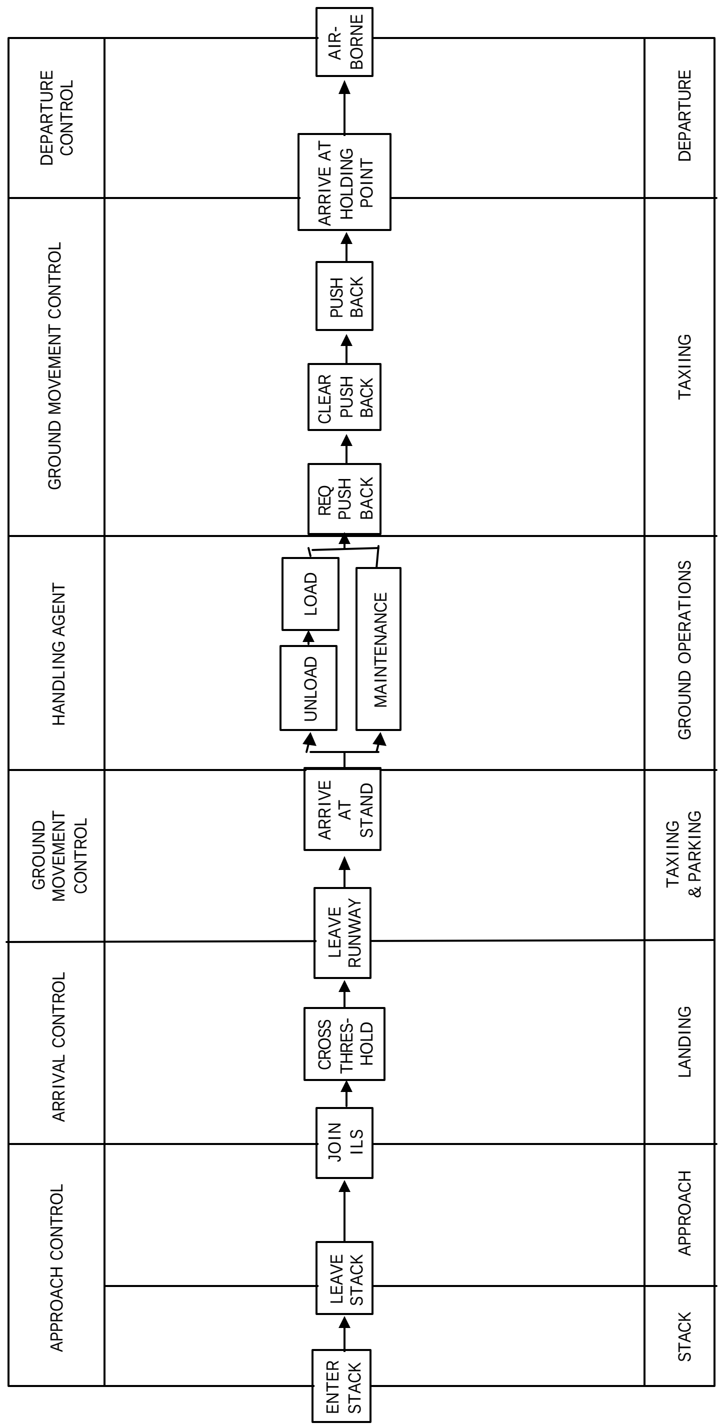


Figure 3-1 Major Sequence of Stages and Processes Relevant to DAVINCI

Finally, an initial indication of information sharing during these stages was prepared for six airports. All of this information led to series of initial conclusions. Some information sharing already takes place between airlines, airport operators and air traffic control (ATC), mainly to reduce aircraft delays and increase airport capacity. Larger airports often maintain a real-time database system used to enable information sharing between the main players. Current systems have been created by a wide range of organisations. Thus, standardised APTM systems, whose use and development were co-ordinated by one of the players, would be invaluable.

3.1.2. Survey Process

The second step in the DAVINCI Project was the establishment of current user requirements for APTM systems and the expectations of users for the future development of such systems. These requirements were defined based on a survey of 26 European airports using a combination of questionnaire- and interview-based information gathering techniques. The three main players at each airport (airport operator, ATC provider and airlines) were contacted. The airports surveyed were selected on the basis of three overall criteria:

?? The busiest airports in Europe in terms of the number of movements at the airports. The final list of airports includes the top 16 European airports in terms of the number of aircraft movements.
?? Geographic spread of airports, to represent a broad span of airports. The final list of airports is spread across 13 European countries, with a maximum of four airports for France and Germany.
?? Some less busy airports suggested by DAVINCI partners. These airports were included due to certain special characteristics.

The final list of airports selected is presented in Table 3-4, indicating, when known, the number of aircraft movements, the rank based on movements and the number of passenger movements.

Number	Airport	Country	Aircraft Movements	Rank Based on Movements	Passenger Movements
1	London Heathrow	UK	434,524	1	54,452,636
2	Frankfurt	Germany	378,388	2	38,179,543
3	Paris Charles De Gaulle	France	331,365	3	28,355,469
4	Amsterdam	Netherlands	312,806	4	25,355,622
5	Zurich	Switzerland	244,504	5	15,367,419
6	Copenhagen	Denmark	242,090	6	15,034,899
7	Paris Orly	France	239,529	7	26,653,876
8	Stockholm Arlanda	Sweden	225,207	8	13,411,065
9	Brussels	Belgium	224,752	9	12,600,617
10	Madrid	Spain	219,040	10	19,699,740
11	München	Germany	213,951	11	14,867,922
12	Rome Fiumicino	Italy	209,231	12	21,091,388
13	London Gatwick	UK	202,699	13	22,549,304
14	Düsseldorf Rhein/Ruhr	Germany	184,018	14	15,145,643
15	Manchester	UK	169,891	15	14,973,814
16	Vienna	Austria	166,627	16	8,546,233
17	Milan Linate	Italy	151,625	19	10,827,059
18	Köln/Bonn	Germany	133,399	22	4,740,144
19	Nice	France	133,144	23	6,142,883
20	Rotterdam	Netherlands	118,823	28	295,663
21	Palma de Mallorca	Spain	115,196	30	14,619,098
22	Athens	Greece	dna	dna	dna
23	Lisbon	Portugal	79,886	dna	6,414,414
24	Reus	Spain	3138	dna	318,650
25	Toulouse	France	dna	dna	dna
26	Faro	Portugal	28,154	dna	3,660,374

Dna = data not available

Table 3-4 Selected European Airports

A preliminary survey was conducted at 20 of these 26 airports to collect basic data on APTM systems currently in use. At each airport, the three main players involved in the functioning of airports were surveyed by means of a purpose-designed questionnaire: the airport operator, the ATC provider and one representative airline using the airport. The data sought was background data (traffic mix, weather conditions, layout, organisational structure) and relatively high-level information on the APTM systems in use at each airport, including the following:

- Name of any information systems currently in regular use.
- Operational activity to which each information system is applied.
- Indication of what each system helps to do.
- Indication of how well each system meets current requirements.
- Indication of data flows into and out of each airport information system.

In this regard, it should be noted that the term "airport information system" was defined as any system, electronic or otherwise, that receives, processes, stores and/or displays information and which affects the operational aspects of airports.

Completed questionnaires were received from seven airlines, 13 airport operators and 12 ATC providers. From these 32 questionnaires, a total of 49 distinct systems were named and described. These systems were found to fall into eight broad categories, as follows:

- Global Systems: Multi-functional systems that provide various information to many players around the airport, probably negating the need for a number of discrete information systems. These often record data for purposes of charging and planning.
- General ATC Operations: These information systems provide ATC with a range of operational information. The information they provide is unlikely to be applicable to other players at the airport.
- General Airline Operations: These information systems provide an airline with a range of operational information. The information they provide is unlikely to be applicable to other players at the airport. Nevertheless, when an airline also acts as a handling agent for other airlines at the airport, the information may be shared with them.
- General Airport Operator Operations: These information systems provide the airport operator with a range of operational information. The information they provide is unlikely to be applicable to other players at the airport.
- Taxiing/Ground Movement: These information systems provide the player responsible for control of aircraft taxiing and other ground movements with operational information.
- Ground Operations/Ground Handling: These information systems provide the player(s) responsible for carrying out services to the aircraft (such as refuelling or catering) with operational information.
- Passenger Services: These information systems provide information that is of specific use to passengers at the airport.
- Departures: These information systems provide information relating to the departure of aircraft from the airport.

Of the 26 representative European airports originally selected, six were chosen for a more detailed survey, on the basis of their organisational structure, how close the airport is to airside/runway capacity, weather conditions and traffic mix. The six airports selected for further detailed study, using a set of standard questions, were the following:

- Amsterdam/Schiphol.
- Brussels.
- Frankfurt.
- Lisbon.
- London/Gatwick.
- Paris/Charles de Gaulle.

In the course of these interviews, a total of 28 systems relevant to DAVINCI were described. These systems can be broadly categorised in the same categories as above.

Table 3-5 presents all of the systems identified in the course of both the data-gathering process and the survey process which are either implemented and in current use, or undergoing development. For each system identified through the questionnaire or the survey, as well as for most of the systems identified from the documentary sources, the type of system is listed.

System	Location / Player		Type (*)	Uses Described	Information source (**)
"Operational Information"	Gatwick	Airline		Updates and informs on aircraft turnaround progress.	I
4-D Planner	Under development			Purpose is to enable time-exact delivery of an aircraft over the runway threshold taking into consideration all relevant parameters. The system will thus support the controller in the task of aircraft guidance and co-ordination	D
4D-Planner (to replace COMPAS)	Frankfurt	ATC	General ATC Ops.	Enables time-exact delivery of aircraft over the threshold.	I
A-SMGCS (Aerodrome Surface Movement Guidance & Control System)	Heathrow	ATC	Taxiing/ Ground Movements	Enhanced information about aircraft position and movement on ground	Q

System	Location / Player		Type (*)	Uses Described	Information source (**)
ACARS (Air-ground communication of aircraft)	Frankfurt	Airline	General Airline Ops.	Information flows when: Off block, On block, Touch down, ETA changes due to onboard flight plan changes.	I
ADAM (Airport Database for Administration and Management)	Heathrow	ATC	Global	Airport database and information. handling system. Performs functions including stand allocation.	Q
ADIS (Airport Display Information System)	Manchester	ATC	General ATC Ops.	ATC operations-relevant information.	Q
AGATHE	Charles de Gaulle	Airline	Global	Airport resources management (parking, gates, ramps, buses, boarding rooms...). Also manages information display.	I
AGORA	Nice	Airport Op	Global	Airport resource allocation (stands, ramps, check-ins, etc.), display of flight information to passengers)	Q
AIMS (Airport Information Management System)	Zurich	Airport Op	Global	Provides flight information to all interested parties at airport	Q
AMOSS	Under development			"Global" system under development by Airport Operator to replace FMCS system at Manchester. Will support full spectrum of airport operational processes including aircraft handling and passenger and cargo management.	D
AMS	Brussels	ATC	Parking	Database system implemented at Brussels which allocates gates and stands and shares information between the ATC and the airport operator. It is developed toward OTD (optimum time of departure) which provides the time an aircraft has to be at the holding fix.	D
ARAMIS (Advanced Runway Arrival Management to Improve Airport Safety)	Under development			CEC-sponsored project which aims to produce a prototype system demonstrating how desired traffic flow on approach can be achieved, taking into account factors such as aircraft characteristics & weather.	D
ARCO (Alitalia DCS) / CUTE system for other airlines.	Milan	Airline	General Airline Ops.	Alitalia system giving information on check-in, aircraft movements, reservations, flight plans, etc.	Q
ARRCOS (Arrival Co-ordination System)	Frankfurt	Airport Op	Parking	System provides for greater approach data accuracy and establishes the estimated time of landing and gate arrival time, thus furnishing the essential planning data for managing and co-ordinating the necessary ground-handling activities. This is a component/subsystem of FATMAC (Frankfurt Airport Throughput Management And Co-ordination)	D
ARRCOS	Frankfurt	Airport Op	Parking	Communicates actual on-block time.	I
ATIS (Aeronautical Terminal Information Service)	Reus (Also in use at Madrid and Palma)	ATC	General ATC Ops.	Weather report to air navigation users (ATC)	Q

System	Location / Player		Type (*)	Uses Described	Information source (**)
BDV System	Milan	Airport Op	Global	FIDS system, mainly handling activities (apron aircraft management, check-in, gate allocation, baggage movement, etc.). BDV communicates with external systems: SITA network for IATA messages generated by different DCS systems ATC system Admin/planning applications Flight/pier assignment.	Q
CATS (Copenhagen Airport Traffic System)	Copenhagen	Airport Op.	Global	Stand allocation, information to handlers, information to passengers (in halls), etc.	Q
CISS (Centraal Informatie Systeem Schiphol).	Amsterdam	Airport Op	Global	CISS is a large database with flight, gate and boarding information. Flight progress information (including delays). Data also used for strategic planning.	I
COM / AIS	Palma (Also in use at Madrid)	ATC	General ATC Ops.	Information. about NOTAMs, and flight plans	Q
Comparative Problem Solving between Airline Operations Control & ATC Traffic Flow Management	USA	All		A paper describing three operational systems: "The Ground Delay Program", "The Pacific Track Advisory Program" and "The National Route Program". The document stresses that co-ordinated and collaborative methods can produce enhanced solutions.	D
COMPASS (Computer Oriented Metering, Planning and Advisory System)	Frankfurt	ATC	Global	Flow information exchange between En route and Approach control. System used to achieve optimum use of runway capacity taking into account traffic load in individual control sectors, economic flight profiles, etc.	I/D
CONOPER (Operation Control System)	Madrid (Also in use at Palma, and Reus)	Airport Op	Global	Modular system to process operating information in real time, to update airport data bases, provides statistics, information. about aircraft/airport/airline etc.	Q
Database for planning airline capacity and schedule planning for Schiphol.	Amsterdam	Airline	General Airline Ops.	Output is used by KLM to co-ordinate with airport operator the available capacity of Schiphol.	I
DCS (Departure Control System)	Athens	Airline	General Airline Ops.	Passenger check-in. Aircraft load control.	Q
DEPCOS (Departure Co-ordination System)	Frankfurt München At least 9 German airports including Frankfurt	ATC ATC	Departure Departure Departure	Flow information exchange for departures Departing traffic Automatically provides ATC with all information needed about departing flights, assisting them to co-ordinate these flight efficiently.	I Q D
Dispatcher's "Card" (Simple paper record used by dispatcher in charge of aircraft turnaround).	Gatwick	Airline	Ground Ops Handling	Used to plan & control turnaround- - deplaning, maintenance, loading etc.	I
EAT (Expected Arrival Time) System.	Gatwick	ATC	Landing	Computes an EAT for an aircraft as it arrives in the stack.	I

System	Location / Player		Type (*)	Uses Described	Information source (**)
FAIS (Flight Airport Information System)	Düsseldorf	Airport Op.	Global	Provides flight information to all interested parties at airport	Q
FAIS (Flight Airport Information System)	Köln/Bonn	Airport Op.	Global	A/c handling, Stand allocation, apron handling, terminal indication etc. Provides flight information to all interested parties at airport	Q
FAST UK (Final Approach Spacing Tool)	Under development			System under development by UK National Air Traffic Services (ATC provider) to assist less experienced controllers achieve minimum separation between aircraft on approach, leading to more consistent and efficient spacing.	D
FAST USA (Final Approach Spacing Tool)	USA	ATC		Tool implemented in USA from 1994 onwards as part of the FAAs integrated Centre / TRACON Automated System (CTAS). The FAST element provides speed and turn advisories that help controllers achieve an accurately spaced flow of traffic on final approach.	D
FIDS (Flight Information Display System)	Manchester	Airline	General Airline Ops.	Flight information such as arrival and departure times, stand allocation, etc.	Q
	Stockholm	Airport Op	Global	Provides flight information to all interested parties at airport airlines, passenger, handling etc.	Q
	Faro	Airport Op	Global	Provides flight information to all interested parties at airport	Q
FMCS (Flight Movement Control System)	Manchester	ATC	Global	Disseminates flight information for customer services.	Q
FOS (Flight Operations System)	Athens	Airline	General Airline Ops.	Aircraft movements, flight scheduling and updates	Q
GAETAN	Nice	Airline	General Airline Ops.	Check-in and generates boarding cards. Generates all loading information.	Q
GARP (General Airport Resource Planner)	Amsterdam	Airline (KLM) and Airport Op	General Airline Ops.	Used for planning resources such as gates, materials, and personnel.	I
GEMS (Global Environment Management system).	Amsterdam	Airport Op	General AO Ops.	Environmental management. Measures noise level.	I
GOA (Gestion Operationnelle Aéroportuaire)	Toulouse	Airport Op	Global	Provides flight information to all interested parties at airport. (Plus statistics & invoicing).	Q
HERMES, SIMMOD etc.	Gatwick	Airport Op/ NATS	General ATC Ops.	Determination of runway capacity. Key strategic planning information.	I

System	Location / Player		Type (*)	Uses Described	Information source (**)
IDAHO (ICL Database for Airport Handling Operations)	Gatwick	Airport Op	Global	Global database system. Collects & stores information about each flight.	I
				A flight information system based on a database. Several hundred data items are held for each flight movement, and this is made available to all players. This system is known as ADAM at Heathrow.	D
INFO	Frankfurt	Airport Op	General Airline Ops	Schedule information.	I
Information displays / monitors and public address system	Reus	Airport Op	Passenger Services	Display of flight information to passengers - flight schedule, boarding, check-in etc.	Q
INSITA (Integrated system to handle IATA messages)	Milan	Airport Op	General AO Ops	Manages and interprets IATA messages in real time.	Q
LOIS	Gatwick	ATC	General ATC Ops	Captures data similar to IDAHO with manual feed. Soon to be replaced.	I
MACH (Multi User Airport Control and Handling System)	Vienna	Airline	Global	Centralised airport information system- scheduled times dep/arr, estimated times of dep/arr, actual times of dep/arr (air/block) gates positions etc	Q
		Airport Op	Global	Provides flight information to all interested parties at airport. (Plus statistics & invoicing).	Q
MAESTRO	Charles de Gaulle, Orly, Copenhagen	ATC		A computerised multi-airport and multi-runway decision-support tool for sequencing the arrival of traffic of several airports and/or runways.	D
MAS (Monitor Anzeige System) [Anzeige = information]	München	ATC	Ground Ops/AC Handling	Positioning of aircraft & de-icing activities	Q
OBCCOS (Off-Block Calculation and Co-ordination System)	Frankfurt	Airline & Airport Op	Ground Ops/AC Handling	Communicates recommended & actual off block times between airlines and airport authority.	Q/I
PIS (Passenger Information System)	Gatwick	Airline	Ground Ops/AC Handling	Stores & disseminates passenger numbers plus other data.	I
RCA (Remote Client Application)	Palma	ATC		ATC slots	Q
Resource Allocation	Under development			An operational management tool designed to optimise all airport operations. Uses flight data to determine stand allocation, check-in, etc.	D
SACTA (Spanish Automated Air Traffic Control System)	Reus (Also in use at Madrid and Palma)	ATC	General ATC Ops	General ATC information, such as filed flight plan, routing, origin and destination	Q
SADAMA (Automatic Airport Resource Allocation System).	Madrid (Also in use at Palma)	Airport Op	Ground Ops/AC Handling	Stand allocation, baggage handling, boarding gates	Q
SAFIR	Stockholm	Airport Op	Global	Provides flight information to all interested parties at airport	Q

System	Location / Player		Type (*)	Uses Described	Information source (**)
SARIA (System d'allocation de resources et d'Information Aeroportuaire).	Charles de Gaulle	Airport Op	Global	Improves airport resource usage: parking, boarding rooms, check-in desks, baggage belt..	I
SARP (Signal Automatic Radar Processing).	Amsterdam	ATC	General ATC Ops	A general radar processing system. Provides controllers with information to assess current situation and extrapolate forward a few minutes for planning and conflict detection.	I
SCORE (Slot Co-ordination and Reporting)	Vienna	Airport Op	General AO Ops	Airport slot co-ordination and slot administration	Q
SIGMA	Toulouse	ATC	General ATC Ops	NOTAM information	Q
SIGO (Sistema de Gastão Operacional = Operational Managing System)	Faro	Airport Op.	General AO Ops	Operational management system - including billing, stand planning, statistics.	Q
SIIGAER	Under development		Check-ing	Purpose is to integrate the following systems: Automatic Resource Allocation, Access Control GPS, SIVV, Automatic Guidance and to connect them to the ATC system	D
SIM (Meteorological Integrated Information System)	Madrid	ATC	General ATC Ops	Weather reports for aircraft	Q
SIMA (Airport Resource Information System)	Madrid	Airport Op	General AO Ops	Informs airlines and handling managers about delays & assigned resources to aircraft	Q
SIP (Public Addressed Information System)	Madrid	Airport Op	Passenger Services	Presentation of information. to public (arrival/departure time, gates, boarding time, flight situation etc.)	Q
SLCT	Toulouse	ATC		Flight plan processing	Q
Slot Information and Aircraft Position	Madrid	ATC	General ATC Ops	For ATS services	Q
SMR (Surface Movement Radar)	Stockholm	ATC	Taxiing/ Ground Movements	Monitor aircraft and vehicle movements for ATC (on areas not visible from tower & in low visibility)	Q
SOLARI	Milan	Airline	Passenger Services	Information for passengers.	Q
SOPRANO / MILORD	Toulouse	Airline	General Airline Ops	Check-in functions and generates loadsheet	Q
SRM (Strategic Calculation Model)	Amsterdam	ATC	General ATC Ops	Environmental management. Maintaining and guarding noise contours	I
Stand allocation	Gatwick	Airport Op	Parking	Safe and efficient parking of aircraft.	I
STARMAN (Stand Planning System)	Gatwick	Airline	Parking	Stand planning system used by BA.	I
Strategic stand planning	Gatwick	Airport Op	Parking	Infrastructure planning tool.	I
Surface Movement Radar	Lisbon	ATC	General ATC Ops	To increase safety under low visibility operations and in operational areas not visible from working positions.	I

System	Location / Player	Type (*)	Uses Described	Information source (**)
SWITCH organisation's system	Brussels Airport Op		Distributes information between the different players relating to the terminal buildings. Achieves better co-ordination between the players.	I
TACO	Zurich ATC		Facility to automate routine tasks around flight plans in order to support the work of controllers in the tower. The tool will hold and manage flight plan data, perform routine calculations, and present the plans in a timely, up-to-date, user-friendly manner on each workstation	D
TACO (TWR/APP) & SYCO (ACC)	Zurich ATC	General ATC Ops	Flight plan data processing	Q
TARMAC	DLR ATC Airport Op		An operational management tool to integrate ground movements into air traffic operations with the ability to interface with all relevant ATC systems, Airport systems and Airline systems so that all necessary information is obtained	D
TOP (Total Operations Information System)	Vienna Airline	General Airline Ops	Scheduling, operational control, aircraft rotation management	Q
TRASS (Terminal Resource Allocation System Schiphol)	Amsterdam Airport Op Also said to be used at Heathrow, Brussels, Manchester & Stockholm	Parking	Gate allocation, which is the responsibility of the airport operator. A daily plan is produced.	I
Video of flight progress board (data on paper strips)	Stockholm ATC	General ATC Ops	Surveillance of aircraft on or near the airport	Q
Wake Vortex Warning System	Under development		Purpose is to reduce or suspend the wake vortex separations of aircraft on staggered approaches to parallel runway systems by developing a prognosis tool on wake vortex transport for the adjacent runways 25R and 25L	D
WIAS (Wetter Informations und Anzeige System) [Anzeige = information]	Köln/Bonn ATC	General ATC Ops	ATC weather and general status information (AIS)	Q

Notes: (*) AC: Aircraft
AO: Airport Operator
(**) I: In-depth Interview; Q: Questionnaire; D: Documentary Sources

Table 3-5 APTM Information Systems Identified

The sources of the information input into each of these systems and the destination of the information output from the systems was identified.

3.1.3. Summary and Assessment of User Needs and Requirements

In order to derive user requirements, a question was included in questionnaire regarding how useful each system was considered to be. Users generally felt that the systems were generally successful in meeting their current requirements, in particular Global and General Airline Operations systems. These systems tend to be highly automated and share large amounts of information with other systems. The evaluation by users of APTM systems at the airports at which a detailed survey was conducted was similar overall.

It was generally found that where systems have been created to meet current requirements, these have been fairly well met. Nevertheless, at many airports, current systems do not meet all current requirements, such unmet expectations being equated to "expectations". Airline expectations are not high, although some historical ATC information is required. Airport Operator expectations involved receiving more information from aircraft while they are on the airfield. Finally, ATC expectations tended to be focused towards obtaining more information from within the ATC network and the Central Flight Management Unit (CFMU). Some ATC organisations require limited information from airlines or from the airfield surface.

This led to two overall conclusions. First, the activities that each player undertakes are, in general similar, even at different airports, implying that the information needs for any player type are broadly the same at all airports. Second, for any player type and any application area, each organisation appears to have its own bespoke system, leading to the conclusion that international co-operation to achieve common agreed data interchange/message formats could help to facilitate information exchange and sharing.

3.1.4. Organisational Analysis of Real-Time Decision-Making Processes

In order to analyse the organisation of real-time decision-making processes in airport management, the first step taken was to identify the functions involved in the arrival/departure process which generally takes place at an airport. Thirty functions were identified, as follows:

?? Supervision of Operational ATC Team.
?? Control of Arriving Aircraft in the TMA.
?? Control of Waiting Aircraft in the TMA.
?? Control of Arriving Aircraft from Initial Approach to Final Approach.
?? Control of Arriving Aircraft Movements in the Final Approach Area.
?? Control of Landing Aircraft until Clear of Runway.
?? Control of Departing Air Traffic from Holding Point to Take-Off.
?? Control of Departing Aircraft from Take-Off to Transfer to APP.
?? Control of Departing Aircraft Movements in the TMA until Transfer to ACC.
?? Planning of Arriving Flights.
?? Sequencing of Arriving Flights.
?? Planning of Departing Flights.
?? Sequencing of Departing Flights.
?? Planning of Individual Aircraft Taxi Routes.
?? Control of Aircraft and Vehicles on Manoeuvring Areas/Taxiways.
?? Control of Aircraft and Vehicles on Parking Aprons.
?? Follow-Me Co-ordination for a Manoeuvring Area.
?? Management of Ground-Based Guidance.
?? Aerodrome Terminal Information Service Handling by Control Side.
?? ATC Flight Plan Processing.
?? Start-Up Clearance Delivery.
?? Airways Clearance Delivery.
?? PushBack Clearance Delivery.
?? CFMU Flight Plan Processing.
?? Airport Schedule Co-ordination.
?? Stand/Ramp Allocation.
?? Allotment and Gate Allocation.
?? Airline Central Load Control.
?? Airline Flight Plan Processing.
?? To Pilot (guiding the aircraft in accordance with aeronautical rules and in conformance with ground control instructions).

The decisions which need to be made in carrying out these functions were then identified. These decisions are general, and may be associated with more than one person or system carrying out a function. The identified decisions were classified into the following four categories:

?? Decisions regarding clearance.
?? Decisions regarding control instructions.
?? Decisions regarding information messages.
?? Decisions regarding ATFM resources.

Each of these categories includes numerous decisions, which were described on the basis of the scope of the decision and its substance. The scope of the decision described what is performed by the associated action (e.g., requesting, delivering, suspending). The substance of a decision is what the scope will be applied to. Two decisions with the same scope can be very different, depending on the substance: e.g., requests to taxi and requests for landing clearance are clearly very different. Table 3-6, Table 3-7, Table 3-8 and Table 3-9 summarise the decisions identified regarding clearance, control instructions, information messages and ATFM resources, respectively, cross-mapping the scope and substance of each decision.

Decision substance	**Decision scope**				
	Request	**Deliver**	**Modify**	**Suspend**	**Refuse**
Landing		x			x
Taxi	x	x	x	x	x
Startup	x	x	x	x	x
Pushback	x	x	x	x	x
En route	x	x	x	x	x
Take-off	x	x	x	x	x

Table 3-6 Clearance Decisions

Decision substance	Decision scope					
	Request	Plan sequence	Delivery	Modification	Update	Acknowledge
Taxi route		x	x	x	x	x
Hand-over in/out		x	x			x
Movement		x	x	x	x	x
Line-up behind		x	x	x	x	x
Wake wortex		x	x			
Visual landing	x	x	x	x		x
Departure procedure		x	x	x	x	x
Arrival procedure		x	x	x	x	x
Push-back	x	x	x	x		
Pull-back	x		x			
Report point			x	x	x	x
Holding point			x	x	x	
Exit point			x	x		x
SST code			x			
ATIS			x	x	x	
Frecuency change	x		x			x

Table 3-7 Control Instruction Decisions

Decision substance	Decision scope			
	Request	Update	Delivery	Reports
Weather		x	x	
Equipment status		x	x	
Fligh progress data	x	x	x	
Conflicts warning		x	x	
Sequence number	x	x	x	x
Segments capacity		x	x	x
Traffic	x	x	x	x
Crossing traffic	x		x	x
Targets identification	x	x	x	x
4D positioning	x		x	x
Incidents			x	x

Table 3-8 Information Message Decisions

Decision substance	Decision scope				
	Request	Change status	Resources allocation	Planning estimation	Modification
Navaids	x	x	x	x	x
Guidance	x	x	x	x	x
Movement	x	x	x	x	x
Radio Frequencies	x	x	x	x	x
Runways	x	x	x	x	x
Taxiways	x	x	x	x	x
Gate&allotment	x	x	x	x	x
Stand / parking	x	x	x	x	x
CFMU slot	x		x	x	x
Aircraft sequence	x		x	x	x
Handling sequence	x		x	x	x
Segments capacity			x	x	

Table 3-9 ATFM Resources Decisions

Having identified these decisions, the next step was to conduct an organisational analysis of the decisions in order to determine the way in which these decisions are actually made at the airports studied. The analysis included a study of decision-making allocation, organisational boundaries and system interfaces, on the basis of the results of the questionnaires and the surveys. In order to perform this analysis, the decisions were grouped together into six overall activities:

- Control Aircraft on Final Approach.
- Control the Active Landing Runway.
- Control Taxiways.
- Control Apron.
- Allocate Stands or Ramps.
- Control Aircraft as They Take Off.

The principal actors who make decisions at airports are aircraft operators, ATC, and the airport operator. Airports were examined according to the responsibility for each activity, and the following four groups were identified:

- All control activities are undertaken by the airport operator, with the exception of Control Aircraft on Final Approach and Control Aircraft as They Take Off.
- All control activities are undertaken by ATC, with the exception of the Control Apron and Allocate Stands or Ramps.
- All control activities are undertaken by ATC, with the exception of Allocation of Stands or Ramps.
- All control activities are undertaken by ATC.

As regards the organisational boundaries, it was found that they correspond to geographic boundaries, such that an aircraft which enters this area on the aerodrome comes under the responsibility of the particular organisation. Four geographical boundaries were identified: the stand, the apron, the taxiways and the runway. Normally, only one organisation takes part in the functions performed in each geographic area, although there may be co-ordination between the players. At the boundary of each area, responsibility is transferred by way of a hand-over or take-over.

Next, a general picture of information flows was obtained for the six airports studied in detail through the interview process. In order to obtain this picture, ground handling agents were included as actors, because since they co-ordinate and control the turnaround of aircraft, they have a major influence on delays and airport capacity.

Table 3-10 shows the broad picture obtained for systems interfaces, indicating the information flow to/from one player to/from another and giving a simple view of information sharing. It should be noted that only information expressly given during the course of the interviews at the relevant airport has been included in the table.

INFORMATION FLOWS - From & To											
Information to Control or Coordinate this Function	**Airline**	**Airport Operator**	**ATC**	**Ground Agents**	**Amsterdam**	**Brussels**	**Frankfurt**	**Lisbon**	**Gatwick**	**Charles de Gaulle**	
Short Timescale											
ATC - Enroute Control	To		From						✍		
ATC - Approach Control	To		From								
Estimated Time of Arrival	To	To	From		✍					✍	
Delays to arriving & departing flights	To	From	From		✍		✍		✍		
Landing	To		From					✍			
Taxiing	To		From					✍			
Parking Gate	To	From		From	✍		✍		✍		
Onblock time	From	To									
Aircraft Turnround on Ground	To			From					✍		
Resouce allocation & handling - (Airport Central Database).	To	From/To	To/From	To	✍	✍			✍	✍	
Passenger ground information - (Airport Central Database)	From	From			✍	✍	✍		✍	✍	
Offblock time/Pushback	To	To	From						✍		
Take-off	To		From								
Long Timescale											
Flight schedule planning at this airport	To	From	From		✍						
Flight schedule proposed at this airport	From	To	To		✍		✍			✍	
Noise measurement		To	From		✍						
Service agreement between airline/AO/ATC	From/To	From/To	From/To			✍			✍		
Stategic planning	From/To	From/To	From/To		✍	✍	✍	✍	✍	✍	
Parking (Gate assignment - strategic)	To	From	From						✍		
Runway capacity	From	To	From						✍		

Table 3-10 System Interfaces Data

Finally, all of this information was used to derive an object-oriented-type model for real-time decision making at the six airports studied in depth. The model was based on a set of high-level decisions selected from the full list of decisions identified previously, for clearances, control instructions and ATFM resources. Each of these decisions was described by way of its identification, its location in time with respect to others, what happens before the decision and what happens after the decision.

Upon initial analysis of these decision-making process, several similarities were found, due to the application of common regulations such as ICAO/IATA (e.g., necessary voice co-ordination between the pilot and the controller to deliver start-up clearance). Another similarity is in the concept of optimisation, in which one function (e.g., apron control) is optimised on the basis of what happens in the neighbouring functions in the arrival/departure cycle (e.g., taxiway and start-up control). The differences found were based on differences in organisation and the systems used.

The organisational analysis of real-time decision-making processes showed that, although it is possible to describe analytically the traffic management functions that take place at an airport, implementation of these functions varies at each airport. The organisations which carry out these functions and decisions and the system interfaces to co-ordinate them also vary widely from airport to airport, although a basic set of co-ordination techniques is commonly used. Conversely, real-time decision-making processes appear to be similar, but in fact the sequence of these processes, co-ordination mechanisms and information exchanges for co-ordination purposes vary greatly from airport to airport. This diversity demonstrated the need for co-operative arrival and departure management to improve traffic flow and for a common view by all actors of airport traffic management tools.

3.1.5. Identification, Classification and Selection of Three Generic Operational Scenarios

The final work done in Phase I was to identify, design and select three generic operational scenarios representative of the six airports studied in depth, which were intended to serve as the basis for the demonstration conducted with the DAVINCI demonstrator. This work was performed in four steps:

- Definition of the concept of a generic scenario and analysis of the six airports studied in depth for possible selection as a generic scenario.
- Definition of a method for describing airports and scenarios which would include both physical characteristics and organisational structure.
- Description of each of the selected airports using the method defined in the previous step in such a way as to point out the differences in characteristics/features of the selected airports and scenarios.
- Documentation of the technical description for each of the three selected generic scenarios.

The generic operational scenarios are operational models of airports, representative of the ways in which airport traffic management takes place in Europe. In order to derive these scenarios, the differences for distinguishing two to four generic scenarios were defined, so that a modular description format could be defined for the general patterns at the selected airports.

The selection of generic scenarios needed to be based on a series of parameters. An initial list was drawn up of seven parameters considered important. These were found to be unable to sufficiently characterise airports, so a new two-step approach was taken. First, the facts constraining factors for arrival and departures were identified: runways, taxiways, the apron and parking stands. It was decided that, since runways are the first areas in which both inbound and outbound traffic may have to be combined, a distinction would be made between airports at which there is a significant level of co-ordination on the runway and those at which co-ordination is far less significant. Second, taking into account that co-operation between two different organisations cannot be as efficient as if all operations are carried out by the same organisation, it was further decided to distinguish between the number of organisations responsible for ground movements. Thus, the criteria chosen for selecting the generic scenarios were as follows:

- Whether arrivals and departures are combined mainly on the runways or on the apron and taxiways.
- Whether the responsibility for ground movements is shared by two different organisations or assigned to a single organisation.

These criteria were found to be independent and could therefore be crossed with each other. The six selected airports were categorised by these criteria, giving rise to three generic scenarios as indicated in Table 3-11 below.

Responsibility for Ground Movements	**Main Location of Departure and Arrival Combination**	
	Runway(s)	**Apron /Taxiway(s)**
Shared by two different organisations		Frankfurt **GENERIC SCENARIO Nº 2**
Assigned to a single organisation	Paris/Charles de Gaulle London/Gatwick Lisbon **GENERIC SCENARIO Nº 1**	Amsterdam/Schipol Brussels **GENERIC SCENARIO Nº 3**

Table 3-11 Selection of Generic Scenarios

Taking the information contained in Table 3-11, the three generic scenarios selected can be defined by the selected parameters as follows:

- Generic Scenario Nº 1:
  - Responsibility for ground movements assigned to a single organisation.
  - Combination of departures and arrivals performed mainly on the runway(s).

?? Generic Scenario Nº 2:

?? Responsibility for ground movements shared between two different organisations.
?? Combination of departures and arrivals performed mainly on the apron and taxiway(s).

?? Generic Scenario Nº 3:

?? Responsibility for ground movements assigned to a single organisation
?? Combination of departures and arrivals performed mainly on the apron and taxiway(s).

In order to construct detailed descriptions of these three scenarios for the demonstration with the DAVINCI demonstrator, six airport components were selected, as follows:

?? Airspace: Airspace configuration/organisation.
?? Air/ground side: Runway configuration/organisation.
?? Ground side: Taxiway/apron configuration/organisation.
?? Aircraft side: Traffic characteristics.
?? Environmental/weather conditions.
?? Airport Information System (Configuration/organisation).

These components were represented by elements which were broken down into indicators and metrics to enable comparisons between airports and identification of deviations. Thus, each of the three generic scenarios developed in Phase I of the DAVINCI project can be technically described as a combination of cases for the various indicators describing each element of each component, for one representative airport. Other airports matching the generic scenario make it possible to identify deviations. For instance, two airports classified within the same generic scenario may have different traffic mix levels and only one may have a terminal layout segregated by airlines.

Table 3-12 shows the general patterns of the values for the metrics derived for the generic scenarios. The purpose of these patterns is to highlight the divergences prior to defining a common departure/arrival management system for co-operative improvement of airport traffic flows.

COMPONENT	ELEMENT	INDICATOR	GENERIC SCENARIO		
			Nº 1	Nº 2	Nº 3
Airspace Configuration/ Organisation	Configuration	Approach procedure diversity	medium	high	high
		Departure procedure diversity	high	high	high
	Organisation	Radar separation	little	little	medium
		Separated arrivals and departures	yes	yes	no
		Approach co-ordinator	yes	no	yes
Runway Configuration/ Organisation	Runway	Number of runways	2	3	5
		Landing and take-off runways	balanced	unbalanced	balanced
Taxiway/ApronConfiguration/ Organisation	Tower	Tower co-ordinator	yes	no	yes
	Taxiways	Number of taxiways	high	high	high
		Taxiway route crossings	few	many	many
	Aprons	Area of responsibility	little	many	little
	Terminal Restrictions	Segregated by airlines	yes	no	no
Traffic Configuration/ Organisation	Traffic Mix	Variety	little	little	no
	Traffic Density	Density	high	high	high
	Mature APATSI Procedures	Application	partial	complete	partial
Environmental/Weather Conditions	Weather	Frequency of constraints	high	high	high
	Noise	Existence of constraints	yes	yes	yes

Table 3-12 General Patterns of Generic Scenarios

It should be noted that Generic Scenario No. 1, contrary to Nos. 2 and 3, has been defined in such a way that arrivals and departures are combined on the same runways. Co-ordinators are mandatory for runway and approach operations for this scenario.

Based on the technical descriptions of the generic scenarios, the detailed descriptions of the generic scenarios were then generated. A standard format was defined for the detailed presentation of each of the three selected generic scenarios. This format was broken down into a description of the physical characteristics and the organisational aspects of each of the scenarios.

The physical characteristics were simplified, only presenting sufficient information to set the context for the organisational structure. These physical characteristics consisted of:

- Communication Services: identification, fax numbers, telephone numbers, AFTN addresses, radio frequencies.
- Ground Area Description: identifier (apron or taxiway), number of parking positions, identification of entry taxiways, identification of exit taxiways. Includes two figures with a model of the airport layout, one for ground traffic flows for arrivals and one for traffic flows for departures.
- Airfield Description: runway identifier, number of Standard Terminal Arrival Routes (STAR) or Standard Instrument Departure (SID) procedures, type of procedure (STAR or SID), description of procedure (e.g., normal, noise abatement).
- Runway Description: preferential runway system (runway identifier, use for take-off/landing, working hours, lateral windspeed, humidity); general runway characteristics (take-off runway available, landing distance available, displaced thresholds); and runway entry and exit points (identifier, taxiways, runway, available distance available).

The organisational aspects were defined by listing the functions performed in the scenario, and then presenting two tables:

- A first table which contains all existing function links for high-level decisions, characterising them as either actions (if responsible for high-level decision-making, inputs (if they participate in the decision-making process before the decision is made) or outputs (if they participate in the decision-making process after the decision has been made).
- A second table which contains the interfaces between the combinations of functions determined by the high-level decision-making processes, describing the exchanges for each item of information identified for the decision-making process.

The generation of the generic operational scenarios demonstrated that, although there is a significant level of variation in many airport aspects, generic scenarios can be defined using a strictly analytical process. In the selection of criteria to compare airports, it was necessary to "construct" synthetic metrics, since there are currently no single value metrics enabling comparisons to be made. Deviations were identified for two generic scenarios, demonstrating that the organisational structure depends on airport characteristics and highlighting the need to find common organisational "tendencies" in generating generic scenarios.

3.2. Phase II: Solution

The second phase of the DAVINCI project identified and described various potential solutions to the needs identified in the first phase. The most appropriate solution was selected and described in detail, on the basis of technical feasibility, impact on ATC and airport operations, and performance evaluation.

The first stage of the work done in this phase was to analyse the generic operational scenarios defined in the first phase, in order to determine whether requested data are available for making optimised decisions and whether co-operative management could be beneficial to improve efficiency. The purpose of this analysis was to provide information to be used in defining the DAVINCI solution. The approach taken was to either increase the capacity of each of the airport components (e.g., airspace, taxiways) or improve the data flows entering the planning systems to improve the capacity of individual system components, based on existing practices and the following overall objectives:

- To optimise the use of airport component capacity through the interrelationship between functions.
- To reduce the workload of some functions relating to co-ordination matters.
- To promote the idea of overall airport traffic fluidity.

A set of scopes for improvement was identified, applicable to either arrivals, departures, or both arrivals and departures combined. Possible techniques for improving traffic flow were also identified, as follows:

- To provide planning and/or supervisory functionality to improve the traffic situation awareness of the players, by enhancing radar images or airport cartography.
- To reduce manual actions by automating some specific actions, such as the validation of flight progress times or ATIS handling.
- To increase data availability by reducing the co-ordination needed by some players to obtain data, such as estimated arrival/departure times or aircraft characteristics.
- To improve communication tools.
- To investigate original procedures to reduce workload.
- To provide data fusion functionality.

For each of the six selected airports, improvements were proposed in three areas: airport data flow, co-operation procedures and co-operative management planning techniques. These improvements were classified as improvements for departures, improvements for arrivals and improvements for combined arrivals and departures. They were derived by a detailed study of the decisions which need to be made.

First, improvements were proposed to the existing airport data flow, including such aspects as the timing of data exchanges and update rates. A total of 32 improvements were proposed, giving for each the data content and a statement of the possible improvement identified. These proposed improvements are listed in Table 3-13. It should be noted that the non-shaded entries in Table 3-13, almost one-third of the total, could be implemented through a one-way transmission channel, without the need for co-ordination.

Name	Data contents	Improvement
DF1.1	Aircraft call sign & take off signal	To increase estimate computation accuracy
DF1.2	Airport capacity status	To share the supervisor information To improve awareness on airport capacity
DF1.3	Flight plans overview	To estimate global traffic situation & evolution
DF1.4	Stands occupation plan	To share parking traffic situation and evolution
DF1.5	CFMU slots, EOBT, CTOT	To have on the same display all information on a flight
DF1.6	Parking position number Aircraft registration number	To have on the same display all information on a flight
DF1.7	Handler services duration	To have optimum co-ordinated off-block times
DF1.8	Aircraft radio and navigation equipment	To inform controllers without asking to pilots
DF2.1	Aircraft allocated runway Scheduled time at feeder fix Delay to be absorbed	To have an optimum planning and execution of the arrival sequence
DF2.2	Aircraft navigation equipment performance	To avoid verbal message with the pilot during the process of runway allocation
DF2.3	Allocated parking number	To minimise the aircraft taxiing times
DF2.4	Preferred landing runway Preferred order in arrival Sequence in the aircraft operator fleet	To allow a co-ordination process when an aircraft operator would like to change the landing order of some of its aircraft
DF2.5	On-block time adjustments	To optimise the parking management
DF2.6	Scheduled time at feeder fix Delay to be absorbed	To optimise arrival sequences by co-ordination and co-operation with en route controllers.
DF2.7	Aircraft allocated runway scheduled time at feeder fix delay to be absorbed	To simplify the stack management. To reduce co-ordination between approach control, en route control and stack control.
DF2.8	Aircraft allocated runway Scheduled time of arrival Delay to be absorbed	To improve the runway capacity. To allow a better integration of the departure flights in the arrival sequence.
DF2.9	Aircraft allocated runway Scheduled time at runway Delay to be absorbed	To allow controllers to prepare the reinsertion of the aircraft in the arrival sequence in case of missed approach.
DF2.10	Arrival and departure sequences	To allow anticipation of possible problems. Improvement of the use of the runways.
DF2.11	Aircraft allocated runway	To allow anticipation in the use of the runway and taxiway.

Name	Data contents	Improvement
	Scheduled time at rwy exit	To plan better-mixed taxi in and out routes
DF2.12	Preferred order in arrival Sequence in the aircraft operator fleet	To allow to refine the planning of taxi-routes. To allow aircraft operators to send their priorities.
DF2.13	Aircraft identification Radar positions and speeds Airport resources locations	To provide the controller a global view of the ground movement situation and evolution
DF2.14	Arrival aircraft ten minutes before landing	To improve follow-me efficiency by a planning activity resulting from co-ordination
DF2.15	Aircraft allocated runway Scheduled and estimated arrival time at the runway	To optimise the real-time planning of stand/ramp allocation.
DF2.16	Arrival aircraft id ten minutes before landing	Refine planning of parking position allocation. Monitor feasibility of the new planning
DF2.17	Arrival aircraft id ten minutes before landing	Refine planning of gate allocation. Monitor feasibility of the new planning
DF2.18	The aircraft stack entry time, its stack exit time, runway, off-block time and missed approach event	To allow the aircraft operators to manage more efficiently their own resources.
DF2.19	Aircraft allocated runway scheduled and estimated arrival time at the runway	To allow the aircraft operators to send their priorities
DF2.20	Taxi route plan estimated on-block time	To allow the aircraft operators central load function to take into account taxi times
DF2.21	Assigned runway	To allow the pilot's anticipated preparation for this runway
DF3.1	arrival sequence: runway, schedule time of arrival at runway, the delay, the forward and backward limits	To allow to insert take-off slots in the arrival sequence in a more efficient way.
DF3.2	arrival suggestion rate	To allow, by reducing the arrival rate, to insert more departures if demand is high.
DF3.3	shift of an arrival flight	It is a way to insert a departure in the arrival sequence.

Table 3-13 Data Flow Improvements

The overall findings were that there is a generalised lack of information regarding the location of the aircraft on the ground and little sharing of the data regarding the results of the activities of each of the actors involved in APTM. It was thus concluded that information sharing should be improved to improve the use of airport resources.

Next, improvements were proposed for co-ordinating the co-operating decision cells at the airport, identifying the most appropriate cell to be responsible for specific decisions. Two types of improvements were identified: for independent decision-making procedures and for co-operative decision-making. Again, proposed improvements were identified for departures, arrivals and combined arrivals/departures. A total of 30 improvements was proposed, giving for each the co-ordinating agent and the proposed action. These improvements are listed Table 3-14. It should be noted that non-shaded entries in the table, almost one-third of the total, are instances of simple data transfers which could be implemented without the need for co-ordination.

Ref. no	Co-ordinating Agent	Action
C1.1	Start-up Clearance Delivery	Agree departure taxi route with planning of individual taxi routes (TAXI PLAN)
C1.2	Start-up Clearance Delivery	Obtain estimate of current departure taxiway congestion from TAXI PLAN
C1.3	Start-up Clearance Delivery	Obtain options for ground holding on the departure taxiway from TAXI PLAN
C1.4	Start-up Clearance Delivery	Agree latest convenient stand exit time with stand/ramp allocation (STAND ALLOC)
C1.5	Start-up Clearance Delivery	Agree runway slot time with sequencing of departing flights (SEQ DEP)
C1.6	Start-up Clearance Delivery	Receive runway configuration data and current departure capacity figure from supervision of operational ATC team
C1.7	Sequencing Of Departing Flights	Agree planned take-off time and sequence number with planning of Individual taxi routes
C1.8	Sequencing Of Departing Flights	Deliver planned take-off time and sequence number to control of aircraft and vehicles on manoeuvring areas (TAXI CTR)
C1.9	Sequencing Of Departing Flights	Deliver planned take-off time and sequence number to control of aircraft and vehicles on parking aprons (APRON CTR)
C1.10	Runway Control	Request slot extension from the CFMU
C1.11	Start-up Clearance Delivery	Co-ordinate airport departure restrictions with Airline Flight Plan Processing (AIRL IFPS)
C1.12	Airline IFPS	Co-ordinate flight route with the CFMU
C1.13	Airline IFPS	Co-ordinate flight departure time with the CFMU.
C1.14	Departures planning tool	Co-ordinate start-up plan with start-up controller.
C1.15	Departures planning tool	Co-ordinate pushback delivery plan with apron controller
C1.16	Departures planning tool	Co-ordinate taxiway plan with ground controller
C1.17	Departures planning tool	Co-ordinate departure schedule with runway controller
C2.1	TAXI CTR or APRON CTR	Receive taxi route from TAXI PLAN
C2.2	TAXI CTR or APRON CTR	Acknowledge conflict detection and resolution information from TAXI PLAN
C2.3	TAXI CTR or APRON CTR	Acquire guidance system status from management of ground based guidance (GUID SYS)
C2.4	TAXI CTR or APRON CTR	Agree hand-over conditions with other TAXI CTR or APRON CTR
C2.5	TAXI PLAN	Acquire serviceability status from GUID SYS
C2.6	TAXI PLAN	Obtain stand number and status from STAND ALLOC
C2.7	TAXI PLAN	Obtain arrival priority information from aircraft operator central load control
C3.1	Runway occupancy planning tool	Forward runway occupancy plan to runway controller
C3.2	Runway occupancy planning tool	Co-ordinate runway occupancy plan with start-up plan
C3.3	Runway occupancy planning tool	Co-ordinate runway occupancy plan with push-back plan
C3.4	Runway occupancy planning tool	Co-ordinate runway occupancy plan with taxiway plan
C3.5	Runway occupancy planning tool	Co-ordinate runway occupancy plan with departure schedule planning
C3.6	Runway occupancy planning tool	Co-ordinate runway occupancy plan with arrival schedule planning

Table 3-14 Co-operation Procedure Improvements

The overall findings were that there is a need for a common database, a need for indicators regarding airspace, runway, taxiway and apron congestion, and a need for greater co-operation in decision based on a common view of the situation.

A set of hierarchical, dynamic and distributed co-operative management planning techniques was proposed for DAVINCI, in order to model the generic scenarios. The techniques needed to be capable of modelling physical components, organisational components and data flows/exchanges between functions. The techniques were selected on the basis of the following criteria:

?? Ability to model scenario parameters.
?? Ability to reason about time.
?? Ability to deal with constraints.
?? Real-world technical feasibility.
?? Ability to deal with multiple criteria.
?? Ease/complexity of use within the limits of DAVINCI resources and timescale.

After a review of several co-ordination and planning techniques, it appeared that a centralised planning technique would not be technically adequate, because of both the time needed to compute solutions and to replan, and the modularity required to adapt to very different airports. The techniques selected were distributed dynamic scheduling and principled negotiation, both of which are decentralised co-ordination techniques.

Finally, a detailed model of the selected solution was specified, focusing on the co-operation between airport authority, aircraft operator, ATC and surface movement guidance and control systems. The aim of the co-operation was defined to be making the most efficient use of the available airport resources: airspace, runway(s), taxiway(s), apron(s) and stands. An illustration of the co-operation intended to be provided by the DAVINCI Solution is shown in Figure 3-2.

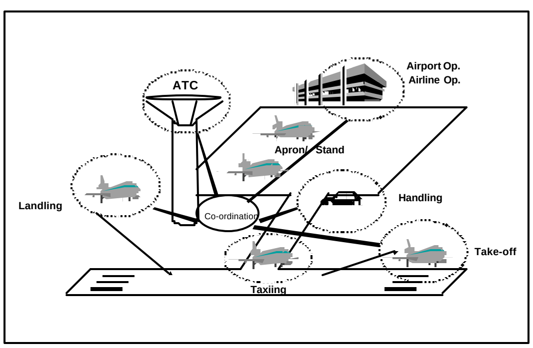


Figure 3-2 Overall View of the DAVINCI Solution

The DAVINCI Solution was designed to bring about the following improvements of those listed in Table 3-13 and Table 3-14 above:

?? Improvements to Data Flow (see Table 3-13): DF1.1, DF1.2, DF1.3, DF1.4, DF2.1, DF2.3, DF2.4, DF2.5, DF2.6, DF2.7, DF2.8, DF2.9, DF2.10, DF2.12, DF2.14, DF2.15, DF2.16, DF2.18, DF2.19, DF2.21, DF3.1, DF3.2.
?? Improvements to Co-operation Procedures (see Table 3-14): C1.1, C1.2, C1.4, C1.5, C1.6, C1.8, C1.9, C1.14, C1.15, C2.6, C2.7, C3.4.

The DAVINCI Solution can be categorised in broad terms as follows:

?? Data flow aspects: Data flow will be improved either by providing information which is not currently exchanged or by improving the quality of existing information exchanges.
?? Improvement of human co-ordination: Human co-ordination will be made more efficient through integrated displays of various sources of information.
?? Use of advanced co-ordination techniques: Planning activities will be based on overall objectives to ensure that traffic flow is improved.

More specifically, the DAVINCI Solution consists of:

?? Providing a data management facility to enable more efficient information transfer between airport authorities, aircraft operators and ATC.
?? Determining a set of indicators for traffic load and the quality of service provided to airspace, runway, taxiway, apron and stands to enable airport authorities, aircraft operators and ATC to have a common view of all operations taking place at the airport.
?? Providing an adaptable mechanism to take changes in the values of the indicators into account in the planning processes.

The solution is based on the addition of two layers in existing airport infrastructure to provide required functionalities: (a) a data management layer, an extension of the central database concept, as the essential transmission medium for co-operation purposes; and (b) a co-operation layer, a mechanism for co-operation between planning tools already in place, which will also provide traffic load and service quality indicators to give a common, synthetic view of arrivals and departures at the airport. A general model of the DAVINCI Solution is shown in Figure 3-3.

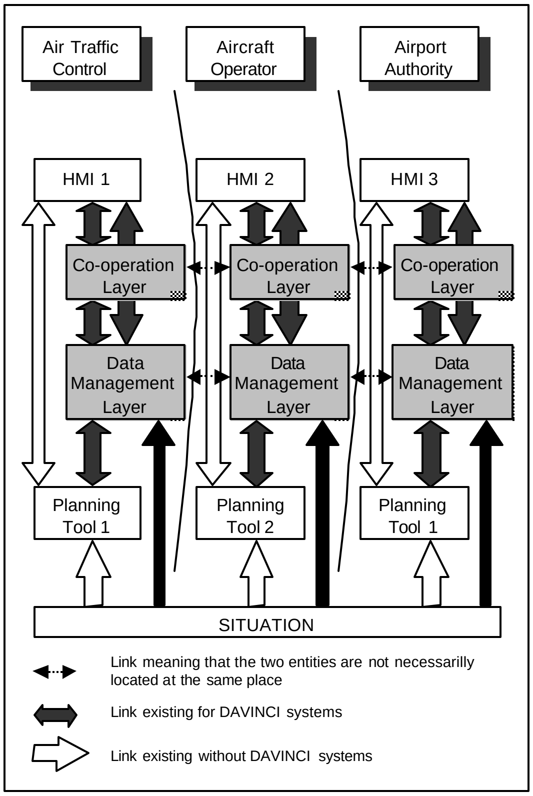


Figure 3-3 General Solution Model

The Data Management layer provides, but does not display, the information to be exchanged. The most visible activity of this layer is the exchange of information for direct display purposes (corresponding to the improvements listed in Table 3-13 and Table 3-14 which were not shaded). The Data Management layer also transmits exchanges needed for co-operation purposes, requiring a database for storing (even if only temporarily) the data it is to transmit. The most significant technical features of the Data Management Layer are the following:

- A store-and-forward feature, which distributes all updated data items to interested subscribers as soon as they are received.
- A provision-on-request feature.
- A consistency-check feature.
- A storage capability, which stores certain data items received.

The Co-operation layer summarises the present situation by way of the traffic load and service quality indicators. In addition, it determines a priority level for each aircraft, for use by the planning tools. Finally, it manages the co-operation between the planning tools by determining an overall strategy based on the indicators, by defining changes to the strategy on the strategy following changes in the indicators. This layer can be broken down into two sub-layers, as follows:

- One sub-layer which computes airport indicators and determine priorities for each flight. The indicators may be of three types: traffic load indicators, planning convergence indicators and service quality indicators.
- One sub-layer which manages the co-ordination between the planning tools.

Finally, a detailed model of the selected solution was specified, focusing on the co-operation between arrival management, departure management and ground movement management subsystems. The model is a functional model, divided into a static view (the core of the model), a dynamic view and a functional (data flow) view.

The static view of the DAVINCI Solution is shown in Figure 3-4 and Figure 3-5 below. Figure 3-4 shows the main parties involved, although other parties involved in airport resource management could also be included. The phrase "impacts on management of" requires the planner to be in either the master or the slave state for this resource.

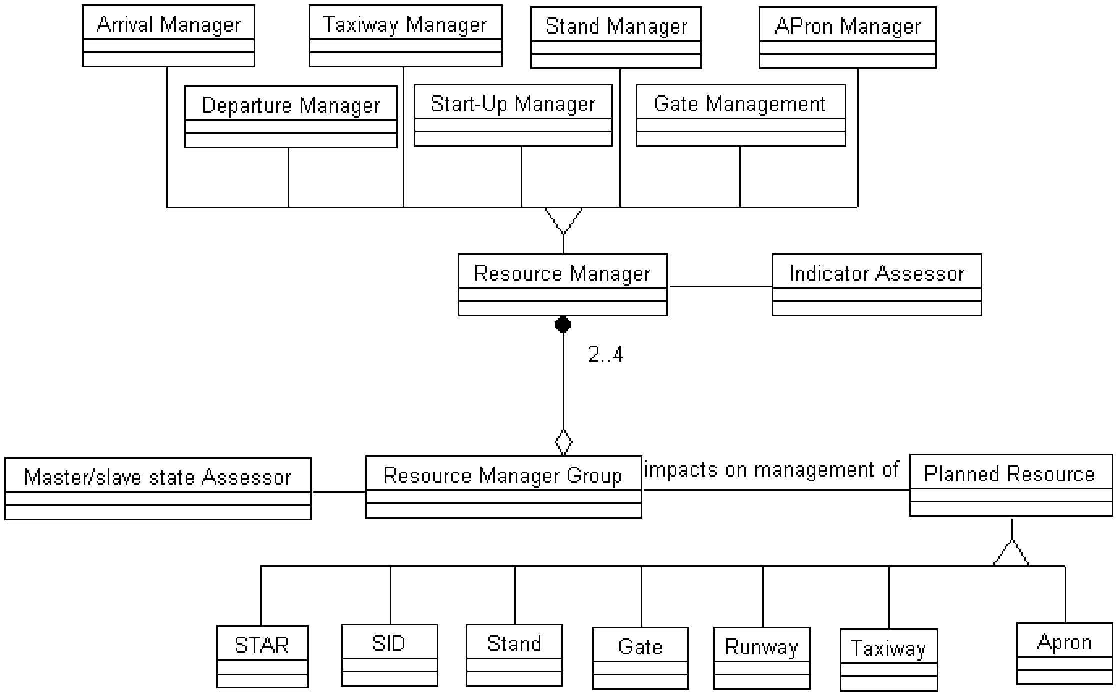


Figure 3-4 DAVINCI Solution: Static View (1)

Figure 3-5 shows the main resources utilised by the planners in performing their planning activities.

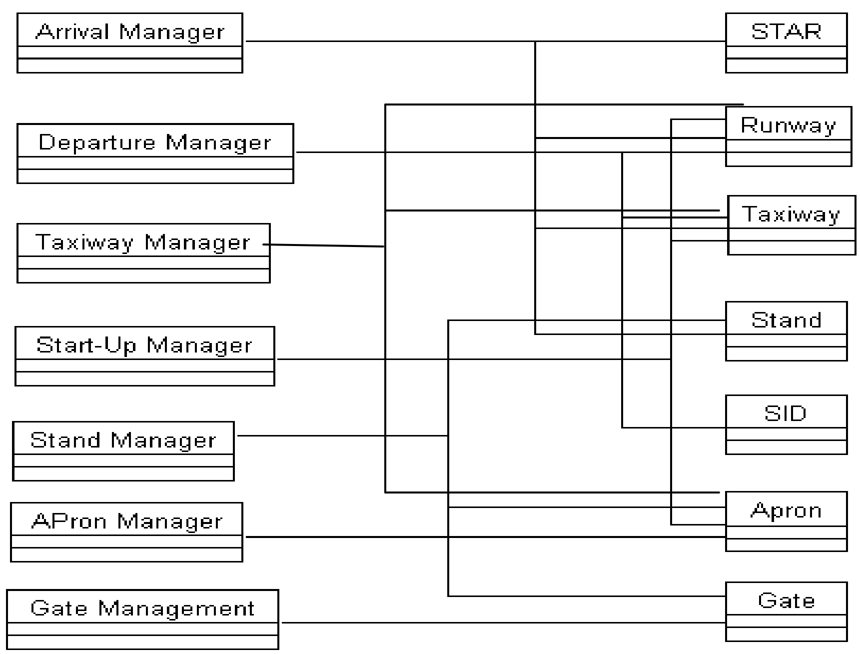


Figure 3-5 DAVINCI Solution: Static View (2)

The functional view of the DAVINCI Solution is shown in Figure 3-6 and Figure 3-7 below. Figure 3-6 shows a proposed functional organisation for the computation of indicators.

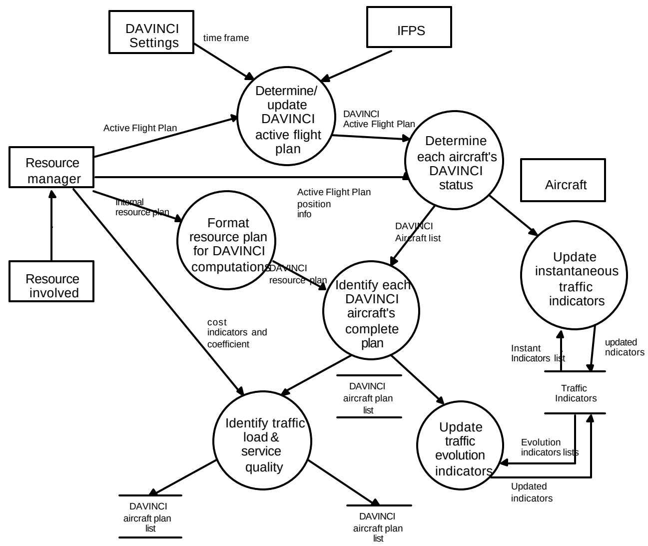


Figure 3-6 DAVINCI Solution: Functional Model: Computation of Indicators

Figure 3-7 shows a proposed functional organisation for the determination of advisories.

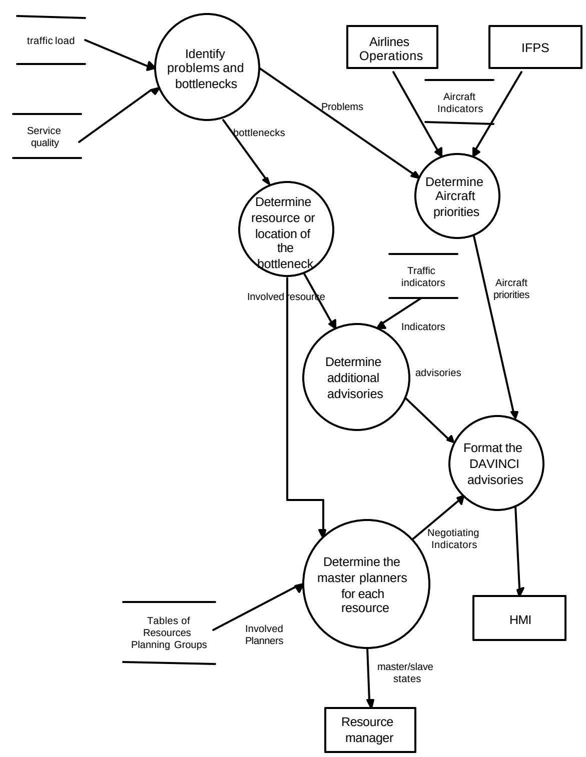


Figure 3-7 DAVINCI Solution: Functional Model: Determination of Advisories

As regards the dynamic view of the DAVINCI Solution, it should be noted that the main states of the planners are "master" or "slave", either with respect to a resource (if a single resource is managed by several planners) or with respect to an interface between resources (in all cases). The difference between these states is that, in the "master" state, the planner may provide constraints on the resource or interface, while in the "slave" state, the planner must take such constraints into account. This concept is illustrated in Figure 3-8, Figure 3-9 and Figure 3-10, for the main states of the arrival manager, departure manager and taxiway manager, respectively.

For the arrival manager, as shown in Figure 3-8, it is assumed that only two master/slave states exist: master or slave for runways used for both arrivals and departures (mixed mode of operation), and a master/slave state for the interface with taxiways. In this figure, states are not usually changed along the diagonal arrows, although this may occur in certain exceptional situations. Changes of states are caused by changes in the situation, and are always decided by the part of the system managing DAVINCI co-operation.

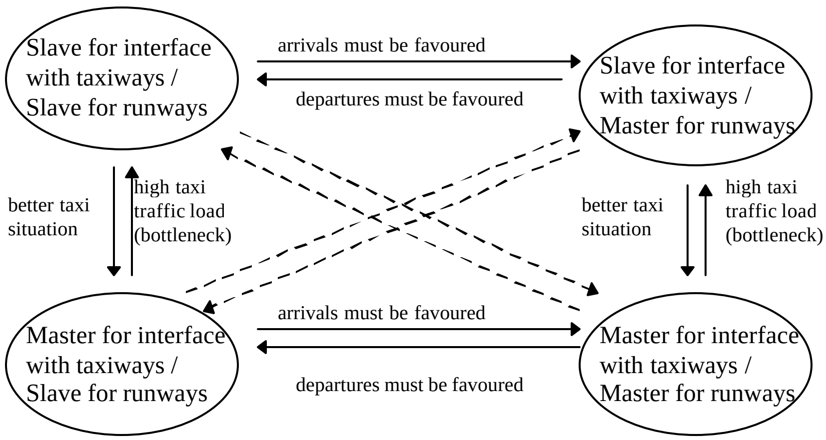


Figure 3-8   DAVINCI Solution: Main States of the Arrival Manager

For the main states of the departure manager, shown in Figure 3-9, the diagram is similar.

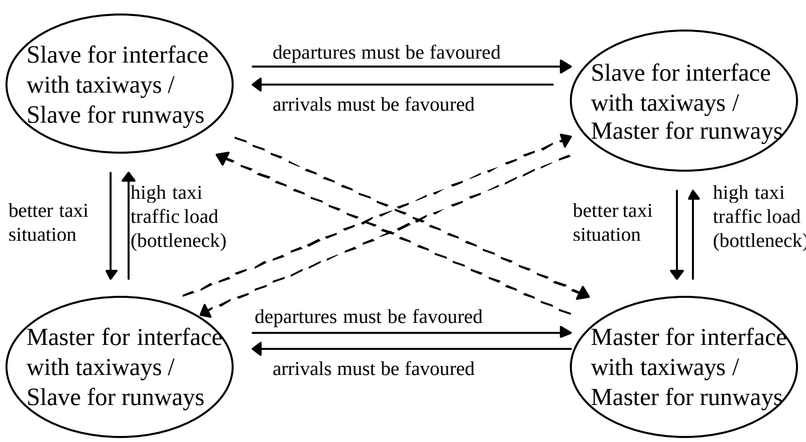


Figure 3-9   DAVINCI Solution: Main States of the Departure Manager

Finally for the taxi manager, the example is slightly different. The diagram in Figure 3-10 assumes a master/state for the interface with runways, and a second master/slave state for the interface with the apron.

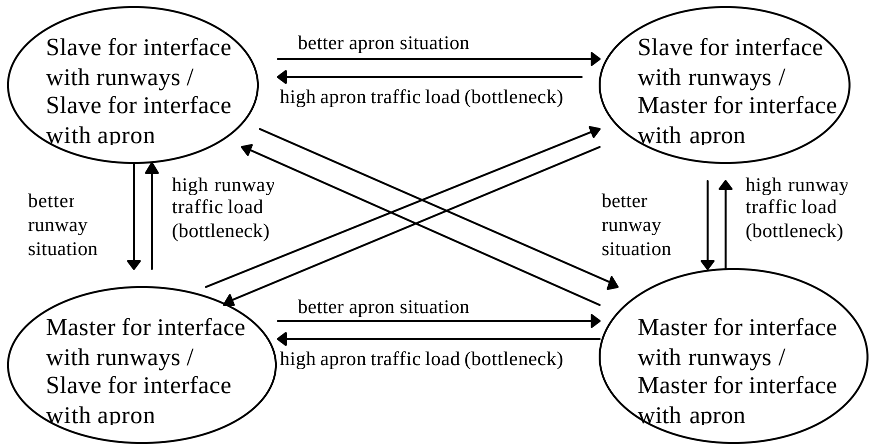


Figure 3-10 DAVINCI Solution: Main States of the Taxiway Manager

The diagrams shown in Figure 3-8, Figure 3-9 and Figure 3-10 should be adapted to each airport situation and each planner at the airport. In some cases, there may be more complex combinations of states, e.g., when three different planners are candidates to be master for the same interface. The DAVINCI Demonstrator is limited to five planners: arrival manager, departure manager, taxi route manager, stand allocation manager and pushback vehicle manager. It should nevertheless be noted that the number of planning systems is potentially unlimited, depending on the organisation at the particular airport.

In addition, techniques were defined and applied to describe the method and architecture of a system implementing the solution. First, a database management architecture was defined, on the basis of the following criteria: performance, scalability, adaptability, consistency, evolvability, interoperability and adaptability. After reviewing several database management options, it was decided to select a central active database, with managed co-operation and indirect communication between components through the central database.

The final work done in this phase was to model the system architecture indicated in the preceding paragraph. The model was designed using the Object Modelling Technique (OMT), a widely used method for object-oriented design.

As a final note regarding the work done in Phase II, it should be noted that neither the solution nor the model for the DAVINCI solution are intended for generalised use. The method must be adapted to each specific airport before being applied.

3.3. Phase III: Development of Demonstrator

The third phase of the DAVINCI project specified, designed and developed a demonstrator of the solution proposed in the second phase. The demonstrator implements the proposed co-operative method for terminal area/airport traffic management and the selected architecture. The DAVINCI solution as described above was refined for implementation as follows:

?? Information is made available to any of the actors who need it. This was implemented by using existing data servers and one new server.

?? A central DAVINCI co-operation tool:

  ?? Computes traffic load or quality of service indicators, some of which are overall, some for each runway and some for particular flights.
  ?? Computes advisories on the basis of indicators.
  ?? Decides on planner priorities, or slave/master states, which relate to specific airport interfaces.
  ?? Synchronises planners, based on a sequencing graph.

?? A DAVINCI HMI displays indicators and advisories, planner priorities and an integrated view of planning.

The DAVINCI demonstrator was designed to perform: (a) a limited set of operational functions, which are a subset of the planning functions performed by the real system; (b) a set of functions specific to the DAVINCI solution; and (c) a set of technical functions for supervising and controlling the simulation and the demonstrator. The operational functions are the following:

?? Planning and sequencing of arriving flights over a period of time, including STAR allocation.
?? Planning and sequencing of departing flights over a period of time, including SID allocation.
?? Taxi route and movement planning.
?? Pushback planning.
?? Stand allocation.

The functions specific to the DAVINCI solution are the following:

?? DAVINCI co-operation tool
?? DAVINCI HMI
?? Central DAVINCI database servers.

Finally, the technical functions are the following:

- Scenario management.
- Air situation feeder.
- Recording of scenarios, events, actions and results.
- Performance of comparative and statistical analysis.

The demonstrator was based on the DAARWIN test bench developed by CENA. Figure 3-11 illustrates the layout of the DAVINCI solution in the demonstrator and the main components which implement this solution.

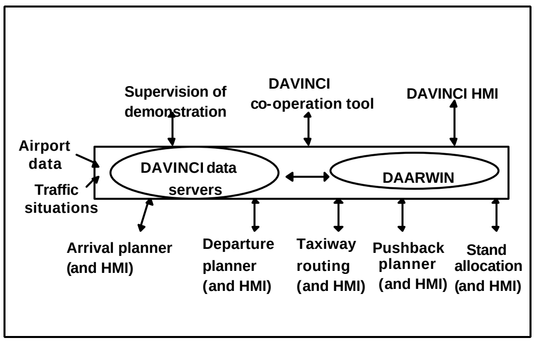


Figure 3-11 Components of the DAVINCI Demonstrator

The planning tools all have a similar architecture, based on a core containing the specific functions and an HMI. Communication between the components takes place through the data servers, in which data is stored. Access to data is possible through remote procedure calls and through subscription/notification. No direct data exchanges between planners are possible. All exchanges must take place through the data servers, thereby ensuring that the information is available to all components.

The demonstration was intended to show how planning is performed at a given time t0, based on a snapshot of the current traffic situation and data on traffic scheduled for the time between t0 and t0 + 60 minutes.

Each planning function is performed by a human operator, assisted by an automated planning tool. Each planning tool provides:

- A planning function able to propose a plan meeting constraints on the basis of the current situation and the current plans for the next hour.
- An HMI providing at least the interfaces needed to display the current plan and the plan proposed by the tool, editing the current plan and the plan proposed by the tool, and validating the plan.

The demonstrator was designed to be flexible, to enable comparisons, evaluation of the overall DAVINCI solution and evaluation of the impact of each part of the DAVINCI solution. This flexibility consists of the following:

- Availability of two main modes of operation. without the DAVINCI solution (eliminating everything relating to master/slave modes, indicators or advisories) and with the DAVINCI solution. Intermediate modes are also possible, either incorporating parts of the DAVINCI solution (e.g., display of indicators and advisories and/or integrated planning view but without automated co-ordination between planners) or incorporating the DAVINCI mode without the DAVINCI HMI display.
- Choice of airport.
- Choice of airport configuration (e.g., simulating what happens when a runway is closed).
- Choice of traffic scenario.
- Ability to set the master/slave configuration and sequencing graph at start-up.
- Ability of human planners to edit plans.

A user manual was drawn up for use of the demonstrator, which contains sections on how to install, launch and use the demonstrator, how to prepare data files and how to make changes in the demonstrator.

The components of the DAVINCI demonstrator include five planning tools, two specific DAVINCI tools, DAVINCI data servers and three non-DAVINCI technical functions. These components are described in the following subsections.

3.3.1. Arrival Planner and Departure Planner

In the DAVINCI solution, the arrival planner and the departure planner are closely co-ordinated. They will thus be discussed in a single section, first describing each planner individually and then discussing their co-ordination in the DAVINCI solution.

The roles of the **arrival planner** are to allocate a runway to each arriving aircraft and to plan arrival sequences of aircraft on runways. It computes a sequence for all arriving flights on a given set of runways. Once sequenced, a flight may have to absorb a delay before landing.

For each aircraft, the arrival planner receives an estimated time of arrival on the approach feeder fix, then computing the estimated time of arrival on the runway using fixed flight times. The scheduling process then chooses the landing runway and produces the scheduled flight time on the runway and the scheduled flight time on the approach feeder fix. These scheduled times enable an en route and approach delay to be computed, as well as actions to be performed by the approach and en route controllers to absorb these delays.

The HMI for the arrival planner displays planned flights by allocated runway, according to their scheduled times, and enables changes to be made. Also displayed are the configurations of planners, which are master and slaves with respect to the use of interfaces between resources (runways, taxiways, stands and pushback). The arrival planner has links with other components through the data servers. Server events are used to receive various types of information.

The role of the **departure planner** is to allocate a runway to each departing aircraft and to sequence departing aircraft. It computes a sequence for all departing flights on a given set of runways. For each aircraft, the departure planner chooses a take-off runway and computes a scheduled time of departure on the runway. To build the sequence, the departure planner takes into account a set of constraints concerning the wake vortex classes, speed classes or exit points of two consecutive flights. The approach controller can modify the sequence, although this modification may be refused by the departure planner in certain circumstances.

The HMI for the departure planner displays planned flights by allocated runway, according to their scheduled times, and enables changes to be made. This HMI may be in common with the HMI for the arrival planner. The departure planner has links with other components through the data servers. Server events are used to receive various types of information, especially actions taken by the controller or arrival manager.

The arrival and departure planners can **co-ordinate** to improve runway use if landings and takeoffs use the same runways. At the strategic level, the departure planner proposes changes in the arrival and departure runway rates to the arrival manager. At the tactical level, the arrival planner computes a maximum delay for each arriving aircraft which can be used by the departure planner to move the aircraft forward or backward to insert a take-off.

The DAVINCI **co-operation** tool (see Section 3.3.5 below) computes indicators and applies decision rules to decide which strategy to adopt. These strategies define the manner in which the planners should behave. Strategies applicable to the arrival and departure planners address the airport and aircraft. At the airport level, the DAVINCI co-operation tool decides the mode of operation of each planner and the values of the runway rates. At the aircraft level, for each of these aircraft, it computes a priority which will be used by the planners. These strategies are illustrated in Figure 3-12 below.

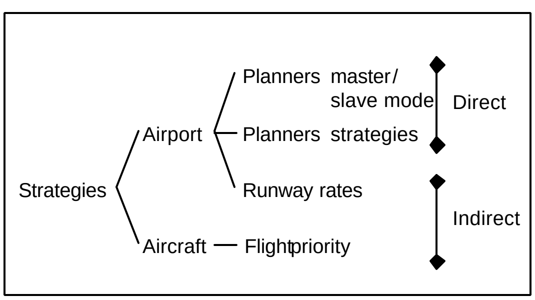


Figure 3-12 The DAVINCI Strategies for the Arrival and Departure Planners

Although the airport strategies are necessarily overall strategies applying to all traffic, they can be used to either modify the overall airport strategy or improve the specific situation of a given flight. Furthermore, the planners' mode of operation determines the planner which constrains the other planner, thereby defining the manner in which the planners should dialog. This type of strategy is called "direct co-operation". For the other types of strategies, the DAVINCI co-operation tool defines some characteristics of the airport or of the aircraft, but no further dialogue is necessary between the planners. This type of strategy is called "indirect co-operation".

Direct co-operation is based on master/slave modes. In order to obtain smooth integration, the sequence of the planning tools must be organised and the tools must be required to take into account the results of the plans computed by tools with a higher priority. The priorities between the planners are defined by the DAVINCI co-operation tool, determining which planners are constrained by the other planners. The priorities of the arrival and departure planners are especially important, since they cannot have the same priority on a given mixed-mode runway at the same time: one must be the master while the other is the slave. Two strategies, common to both planners, are available: minimum taxiing, in which the planners try to allocate aircraft to the runway giving the lowest taxiing time when the air traffic load is low, and no crossing, in which the tools try to allocate aircraft to the runway closes to the feeder fix in situations of a high air traffic load.

Indirect co-operation takes place in two areas:

?? To define runway rates, which will be proposed to arrival and departure controllers by the DAVINCI co-operation tool and then used to draw up their plans.

?? To define flight priorities, which will be computed by the DAVINCI co-operation tool and used by the planners to perform their activities.

3.3.2. Taxiway Routing Planner

The role of the Taxiway Routing Planner is to determine the route, from among a set of predetermined routes, which each arriving and each departing aircraft should take from the runway exit point to the stand or from the stand to the runway entry points. It also plans shedules in and out of the taxi area. In addition to assigning a route to each aircraft, assignments already made may be changed.

Routes may be changed when there is a change in the estimated time of arrival/departure of a flight, a change in the status of a stand resource or a change in status of a taxiway resource. These updated routes are displayed to the user, who can then edit the routes proposed by the planner.

The HMI of the taxiway routing planner enables the user to view the proposed plans, change them and accept either the plans proposed by the tool or as modified by the user. The taxiway routing planner has links with other components through the data servers, mainly to retrieve different types of information stored in them. Server events are used for purposes of synchronisation.

3.3.3. Stand Allocation Planner

The role of the Stand Allocation Planner is to manage stands to ensure that no flights are made to wait due to the unavailability of a stand. In particular, the Stand Allocation Planner allocates stands to aircraft/flights, manages the stands and plans occupation times for each stand. The Stand Allocation Planner may also change previously made stand assignments.

Stand assignments may be changed when there is a change in the estimated time of arrival/departure of a flight, or a change in the status of an apron, stand or taxiway resource. These updated stand assignments are displayed to the user, who can then edit the stands proposed by the planner.

The HMI of the stand allocation planner enables the user to view the proposed plans, change them and accept either the plans proposed by the tool or as modified by the user. The stand allocation planner has links with other components through the data servers, mainly to retrieve different types of information stored in them. Server events are used for purposes of synchronisation.

3.3.4. Pushback Planner

The role of the Pushback Planner is to manage pushback vehicles to ensure that no flights are made to wait due to the unavailability of pushback. In particular, it allocates pushback vehicles to flights needing them and plans occupation times for each of them. The Pushback Planner may also change previously made pushback assignments.

Pushback allocations are made taking into account the estimated time of departure of the aircraft from the stand, the mean time to pushback from the stand to the taxiway, the estimated time from the taxiway to the runway entry point and the characteristics of the pushback vehicle. They may be changed when there is a change in the estimated time of arrival/departure of a flight, or a change in the status of an apron, pushback, stand or taxiway resource. These updated pushback assignments are displayed to the user, who can then edit the plans proposed by the planner.

The HMI of the pushback planner enables the user to view the proposed plans, change them and accept either the plans proposed by the tool or as modified by the user. Other functions are also possible from this HMI. The pushback planner has links with other components through the data servers, mainly to retrieve different types of information stored in them. Server events are used for purposes of synchronisation.

3.3.5. DAVINCI Co-operation Tool

The role of the DAVINCI Co-operation tool is advisory for planners using the DAVINCI solution, providing indicators, and strategies based on these indicators, to assist planners. The strategies may be either advisories and assistance in co-ordination between the planning tools, making decisions on which planners constrain which other planners for each resource or interface between resources, and which planners must take these constraints into account.

The DAVINCI Co-operation tool performs the following main functions:

?? Computation of situation indicators: These indicators may be either overall (e.g.,. traffic load indicators for airspace, runways, taxiways, apron and pushback; and overall service quality indicators) or for a particular flight (quality indicators for aircraft, runway, taxiway and apron). A specific metric has been defined for each of these indicators.
?? Computation of advisories: In this context, advisories can be defined as rules for optimising the situation proposed by the DAVINCI Co-operation tool. These rules govern how to share a runway between arrivals and departures, the proposed runway allocations and priority rules for flights.
?? Decision on priorities: The priorities take the form of a master/slave state for each resource or interface between resources, when applicable and as decided by the DAVINCI Co-operation tool. When master, a planner constrains the slave, since the slave must comply with the plans decided by the master. Only six configurations of master/slave states are allowed. For these configurations, planners may only make new plans official after having received plans set by their predecessor in the priority.
?? Co-ordination of planners: In some cases, even if a planner is acting as a master, it may have to reconsider its plans because they are unfeasible in some way. In such cases, the planner must comply with the plans set by the slave planner which discovered this unfeasibility. For this purpose six sequencing graphs were developed, one for each possible master/slave configuration, which define the sequence of events in the event of unfeasibility.

The HMI of the DAVINCI co-operation tool is described in the following section. The DAVINCI co-operation tool has links with other components through the data servers. Data relating to the DAVINCI solution are set by the DAVINCI Co-operation tool. Server events are used for purposes of synchronisation.

3.3.6. DAVINCI HMI

The role of the DAVINCI HMI is to display the information processed during the execution of a scenario in the demonstrator and enables the introduction of some external inputs into the system. This information is mainly provided by the DAVINCI Co-operation tool. In addition to the DAVINCI HMI, each planning tool has its own individual HMI. Thus, each human planner will use two HMIs: the one for the planner and the DAVINCI HMI.

The DAVINCI HMI performs the following functions:

?? Display of indicators: Overall indicators are displayed in both graphic and tabular form, and are updated at the frequency defined by the DAVINCI co-operation tool for computation of indicators. Indicators for specific flights and by runway/time horizon (in tabular form) are also displayed.
?? Display of advisories: Advisories regarding flight priorities, specific to planners and regarding runway use are displayed in a scrolling list.
?? Display of planner priorities: Priorities among planners, as defined by the DAVINCI co-operation tool, are displayed in tabular form.
?? Display of integrated view of planning: A set of the most important parameters for the arrival and departure processes are displayed in two scrolling lists.

3.3.7. DAVINCI Data Servers

The role of the DAVINCI Data Servers is to provide information on the actual and planned situation and information specific to DAVINCI to all tools. The main functions performed by the DAVINCI Data Servers are data storage, provision of remote procedure calls for access to data and provision of events for automatic notification of relevant information upon client subscription. All information is managed centrally and is accessible to all tools and operators.

Situation information mainly relates to the approach situation and the ground situation. Specific DAVINCI information (indicators, advisories, priorities, co-ordination information) is provided by the DAVINCI co-operation tool. In addition to the basic DAARWIN servers (name, supervision, time and flight servers, among others), there are two main central data servers:

- MOZART server, providing situation information. This server is composed of four services: arrival, departure, ground and environment services.
- DAVINCI server, providing specific DAVINCI information. This server is composed of three services: indicator, advisory and priority services.

3.3.8. Technical Functions

Three non-DAVINCI technical functions are included in the demonstrator. These functions involve the operation of the demonstrator per se; they are not operational and are not part of the DAVINCI solution. They include three components: supervision and control (which manages the demonstrator and scenarios), air situation feeder (which writes the air situation in the database in an appropriate format) and the output recorder/analyser (which records demonstration data, computes indicators for evaluation and stores results in a file).

The Output Analyser stands alone with respect to the simulation. It extracts data from the database and prepares it for obtaining results about improvements in the selected indicators with and without the DAVINCI solution. These data are packed in ASCII format for export to external tools, such as spreadsheets. Links between the Output Analyser and other components are through the data servers.

3.4. Phase IV: Demonstration and Evaluation

The fourth phase of the DAVINCI project proposed a generic validation strategy for APTM systems. In addition, a specific Evaluation Plan was defined and established for the DAVINCI demonstrator. User requirements, validation objectives, indicators and metrics were proposed for the validation conducted within the DAVINCI project. This work was broken down into the following steps:

- Definition and Description of a Validation Strategy.
- Identification of Validation Indicators.
- Selection of Validation Indicators and Associated Metrics.
- Definition and Description of Evaluation Plan.

The validation approach was defined for three layers: the overall APTM system layer, the configuration layer (for the DAVINCI solution) and the validation exercise layer (for the DAVINCI Demonstrator). Validation objectives were defined, types of indicators were identified and requirements for traceability were stipulated. These layers are described in the following subsections.

3.4.1. Validation Approach for overall APTM System

For the overall APTM system layer, high-level validation objectives were defined and types of indicators for each of these objectives were identified. Finally, objectives and attributes for traceability were identified.

The high-level objectives originally selected for DAVINCI were safety, capacity, efficiency, cost-effectiveness, uniformity, national security and environment. At this stage, however, only the three most important high-level objectives, safety, capacity and efficiency, were dealt with in detail. The definitions of these objectives and an indication of the types of indicators selected for each of them are given below.

Safety can be defined as the ability of an entity not to cause, under given conditions, any critical or catastrophic events. Safety can also be considered from the point of view of dependability. Dependability can be defined as the ability of a system to perform several required functions under given conditions, therefore encompassing reliability, availability, maintainability, system safety, etc., and a combination of these properties.

Thus, the concept of safety can be subdivided into the concepts of "risk" and "dependability". These concepts can be further subdivided as shown in Table 3-15.

SAFETY		
Risk		**Dependability**
Classical	**Compound**	
Incidents	Economic	Reliability
Accidents	Individual	Availability
Fatal accidents	Intolerability	System safety
Collisions	Expected non-utility	Confidentiality
Fatalities		Integrity
		Maintainability
		Security

Table 3-15 Breakdown of Safety Concept

Since safety depends very much on the flight phase, (ref. [13]), the APTM System safety objective may also be subdivided based on the flight phases which are relevant to the APTM System, as follows:

- Airport safety;
- Safety during take-off;
- Safety during approach,
- Safety during landing.

several issues regarding the extent of achievement of the safety objective are as follows:

- ?? Minimum risk: The extent to which the system minimises the risks of collisions or incidents either in the air or on the ground to as low a level as is reasonably practical[1] .
- ?? Service availability: The extent to which the system maintains service availability at all times, providing adequate priority for safety critical services.
- ?? System resilience: The extent to which the system is resilient to disruption or abrupt cessation of the services under any circumstances of: air traffic density; unexpected human action; aircraft malfunction, partial system failure or non-availability of service; weather conditions; periods of crisis.
- ?? System protection and resistance: The extent to which the system is protected from and resistant to physical or electronic security breaches which can compromise safety.
- ?? Contingency provision: The extent to which the system provides contingencies to cover system availability, system resilience, and system protection and resistance.
- ?? Human element assistance: The extent to which the system provides adequate assistance to the human element in the form of back-up facilities and fail-safe options in respect to system failure situations.

Several indicators (and their associated metrics) of the extent to which the capacity objective is achieved were defined (see section 3.4.3. below).

As noted in section 3.4 of [5] or in EUROCONTROL, European Air Traffic Management System (EATMS) Mission Objectives and Strategy Document (MOSD) ([9]), **APTM system capacity** is dependent on various factors, the most important being: ATC capacity (partially); airport capacity; airspace capacity; aircraft operator capacity; and environmental constraints. The APTM system capacity objective is subdivided here into:

- ?? runway capacity;
- ?? airport capacity;
- ?? ATC capacity (partial);
- ?? airspace capacity;
- ?? aircraft operator capacity.

Each of these "capacities" may be characterised by more elementary quantities. For example, ATC capacity is dependent on controller capacity, ATC staffing, and the ATC systems and procedures in use. Several issues regarding the extent of achievement of the capacity objective could be as follows:

- ?? Service capacity: The extent to which the system minimises delays for all users, taking into account the mix and geographical distribution of demand.
- ?? Capacity flexibility: The extent to which the system can handle abnormal air traffic situations.
- ?? Forecast demand: The extent to which service demand can be appropriately forecast.

[1] For some types of operation, minimum risk may be related to "maximum acceptable risk".

- ?? Optimum human resources: The extent to which human resources are optimised in order to eliminate APTM system-related constraints.
- ?? Capacity increases: The extent to which additional capacity increases, as determined by the traffic forecast, can be provided in a cost-effective way.

Several indicators (and their associated metrics) of the extent to which the capacity objective is achieved were defined (see section 3.4.3 below).

The EATMS **efficiency** objective is defined in [9] as follows: "The EATMS shall enable all airspace users to operate efficiently while accommodating both civil and military operators' needs". Unlike safety and capacity, efficiency is a relative rather than an absolute objective for the APTM system. Although there are many aspects within the APTM system which may be considered to lead to inefficiency from an aircraft operator's point of view, the most significant ones are the following:

- ?? Unavailability of optimum approach levels,
- ?? Unavailability of shortest routes, for approaching or taxiing.
- ?? Inability to adhere to scheduled departure and arrival times,
- ?? Excessive user charges

Several issues regarding the extent to which the efficiency objective is achieved are as follows:

- ?? Freedom of movement: The extent to which aircraft are permitted maximum, reasonable freedom of movement.
- ?? Efficiency flexibility: The extent to which the plans and requirements of each type of operator are taken into account, including aircraft capabilities as well as the corresponding flexibility to accommodate real-time changes in the operators' intentions.
- ?? Capability flexibility: The extent to which advantage is taken of the capabilities of the best-equipped aircraft, while providing service to the least-equipped aircraft.
- ?? New technology flexibility: The extent to which users are allowed to accommodate and exploit new technology seeking to harmonise with military developments whenever possible.
- ?? Service quality: The extent to which a level of service of equal quality is delivered throughout the ECAC area.

Several indicators (and their associated metrics) of the extent to which the efficiency objective is achieved within the DAVINCI System were defined (see section 3.4.3 below). Considering the various metrics for the five efficiency topics, they are seen to be more or less of a statistical nature. In principle, all of the methods and techniques for validating APTM system capacity are relevant for validating efficiency by the 'freedom of movement' indicator, provided they are able to produce the pertinent data.

3.4.2. Validation Approach for the Configuration Layer (DAVINCI Solution)

The system for which the DAVINCI Solution has been specifically designed only includes a subset of the full complement of subsystems which make up the overall APTM system. Specifically, this system consists of an arrival planner, a departure planner, a taxiway planner, an apron planner and a stand planner. Consequently, the validation approach defined in the preceding step for the overall APTM system needed to be refined in order to obtain a specific validation process for the DAVINCI system.

In order to refine the high-level objectives for the system, they were broken down into three types:

?? **Technical-related high-level objectives**, which involve the technical aspects of the system or procedure. They should ensure the high quality of any developed system.

?? **Service-related high-level objectives**, which involve an assessment of the services provided by the system as a whole. Assessment of service should be interpreted broadly. For example, assessment includes the cost of the service.

?? **Human-operator high-level objectives**, which should ensure that the overall system is suitable from the human operator point of view. These objectives also contribute to the quality of the services provided by the ATM system.

All of the seven high-level validation objectives selected for the DAVINCI validation were found to be service-related. Again, the further breakdown of high-level objectives into validation requirements, indicators and metrics was limited to the three most significant high-level objectives: safety, efficiency and capacity. Nevertheless, technical-related and operator-related validation requirements, instantiated to the specific functional configuration of the DAVINCI system, were also identified. These requirements are presented in Table 3-16.

TECHNICAL-RELATED	SERVICE-RELATED			OPERATOR-RELATED
	Safety	Capacity	Efficiency	
Increase dependability of the system Optimise access to database.	Reduce ground conflicts Reduce air conflicts (in the area of the airport).	Increase aircraft operations in airport Increase aircraft operations on the runway Increase aircraft operations at the stand Increase aircraft operations on the taxiway	Reduce arrival delays Reduce departure delays Reduce holding time at Aprons Reduce clearance-waiting time Reduce taxiing time. Improve air navigation slot allocation	Reduce Controller workload. Improve information accuracy. Improve controller situation awareness

Table 3-16 Validation Requirements

These validation requirements were used to derive proposed indicators and metrics for validating the DAVINCI solution, for the technical, service and human-operator areas. These indicators and metrics are listed in the Table 3-17, Table 3-18 and Table 3-19, giving for each indicator and metric the high-level objective and validation requirement from which it was derived. The metrics mainly refer to scheduled and planned times, since no real times were to be measured, with the exception of data capture/recording.

Table 3-17 lists the proposed indicators and metrics associated with the Technical-Related Validation Requirements.

OBJECTIVE	REQUIREMENT	INDICATOR	METRICS (Min, Max, Mean, Standard Deviation, Confidence Intervals)
TECHNICAL QUALITY	Increase dependability of the system	Availability	Number of advisories [1] Number of co-ordination needs [2] Saturated time [3]
		Reliability	Probability of failure on demand [4] Rate of failure occurrence [5] Time between failures [6]
	Optimise access to the database	Data base accessibility	Number of queries [7] Number of subscribes [8]
		throughput / update rate	Response time [9] Concurrence collisions [10]

Table 3-17 Technical-Related Validation Requirements, Indicators and Metrics.

Table 3-18 lists the proposed indicators and metrics associated with the Service-Related Validation Requirements. It should be noted that the term “conflict” in the table relates to:

- Violation of minimum distance separation.
- Runway intrusion.
- Restricted area intrusion.

OBJECTIVE	REQUIREMENT	INDICATOR	METRICS (Min, Max, Mean, Standard Deviation, Confidence Interval)
SAFETY (N/A)	Reduce ground conflicts	Number of conflicts	Number of conflicts detected [11]
		Number of incidents	Number of reported claims [12]
	Reduce air conflicts (in the area of the airport)	Number of conflicts	Number of conflicts detected from the airside (ACAS) [13] Number of conflicts detected from the groundside (STCA) [14]
		Number of incidents	Number of reported claims [15]
CAPACITY	Increase aircraft operations at airport	Aircraft operations at airport (/hour, /peak hour)	Airport departure flow [16] Airport arrival flow [17] Airport departure throughput [18] Airport arrival throughput [19] Airport departure residual flow [20] Airport arrival residual flow [21] Airspace traffic complexity [22]
	Increase aircraft operations on runway	Aircraft operations on runway (/hour, /peak hour)	Runway departure flow [23] Runway arrival flow [24] Runway departure throughput [25] Runway arrival throughput [26] Runway departure residual flow [27] Runway arrival residual flow [28] Runway traffic complexity [29]
	Increase aircraft operations at stand	Aircraft operations at stand (/hour, /peak hour)	Stand occupation [30] Stand occupancy time [31] Apron congestion level [32] Off stand departures [33] On stand arrivals [34] Stand residual flow [35]
	Increase aircraft operations on taxiway	Aircraft operations on taxiway (/hour, /peak hour)	Taxiway departure residual flow [36] Taxiway arrival residual flow [37] Taxiway congestion level [38]
EFFICIENCY	Reduce arrival delays	Arrival delays (/aircraft operation, /STAR, /hour)	Delay at feeder fix points [39] Taxiing arrival delays [40] Arrival holding times [41] Number of arriving aircraft delayed [42]
EFFICIENCY	Reduce departure delays	Departure delays (/aircraft operation, /STAR, /hour)	Departures holding times [43] Taxiing departure delay [44] Number of departing aircraft delayed [45]
	Reduce holding times Aprons.	Hold on Apron	Queue size at Apron entrance [46] Holding time at stand entrance [47]
		Hold at Taxiway entrance	Queue size at Taxiway entrance [48] Holding time at Taxiway entrance [49]
	Reduce clearance-waiting time	Lead time to get clearances	Lead time for clearance granting process[50]
		Queue to get pushback.	Push-Back waiting queue size [51] Push-Back queuing time [52]
	Reduce taxiing time.	Taxiing time (/aircraft operation)	Arrival taxiing time [53] Departure taxiing time [54]
	Improve air navigation slot allocation.	Accuracy in slot assignment	Number of unused slots [55] Number of unmatched slots [56]

Table 3-18 Service-Related Validation Requirements, Indicators and Metrics

Table 3-19 lists the proposed indicators and metrics associated with the Human-Operator Related Validation Requirements.

OBJECTIVE	REQUIREMENT	INDICATOR	METRICS (Min, Max, Mean, Standard Deviation, Confidence Interval)
HUMAN OPERATOR	Reduce Controller workload.	Voice Communications (total, /operation)	Number of voice calls [57] Duration of voice calls [58]
		Co-ordination data exchange (total, /pair of planning systems, /aircraft, /hour)	Number (/type) of co-ordinated data [59] Number of co-ordination actions performed [60] Duration of co-ordination actions performed[61] Number of manual actions for information [62]
	Improve information accuracy.	Information availability (/planning system).	Number of failures to make data available [63] Data transmission time [64]
		Last minute change (LMC), - within 30mn before planned - (/hour, /planning system).	LMC parking assignment [65] LMC taxiing route assignment. [66] LMC PushBack assignment. [67] LMC Runway assignment (arrival, departure) [68]

Table 3-19 Human Operator-Related Validation Requirements, Indicators and Metrics

Finally, the specific scenarios to be used in the validation process for the DAVINCI system were defined. These scenarios were based on the three previously defined generic scenarios, which can be summarised as follows:

?? Generic Scenario No. 1:
- ?? ground movement responsibility assigned to a single organisation,
- ?? departures and arrivals mostly combined on the runway(s).

?? Generic Scenario No. 2:
- ?? ground movement responsibility shared between two different organisations,
- ?? departures and arrivals mostly combined on the apron and taxiways.

?? Generic Scenario No. 3:
- ?? ground movement responsibility assigned to a single organisation,
- ?? departures and arrivals mostly combined on the apron and taxiways.

The relationship between the proposed generic scenarios and the real airports surveyed earlier in the project which illustrate the scenarios is shown in Table 3-20.

	Departures and arrivals mostly combined on the runway (s)	Departures and arrivals mostly combined on the apron and taxiways
Ground movement responsibility shared between two different organisations		**(Scenario 2)** FRANKFURT
Ground movement responsibility assigned to a single organisation	**(Scenario 1)** PARIS-CDG LONDON-GATWICK LISBON	**(Scenario 3)** AMSTERDAM / SCHIPOL BRUSSELS

Table 3-20 Generic Scenarios Compared to Real Airports

The DAVINCI solution was adapted to each of these scenarios. The data-management part of the solution is applicable to all of the scenarios. For the co-operation aspect of the solution, Figure 3-13, Figure 3-14 and Figure 3-15 illustrate the responsibility-sharing between ATC and the airport operator, for Scenarios 1, 2 and 3 respectively.

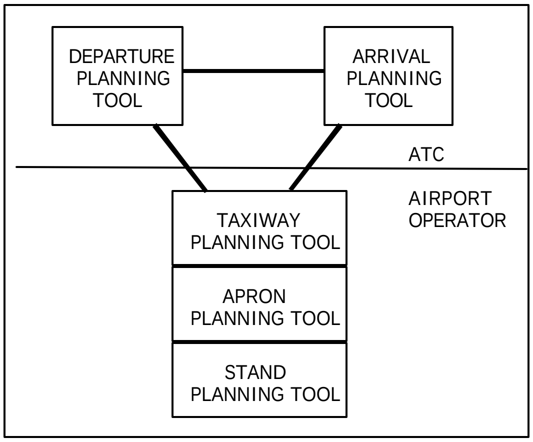


Figure 3-13 DAVINCI Solution for Scenario 1

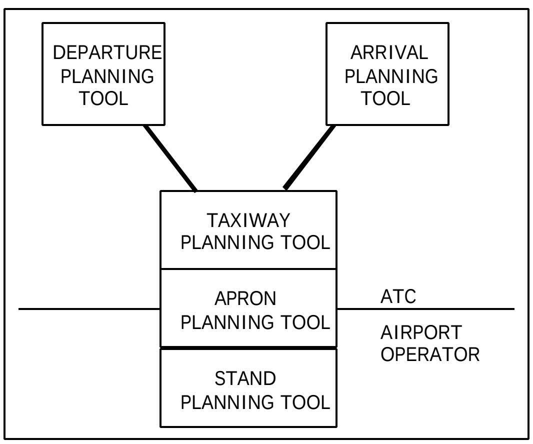


Figure 3-14 DAVINCI Solution for Scenario 2

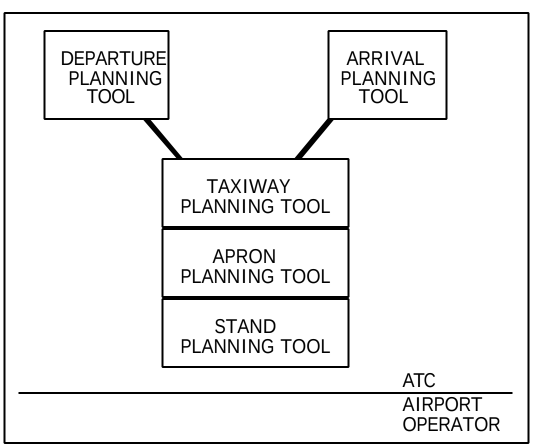


Figure 3-15 DAVINCI Solution for Scenario 3

As can be seen in the preceding figures, the three scenarios provide a set of configurations for interconnecting planning tools, thereby fulfilling the co-operation requirement. The three generic scenarios were therefore decided to be sufficient to provide a test set for the co-operation envisaged as part of the DAVINCI solution.

3.4.3. Validation Approach for the Validation Exercise Layer (DAVINCI Demonstrator)

Finally, the validation approach for the DAVINCI demonstrator was defined. The scope of this approach was determined by the fact that what would actually be evaluated was not the operational DAVINCI system, but a demonstrator, with its limitations and constraints. The subject of validation was the DAVINCI Solution and architecture, from the technical and operational perspectives. The validation would be conducted following an Evaluation Plan.

The Evaluation Plan was defined by conceptually starting from complete validation of the DAVINCI system and, through refinement, moving down to the very specific Evaluation Plan to be used for the DAVINCI Demonstrator. This process was carried out as follows:

?? An overall validation approach for the DAVINCI Solution was first defined. This approach focused on all the relevant aspects of the DAVINCI Solution, regardless of their degree of implementation in the Demonstrator. The approach covered all aspects of a complete Validation Process (except evaluation). Although there were no specific detailed User Requirements, there were user expectations, making it possible to identify: Validation Objectives, Validation Requirements, and Validation Indicators/Criteria.

?? The Demonstrator included neither all of the functionalities of the DAVINCI Solution, nor the full set of APTM systems. Thus, requirements, indicators and their associated metrics that were relevant to the DAVINCI Demonstrator were selected from the full set of requirements, indicators and metrics identified for the full DAVINCI Solution.

?? A Validation Strategy was drafted for the DAVINCI Solution based on the Demonstrator, addressing all the validation activities that the Demonstrator could support in a complete Validation Process.

?? Finally, since the DAVINCI Project timeframe and budget did not enable the entire Validation Process (as specified in the Validation Strategy defined in the preceding step), to be carried out, a specific Evaluation Plan (subset of the complete Validation Process) was defined for evaluating the DAVINCI Demonstrator. addressing the most significant issues of the Validation Strategy.

The indicators and metrics listed in the following Table 3-21 technical-related, service-related and human-operator related, respectively, were initially selected for evaluation with the DAVINCI demonstrator. An indication is given, for each metric, of whether it was felt to be adequate, not adequate or missing information to decide whether or not it would be useful for purposes of the DAVINCI validation process. Table 3-21 lists the indicators and metrics associated with the **Technical-Related** Validation Requirements.

??

OBJECTIVE	REQUIREMENT	INDICATOR	METRICS (Min, Max, Mean, Standard Deviation, Confidence Interval)
HUMAN OPERATOR	Reduce Controller workload.	Voice Communications (total, /operation)	Number of voice calls [69] (NA) Duration of voice calls [70] (NA)
		Co-ordination data exchange (total, /pair of planning systems, /aircraft, /hour)	Number (/type) of co-ordinated data [71] (A) Number of co-ordination actions performed [72] (A) Duration of co-ordination actions performed [73] (NA) Number of manual actions for information [74] (NA)
HUMAN OPERATOR	Improve information accuracy.	Information availability (/planning system).	Number of failures to make data available [75] (A) Data transmission time [76] (A)
		Last minute change (LMC), - within 30mn of planned - (/hour, /planning system).	LMC parking assignment [77] (NEI) LMC taxiing route assignment. [78] (NEI) LMC Push-Back assignment. [79] (NEI) LMC Runway assignment (arrival, departure) [80] (NEI)

?? A: Adequate
?? NA: Not Adequate
?? NEI: Not Enough Information

Table 3-21 Technical-Related Validation Requirements, Indicators and Metrics

Table 3-22 lists the indicators and metrics associated with the **Service-Related** Validation Requirements

OBJECTIVE	REQUIREMENT	INDICATOR	METRICS (Min, Max, Mean, Standard Deviation, Confidence Interval)
SAFETY (N/A)	Reduce ground conflicts	Number of conflicts	Number of conflict detections [11] (NA)
		Number of incidents	Number of reported claims [12] (NA)
	Reduce air conflicts (in the area of the airport)	Number of conflicts	Number of conflict detections from the airside (ACAS) [13] (NA) Number of conflict detections from the ground side (STCA) [14] (NA)
		Number of incidents	Number of reported claims [15] (NA)
CAPACITY	Increase aircraft operations at airport	Aircraft operations at airport (/hour, /peak hour)	Airport departure flow [16] (A) Airport arrival flow [17] (A) Airport departure throughput [18] (A) Airport arrival throughput [19] (A) Airport departure residual flow [20] (A) Airport arrival residual flow [21] (A) Airspace traffic complexity [22] (NA)
	Increase aircraft operations on runway	Aircraft operations on runway (/hour, /peak hour)	Runway departure flow [23] (A) Runway arrival flow [24] (A) Runway departure throughput [25] (A) Runway arrival throughput [26] (A) Runway departure residual flow [27] (A) Runway arrival residual flow [28] (A) Runway traffic complexity [29] (NA)
CAPACITY	Increase aircraft operations at stand	Aircraft operations at stand (/hour, /peak hour)	Stand occupation [30] (A) Stand occupancy time [31] (A) Apron congestion level [32] (A) Off stand departures [33] (A) On stand arrivals [34] (A) Stand residual flow [35] (A)
	Increase aircraft operations on taxiway	Aircraft operations on taxiway (/hour, /peak hour)	Taxiway departure residual flow [36] (A) Taxiway arrival residual flow [37] (A) Taxiway congestion level [38] (A)
EFFICIENCY	Reduce arrival delays	Arrival delays (/aircraft operation, /STAR,	Delay at feeder fix points [39] (NEI) Taxiing arrival delays [40] (A)

OBJECTIVE	REQUIREMENT	INDICATOR	METRICS (Min, Max, Mean, Standard Deviation, Confidence Interval)
		/hour)	Arrivals holding times [41] (A) Number of arriving aircraft delayed [42] (NEI)
	Reduce departure delays	Departure delays (/aircraft operation, /STAR, /hour)	Departure holding times [43] (A) Taxiing departure delay [44] (A) Number of departing aircraft delayed [45] (A)
EFFICIENCY	Reduce holding times at Aprons.	Hold at Apron	Queue size at Apron entrance [46] (A) Holding time at stand entrance [47] (A)
		Hold at Taxiway entrance	Queue size at Taxiway entrance [48] (A) Holding time at Taxiway entrance [49] (A)
EFFICIENCY	Reduce clearance waiting time	Lead time to get clearances	Lead time for clearance granting process [50] (NA)
		Queue to get push-back.	Push-Back waiting queue size [51] (A) Push-Back queuing time [52] (A)
	Reduce taxiing time.	Taxiing time (/aircraft operation)	Arrival taxiing time [53] (A) Departure taxiing time [54] (A)
	Improve air navigation slot allocation.	Accuracy in slot assignment	Number of unused slots [55] (A) Number of unmatched slots [56] (A)

?? A: Adequate
?? NA: Not Adequate
?? NEI: Not Enough Information

Table 3-22 Service-Related Validation Requirements, Indicators and Metrics

Table 3-23 lists the indicators and metrics associated with the **Operator-Related** Validation Requirements

OBJECTIVE	REQUIREMENT	INDICATOR	METRICS (Min, Max, Mean, Standard Deviation, Confidence Interval)
HUMAN OPERATOR	Reduce Controller workload.	Voice Communications (total, /operation)	Number of voice calls [69] (NA) Duration of voice calls [70] (NA)
		Co-ordination data exchange (total, /pair of planning systems, /aircraft, /hour)	Number (/type) of co-ordinated data [71] (A) Number of co-ordination actions performed [72] (A) Duration of co-ordination actions performed [73] (NA) Number of manual actions for information [74] (NA)
HUMAN OPERATOR	Improve information accuracy.	Information availability (/planning system).	Number of failures to make data available [75] (A) Data transmission time [76] (A)
		Last minute change (LMC), - within 30mn of planned - (/hour, /planning system).	LMC parking assignment [77] (NEI) LMC taxiing route assignment. [78] (NEI) LMC Push-Back assignment. [79] (NEI) LMC Runway assignment (arrival, departure) [80] (NEI)

?? A: Adequate
?? NA: Not Adequate
?? NEI: Not Enough Information

Table 3-23 Operator-Related Validation Requirements, Indicators and Metrics

The Validation Scenarios to be used in the demonstration of the DAVINCI Solution were then defined. These scenarios relate to the Traffic and Airport configuration to be "injected" in the Demonstrator, and not to the configuration of the DAVINCI Solution.

A distinction should be made between "Validation Scenarios" and "Demonstrator Scenarios". A Validation Scenario is a scenario in a real airport with a real operational environment. A Demonstrator Scenario is a simplification of the Validation Scenario, taking into account the limitations and constraints of the Demonstrator. Nevertheless the Demonstrator Scenario should simulate the Validation Scenario with a sufficient degree of realism.

These scenarios are defined in Table 3-24. The Validation Scenarios are composed of airport information and traffic information. The first row of the table describes the airport information to be collected from the airport to be simulated. The traffic data should be recorded from real operations. The Demonstrator Scenarios also contain the operator configuration and the system configuration data. The aeronautical configuration is similar to the configuration for the Validation Scenario.

	AIRPORT				
	AIRSPACE	**RUNWAYS**	**TAXIING ROUTES**	**STANDS**	**PUSH-BACK FACILITIES**
VALIDATION SCENARIO	TMA Airspace SIDs STARs	Runway configuration.	Taxiing routes configuration	Stands configuration	Push-Back facilities/ capabilities.
DEMONSTRATOR SCENARIO	Simulated TMA Airspace SIDs STARs	Simulated Runways.	Simulated Taxiing Routes.	Simulated Stands	Simulated Push-Back facilities.

Table 3-24 Airport Scenario Data

For purposes of the demonstration the priority of the Generic Scenarios would be as follows:

?? Generic Scenario No. 1.
?? Generic Scenario No. 3.
?? Generic Scenario No. 2.

Nevertheless, due to budgetary and time constraints of the DAVINCI Project, it was decided to evaluate the Generic Scenarios corresponding to the following real airports:

?? Paris-CDG (Generic Scenario No. 1).
?? Frankfurt (Generic Scenario No. 2).

At this stage, the Evaluation Plan was defined. In order to evaluate the improvements obtained with the DAVINCI system, it was necessary to compare the results of operating the system with the real world. The Demonstrator, however, was designed to simulate only a reduced set of the functions involved in real-world airport operation. Thus the comparison could not be made directly with the real world. It was necessary to take a representation of the real world to calculate the improvement brought about by the DAVINCI Solution in this representation. The evaluation process defined for the DAVINCI Demonstrator is illustrated in Figure 3-16.

The Evaluation Process consisted of the following phases:

?? **Phase 1: Data capture/recording**: For each of the proposed Generic Scenarios, there was a set of data captures/recordings of the real operation of the selected airport.

?? **Phase 2: Evaluation of the Demonstrator Scenario**: The Validation Scenario was then introduced in the Demonstrator in the form of a Demonstrator Scenario, which was used to run the Demonstrator without the DAVINCI solution. The metrics and indicators obtained from the exercise were analysed and compared to those obtained during real operation in the previous phase. The result of the analysis and comparison provided an evaluation of the accuracy and representativeness of the Generic Scenario, and of the Demonstrator.

?? **Phase 3: Validation Exercise Performance**: The Demonstrator was then configured with the DAVINCI Solution and the planned Validation Exercises were conducted for various configurations of the DAVINCI Solution. The metrics obtained from the Evaluation Exercises were then compared (statistical comparison when statistical metrics) to the ones obtained in the previous phase (Evaluation of the Demonstrator Scenario) in order to evaluate the DAVINCI Solution.

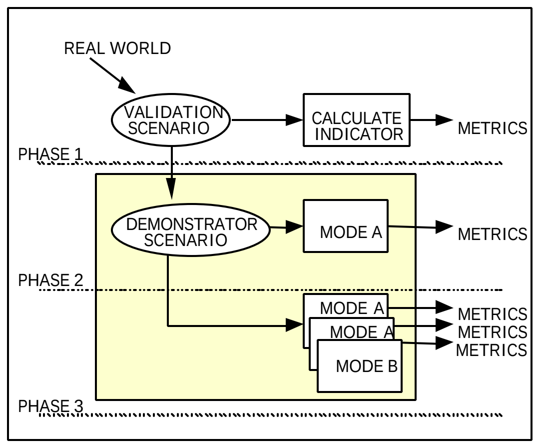


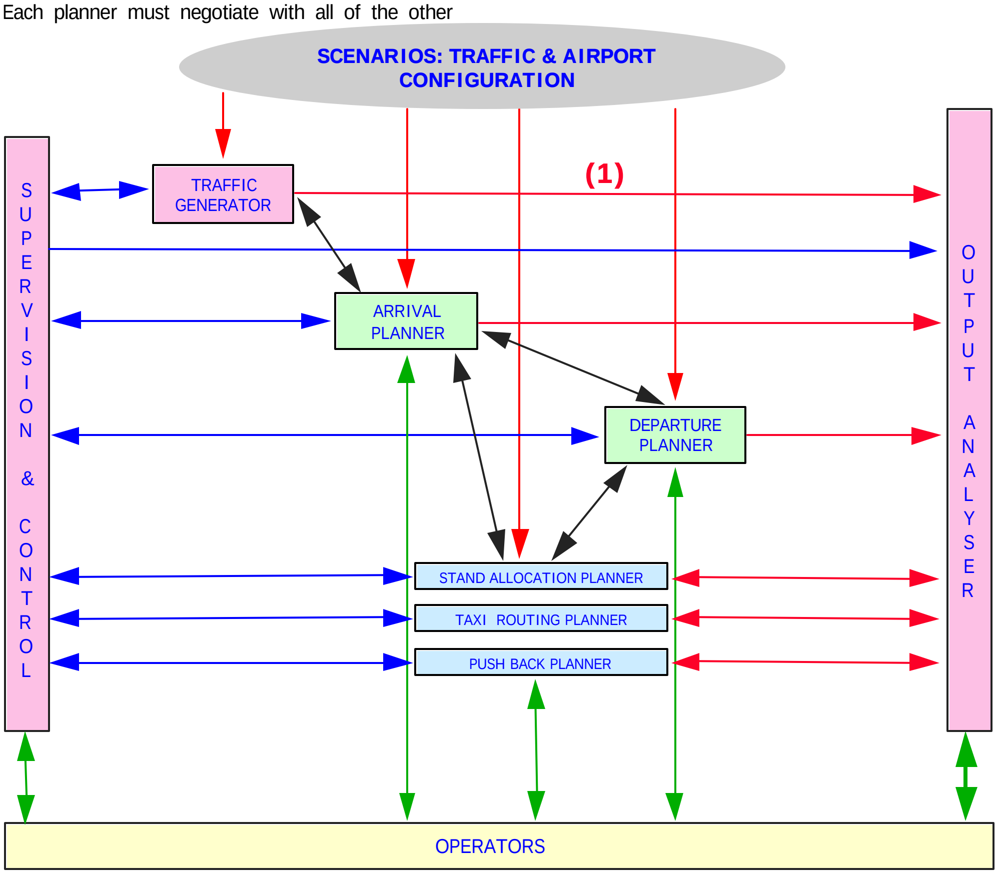
Figure 3-16 Evaluation Process

The specific evaluation tests were of two types: subjective tests, in the form of questionnaires to be completed by experts and users of the DAVINCI system, and objective tests, consisting of direct or statistical comparison of the indicators and metrics.

The Demonstrator was designed to implement two operating modes to support the evaluation strategy defined above. These modes were defined as Mode A, operation without the DAVINCI Solution, and Mode B, operation with the DAVINCI Solution. The configurations of these modes are as follows:

In Mode A, the Demonstrator simulates the current operation of airport systems, in which co-ordination between planners follows the one-to-one model. The automated co-operation functions between the planners are not supported by this mode of operation. Co-ordination information (such as flight data) between planners remain available to all planners. In this mode there are no priorities among the planners. Each planner must negotiate with all of the other planners. The Output Analyser does not act in the simulation because it is operated off-line, only extracting the data to be analysed.

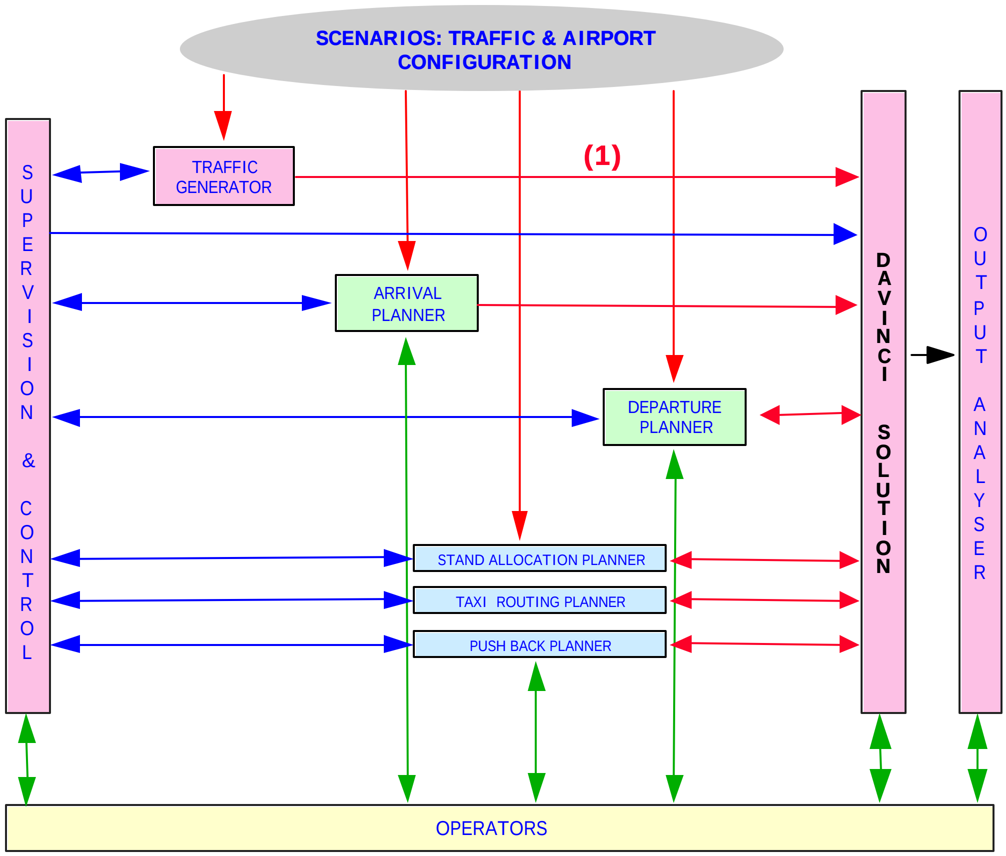
Mode A is illustrated in Figure 3-17 below.



(1) Due to the limitations of the tools used, and time and budget constraints, updating of the traffic scenario was not included within the DAVINCI project.

Figure 3-17 Mode A of Operation of the DAVINCI Demonstrator

In Mode B, the DAVINCI solution is activated. In this mode, the planners co-operate through the DAVINCI Solution module. By changing the priorities of the planners, the Demonstrator is able to simulate the most relevant planner in real operation, enabling a comparison of the improvement brought about by the changes on overall performance. Figure 3-18 shows the DAVINCI configuration in Mode B.



(1) Due to the limitations of the tools used, and time and budget constraints, updating of the traffic scenario was not included within the DAVINCI project.

Figure 3-18 Modo B of Operation of the DAVINCI Demonstrator

The static and dynamic scenarios for the DAVINCI Demonstrator were defined, as were three test cases and 14 test case descriptions. Table 3-25 and Table 3-26 show, respectively, the test cases and test case descriptions which were defined.

#	OBJECTIVE	CONFIGURATIONS	FRANKFURT		PARIS - CDG	
			PEAK HOUR	OTHER TRAFFIC	PEAK HOUR	OTHER TRAFFIC
1	Evaluation of Demonstrator Scenario.	Demonstrator Mode A.	X	N/A	X	N/A
2	Evaluation of DAVINCI Solution with Configuration I.	Demonstrator Mode B. DAVINCI Configuration I.	X		X	
3	Evaluation of DAVINCI Solution with Configuration II.	Demonstrator Mode B. DAVINCI Configuration II.	X		X	

NOTE: DAVINCI Configuration refers to specific Master/Slave configuration of planners.

Table 3-25 Test Case Identification

TEST CASES	Description			SHEET 1
	TEST: demonstrate DAVINCI			
No. TEST CASE	IDENTIFICATION	DATE		RESULT
		START	END	
F_RO_1	Static Scenario : Frankfurt. Dynamic Scenario : Peak Traffic Scenario Mode of Operation : Real Operation	Day D, Time: H-30 min	Day D Time: H+90min	Data Capture
F_RO_2 (Optional)	Static Scenario : Frankfurt. Dynamic Scenario : Landing Traffic Scenario Mode of Operation : Real Operation	Day D, Time: H-30 min	Day D Time: H+90min	Data Capture
F_RO_3 (Optional)	Static Scenario : Frankfurt. Dynamic Scenario : Departing Traffic Scenario Mode of Operation : Real Operation	Day D, Time: H-30 min	Day D Time: H+90min	Data Capture
P_RO_1	Static Scenario : Paris CDG. Dynamic Scenario : Peak Traffic Scenario Mode of Operation : Real Operation	Day D, Time: H-30 min	Day D Time: H+90min	Data Capture
P_RO_2 (Optional)	Static Scenario : Paris CDG. Dynamic Scenario : Landing Traffic Scenario Mode of Operation : Real Operation	Day D, Time: H-30 min	Day D Time: H+90min	Data Capture
P_RO_3 (Optional)	Static Scenario : Paris CDG. Dynamic Scenario : Departing Traffic Scenario Mode of Operation : Real Operation	Day D, Time: H-30 min	Day D Time: H+90min	Data Capture
F_MA_1	Static Scenario : Frankfurt. Dynamic Scenario : Peak Traffic Scenario Mode of Operation : Mode A	Day D, Time: H	Day D Time: H+60min (Planning horizon)	Evaluation of Demonstrator
F_MB_1	Static Scenario : Frankfurt. Dynamic Scenario : Peak Traffic Scenario Mode of Operation : Mode B	Day D, Time: H	Day D Time: H+60min (Planning horizon)	Evaluation PTS-DAVINCI Configuration
F_MB_2 (Optional)	Static Scenario : Frankfurt. Dynamic Scenario : Landing Traffic Scenario Mode of Operation : Mode B	Day D, Time: H	Day D Time: H+60min (Planning horizon)	Evaluation LTS-DAVINCI Configuration
F_MB_3 (Optional)	Static Scenario : Frankfurt. Dynamic Scenario : Departing Traffic Scenario Mode of Operation : Mode B	Day D, Time: H	Day D Time: H+60min (Planning horizon)	Evaluation DTS-DAVINCI Configuration
P_MA_1	Static Scenario : Paris. Dynamic Scenario : Peak Traffic Scenario Mode of Operation : Mode A	Day D, Time: H	Day D Time: H+60min (Planning horizon)	Evaluation of Demonstrator
P_MB_1	Static Scenario : Paris. Dynamic Scenario : Peak Traffic Scenario Mode of Operation : Mode B	Day D, Time: H	Day D Time: H+60min (Planning horizon)	Evaluation PTS-DAVINCI Configuration
P_MB_2 (Optional)	Static Scenario : Paris. Dynamic Scenario : Landing Traffic Scenario Mode of Operation : Mode B	Day D, Time: H	Day D Time: H+60min (Planning horizon)	Evaluation LTS-DAVINCI Configuration
P_MB_3 (Optional)	Static Scenario : Paris. Dynamic Scenario : Departing Traffic Scenario Mode of Operation : Mode B	Day D, Time: H	Day D Time: H+60min (Planning horizon)	Evaluation DTS-DAVINCI Configuration

Table 3-26 Test Case Descriptions

Finally, a set of templates to be used in recording data regarding the demonstration were drawn up. These templates were as follows:

?? Hardware description.
?? Software description.
?? Operational configuration description.
?? Human operator knowledge.
?? Scenario data capture.
?? Data reduction and analysis questionnaire.

3.4.4. Demonstration

The objectives of the demonstration conducted with the DAVINCI demonstrator were as follows:

?? To demonstrate the feasibility of the proposed method and architecture. The demonstrator is operational and produces consistent results when demonstrator parameters are changed.
?? To evaluate the benefits of the DAVINCI Solution by comparing the results without DAVINCI and with DAVINCI, both quantitative and qualitative.

In order to prepare the demonstration, a set of exercises was run for both Charles de Gaulle and Frankfurt airports. Each exercise was a combination of an airport scenario (consisting of runways, stands, taxi and push-back), a traffic scenario and a DAVINCI configuration. Each DAVINCI configuration consisted of the status of each of the planning tools with regard to each of the resources or resource interfaces (master, slave or not applicable) in one of six configurations. The configurations were:

?? No shortcomings
?? Shortcoming in parking position
?? Shortcoming in stands
?? Shortcoming in push-back
?? Too many scheduled departures
?? Shortcoming in runway and push-back vehicle

The exercises were broken down into individual test cases, whose purpose was to evaluate the demonstrator scenario (with the demonstrator in DAVINCI Mode A), to evaluate the DAVINCI solution with the set of DAVINCI configurations (demonstrator in DAVINCI Mode B and each of the configurations). All of the test cases were designed for peak hour traffic. A sequence of planning tools was devised for each case. An example of a test case for the No Shortcoming configuration is shown in Figure 3-19.

CONFIGURA-TION 1	Mixed mode	RW/ TWY	TWY/ ST	Push/ Stands
AM	M	M (Arr.)		
DM	S	M (Dep.)		
TM		S	M	
SM			S	M
PM				S

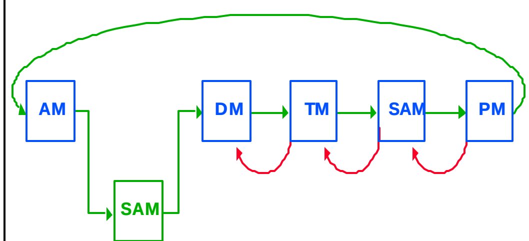


Figure 3-19 Example of Test Case for the "No Shortcoming" Configuration

The test cases selected are shown in Table 3-26.

DAVINCI SOLUTION CONFIGURATION	CONGESTION IN RWY (DEP)	CONGESTION IN STANDS	PARTICULAR CASE
1. NO SHORTCOMING	X	X	X
2. SHORTCOMING IN PARKING POSITION			X
3. SHORTCOMING IN STANDS		X	
4. SHORTCOMING ON PUSH-BACK			
5. TOO MANY SCHEDULED DEPARTURES	X		
6. SHORTCOMING IN RWY AND PUSH-BACK VEHICLE			

Table 3-27 Selected Test Cases

This demonstration was conducted on 17 June 1999 at Bagneux near Paris (Airsys ATM facilities).

The demonstration was conducted for the scenario at Charles de Gaulle, with the following characteristics:

?? Traffic: A real peak-hour situation with 80 aircraft
?? Initial situation: plans already exist, simulating current plans, but drawn up some time ago.
?? Objective: To adapt plans, as needed, to the current situation.
?? Process: Each planner makes decisions and, in turn, updates the plans in the data server.
?? Desired final situation: New plans, guaranteed to be consistent.

3.4.5. Evaluation of Demonstration Results

On the basis of the evaluation indicators, an evaluation was made of the adequacy of the demonstrator and the adequacy of the DAVINCI Solution. The demonstrator was evaluated by a qualitative assessment of the DAVINCI planning tools, identifying significant deviations. For this evaluation, the real operational data were compared with the non-DAVINCI mode.

The evaluation of the DAVINCI solution was made by a statistical and a subjective comparison of the indicators and an analysis of specific flights. The non-DAVINCI mode was compared with the DAVINCI mode in order to evaluate improvements in operation. The DAVINCI mode was evaluated in different operational configurations of the DAVINCI solution (master/slave matrix, i.e., sequencing of the DAVINCI planning tools).

Comparisons were made of the following:

- Real operation with the Non-DAVINCI mode
- Non-DAVINCI mode with the DAVINCI mode
- The various DAVINCI configurations with each other

The overall evaluation procedure for the results of the demonstration is illustrated in Figure 3-20

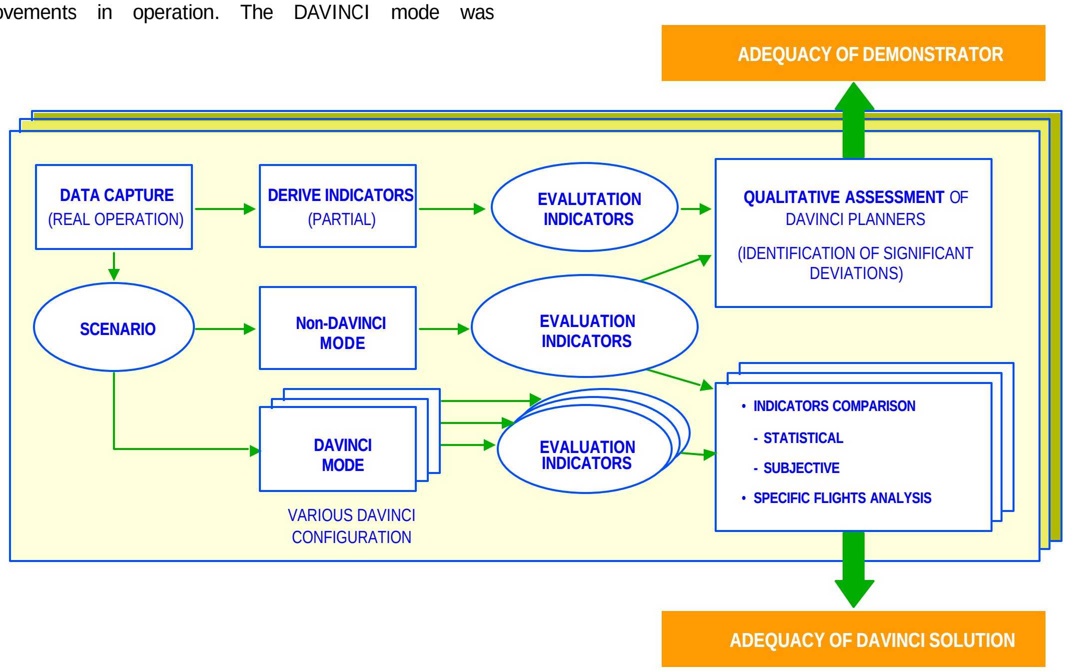


Figure 3-20 DAVINCI Evaluation Procedure

The findings of this evaluation process and the conclusions which can be reached from them are included in the following section.

4. Conclusions

4.1. Findings and conclusions of the evaluation

4.1.1. Comparison of DAVINCI Modes of Operation

The adequacy of the Demonstrator and of the DAVINCI solution was evaluated using the evaluation indicators and questionnaires. The demonstrator was evaluated by a qualitative assessment of the DAVINCI planning tools, identifying significant deviations. For this evaluation, real operational data were compared with the results obtained in the non-DAVINCI mode.

The DAVINCI solution was evaluated by a statistical and subjective comparison of the indicators and an analysis of specific flights. The non-DAVINCI mode was compared with the DAVINCI mode in order to evaluate improvements in operation. The DAVINCI mode was evaluated in different operational configurations of the DAVINCI solution (master/slave matrix, i.e., sequencing of the DAVINCI planning tools). The results of these evaluations are presented below.

Comparison of real operation and non-DAVINCI/DAVINCI modes

A comparison of the planning produced with the non-DAVINCI mode and the planning information captured in real operation showed no significant differences, although real operation does not use the planner tools integrated in the Demonstrator. These planners either do not exist or they are different (e.g., only Paris-CDG airport uses arrival and departure planners similar to the ones in the Demonstrator).

In the comparison of real operation with the DAVINCI mode, runway throughput was approximately equal, off-block departure was 12 minutes less and the total throughput was 15 minutes less. The advantages found here were no queues (although some amount of queuing may be necessary to ensure efficient airport operations) [2] and better planning of the interfaces between pushback, taxiway, runway and take-off.

Although the comparison of DAVINCI plans with real operation may not be completely accurate and, with the exception of the Arrival Manager, the planning tools have not been evaluated, these results are still positive.

Comparison of non-DAVINCI and DAVINCI modes

The Demonstrator produces a complete set of plans generated by each tool (in the non-DAVINCI mode) and consistent planning in the DAVINCI mode. The non-DAVINCI mode implemented in the Demonstrator requires an initialisation process “from scratch” to initialise aircraft allocation, which launches a specific sequence of DAVINCI planners. This makes it similar to the operation of the DAVINCI configuration with no shortcomings.

A comparison of the results obtained from the exercises with non-DAVINCI and DAVINCI modes was less significant than expected. This is, in part, due to the fact that the selected scenarios already had an “adequate” profile, such that no significant differences were found in terms of statistical values of the evaluation indicators.

A detailed analysis of the flights showed a reduction in the DAVINCI mode of the interface time (e.g., transition time between push-back and taxiing) for several aircraft (average of five minutes). Planning of interfaces was better and there were no queues [3]. There were nevertheless no significant improvements in planned departure time, despite the improvement in the interface time. This would seem to be due to the fact that the planning tools developed within DAVINCI are not optimal, and should be upgraded to optimise the plans they are producing. It should be noted that one scenario performed worse in the DAVINCI mode.

Three reservations should be made about the results of this evaluation:

- ?? The validity of the non-DAVINCI mode plans has not been proven .
- ?? Planners do in fact co-ordinate their plans.
- ?? Inconsistent plans may be produced by the non-DAVINCI mode, indicating unreliable results of the indicators.

Comparison of various configurations of the DAVINCI mode

In comparing different configurations of the DAVINCI mode, no significant differences were found. There is a clear need to refine the tuning of the co-ordination parameters to the very specific behaviour and characteristics of each airport scenario and operation. Additional experimental scenarios, with controlled traffic situation and scenario, will be necessary in future projects to complete the evaluation/validation process.

4.1.2. Technical/operational conclusions

4.1.2.1. Data sharing and consistency

All the data within the DAVINCI solution are shared and could be made available to all the other planners and operational positions. This would improve the decision making process by supporting the evaluation of the current situation and the selection of the best strategy for each planner, based on:

- ?? Indicators[4] (e.g. traffic load indicators and service quality indicators) that synthesise the current and future-planned situation,
- ?? Advisories[5] computed on the basis of the indicators, which provide information regarding the best planning strategy for each planning tool, specific flight priorities and average traffic rates.
- ?? Planning information that could be made available by each planner.

All this information is computed and exchanged automatically, thereby significantly reducing the currently-required amonunt of voice communication.

4.1.2.2. DAVINCI Configurations and synchronisation issues

All of the planners produce plans following a specific “activation” sequence. This synchronisation (based on the master/slave status of the various planners) makes the plan official only at a given time, when it is that planner's “turn”. The sequence is based on a semiautomatic comparison of the computed indicators (thus of the future situation), which then gives priority to specific planners. This prioritisation may not always be acceptable from an operational point of view, and may vary greatly for different airports, based on their specific organisation and responsibility-sharing.

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2 In real operation, queues could be used to ensure efficient airport operation. Operational tests with planning tools must determine the optimal size of queues, given that planning tools, monitoring tools and replanning tools are in place. The current DAVINCI tool eliminates, for example, the runway holding queues by attaching the taxiing and take-off phases to each other. It may, however, just as well maintain at all times a queue of size n, without negatively affecting the performance or efficiency of the planners or the co-operation tools.

3 See previous note.

4 These indicators should be simple and sufficiently representative. The indicators proposed in DAVINCI should be assessed and refined. The indicators should be customised for each airport.

5 The proposed set of advisories should be assessed and refined. They should probably be customised for each airport.

The DAVINCI solution supports the flexibility and adaptability required to cope with specific constraints. Algorithms and thresholds used to compute master/slave states should be tuned for each airport. Nevertheless, the master/slave "technique" should receive further study and refinement[6].

4.1.2.3. DAVINCI HMI

The HMI produced within DAVINCI is experimental. Only the Arrival and Departure Managers have ever been integrated in an operational HMI. Nevertheless, because different airports use different terminology or definitions of terms, the HMI can be adapted to the terminology used at each airport.

DAVINCI does not replace the human operator. It has been found that the DAVINCI solution is a support for planning operations at an airport. Planning with DAVINCI would not be better than manual planning performed by operators if the planning task could last as long as required, which is not the case. This conclusion is obvious, since operators can make the same plans, and solve the constraints and inconsistencies that appear in real operation based on their expertise. The added value of DAVINCI in this regard is as follows:

- Supports the exchange of operational data
- Provides an accurate view of the traffic situation and the operating status
- Provides recommendations for selecting the most adequate strategy for each planner
- Provides the means for supporting semiautomatic co-ordination and co-operation among planners
- Reduces the workload of planning operators.

4.2. Potential Benefits of DAVINCI

DAVINCI proposes significant improvements in the operational and technical areas of airport traffic management. More specifically, DAVINCI proposes the following operational improvements:

- Data sharing, consistency and visibility of the planning data produced by various planning tools: All planning data within the DAVINCI solution are shared and could be made available to all of the other planners and operational positions, improving the information available and supporting the consistency-checking of the information.
- Production of planning advisories: DAVINCI computes and provides operators with information about the current situation, as well as advisories to support the decision-making process within planning activities. Table 4-1 lists these planning advisories.

PLANNING ADVISORIES	
STRATEGIC PLANNING	Master/Slave Status (DAVINCI Configuration)
	Decision-Making Strategy
	Resource Capacity Sharing
TACTICAL PLANNING	Flight Priority
	Flight Resource Allocation Change

Table 4-1 Types of Planning advisories

- Support of the dynamic prioritisation of the planning tools: Among the most significant benefit provided here is that DAVINCI provides the ability to change the planning priority between different traffic planning tools, thus adapting the overall planning to the specific traffic situation and congested areas in real operation. It supports the creation of different planning scenarios and supports the possibility of operators to adjust/tune the planning/routing tools to the appropriate traffic situation.

In addition to these operational improvements, DAVINCI proposes the following technical improvements:

- Proposed solution independent of the technological implementation: Within the DAVINCI project, the Demonstrator has been supported by a dedicated set of workstations connected to a dedicated LAN. Nevertheless, the technical solution can be implemented with other technologies making extended use of COTS. For example, intranet technology, with appropriate access control, could be appropriate, taking into account its flexibility, openness, user-friendliness and widespread use.
- Open architecture independent of planning tools: The DAVINCI solution is independent of the planning tools. It does not propose any planning tool, but rather the co-operation level needed to co-ordinate/integrate them. This provides a high level of flexibility and adaptability to the existing tools at each airport, which would only require the standardisation of the data interfaces.

4.3. Overall Project Findings

In many areas of Europe, air traffic demand often exceeds the available capacity, giving rise to seemingly inevitable delays caused by non-optimum traffic handling, routing and planning[7], with a significant impact on airport operations. Optimum planning could provide major benefits. All across Europe, at the national and local levels, different types of airport traffic management systems (e.g., airport stand allocation ,airline/airport ramp management, ATC ground movement control, arrival/departure scheduling/sequencing system) are used to manage airport traffic. In addition to

[6] Serious problems appeared during the integration of the demonstrator, due to the constraints of this synchronisation process.

[7] These inefficiencies cause large economic losses to passengers, airports, airlines and air traffic service providers.

current systems, several specific automation tools are currently under development, for the purpose of supporting functions such as arrival management, departure management and surface movement guidance and control.

DAVINCI is a first step directed towards: (a) real integration of these systems so as to maximise the performance of the entire airport system; (b) optimal use of available capacity, both at airports and in terminal area airspace; and (c) optimisation of the efficiency of the tactical Air Traffic Flow Management system and 4D planning. It has demonstrated a method by which different airport planning tools can co-operate. This work is directed at operational use several years in the future. Currently, few airports use even one planning tool. It is this "looking to the future" of the DAVINCI project that is one of its most interesting characteristics.

At the end of the project, several overall conclusions can be reached about the DAVINCI Solution, as follows:

- The DAVINCI project has made manifest the lack of standardisation of airport traffic management system, operation and technology.
- DAVINCI proposes the ability to "choose" the planning priority as a function of the periodic changes in the traffic situation and the associated requirements of real-life operation. Thus, it is an appropriate tool for creating different planning scenarios and adjusting to different planning priorities[8].
- The proposed architecture has many positive features, including that it is open, flexible and independent of the operation of the planning tools available at each airport.
- One important benefit of the DAVINCI Solution is that the plans provided by each planner are visible to all of the other planners, as well as the quality indicators for the expected situation. The human/machine interface supports this visibility/transparency in operation.
- Since the proposed solution is independent of the planning tools, only the data interfaces would need to be adapted.
- The proposed solution is independent of the technological solution used to implement the co-operation tool[9].
- The Demonstrator is available, operational and can be adapted to other airports, although a complex tuning process will be needed due to the large number of parameters to be adapted to the specific configuration of each airport.
- The evaluation made by comparison with real operation was only able to be made subjectively, since real operation does not include taxi, pushback and stand allocation planners.

In conclusion, the DAVINCI project has made a start in improving traffic management at airports by proposing flexible, tool-independent co-operation among the planning tools used in airport operation. Although the specific results obtained by the DAVINCI Demonstrator are not as significant as was initially expected, they are positive overall and point the way to future work.

4.4. Proposals for Further Work

Further work can be done on DAVINCI in several different ways. Since DAVINCI is directed at operational use several years in the future, its findings are, in general, of immediate interest more to the ATM research community than to airport operators. The further work on DAVINCI or reuse of DAVINCI could take the following forms:

- Reuse of DAVINCI information for further research work, in particular to compare DAVINCI plans with real airport operations in greater detail.
- Reuse of DAVINCI information by airports.
- Reuse of the DAVINCI demonstrator, for experimenting with its operational use at an airport, in a larger-scale validation platform or adapting it as it is to an airport.

4.4.1. Use of DAVINCI Information for Further Work

First, DAVINCI information could be used as the basis for continued research on the method and Demonstrator themselves. This work could, for instance, focus on the following issues:

- The principle of master/slave states: (a) should they be allocated to tools or flows?; (b) should they be mandatory?; and (c) should they induce synchronization and how?.
- Possible use of theoretical cooperation methods in ATM (see WP3)
- Definition of indicators
- Definition of current advisories, and identification and definition of new advisories.
- The issue of contingency in plans[10].

In the DAVINCI project, DAVINCI plans were compared with real-life operation at two airports. There were, however, limitations on this comparison. For example, only one hour of traffic was run through the Demonstrator, and limited effort was available for tuning the planners for each airport. DAVINCI plans could be compared with real airport operations in greater detail.

4.4.2. Reuse of DAVINCI Information by Airports

DAVINCI information could be used by airports. This would involve the dissemination of some DAVINCI reports, or parts of some DAVINCI reports, to the airports. The information to be

[8] Operators would have the possibility of adjusting/tuning the planning/routing tools (e.g., A-SMGCS) to the appropriate traffic situation.

[9] Future technologies for implementation of the co-operation tool include intranet-based solutions.

[10] The issue of contingency will need to be addressed to make the demonstrator more realistic. Contingency can be provided in plans in the form of extra time at an interface, which is equivalent to the existence of a queue. This means that if any aircraft cannot achieve its planned time, another aircraft is available to take its place. Contingency is needed in order to maintain the efficiency of operations in situations in which the plan has not been followed exactly.

disseminated would be selected on the basis of its potential utility to airports. A specific example is the D3.1 report, which lists a number of problems at certain airports and proposes specific solutions. Deliverables from WP1 and WP2 could also be useful to airports, if they are restructured and presented with the airport audience in mind.

in order to reuse DAVINCI in this way, the information could be restructured and presented in a manner adapted to the specific airport audience. For example, the types of problems could be classified and the following information could be presented for each such problem:

- The type of problem
- An example at a real airport, when available in the reports
- The proposed solution
- The categories of airports at which this solution is recommended.

This work could be done by concerted actions for airports.

4.4.3. Reuse of the DAVINCI Demonstrator

The DAVINCI demonstrator, or parts of it, could also be reused. This reuse could be in one or several of three ways:

- To experiment with the operational use of DAVINCI at an airport
- To include DAVINCI in a larger-scale validation platform within the 5th Framework Programme
- To adapt the demonstrator, as it is, to an airport (although the interest of doing this is disputable)

It should be noted that the developed tools are not a part of DAVINCI, having only been developed because no existing tools were available. There is therefore no reason to reuse them. If an organization nevertheless wishes to use them, they would need to be reviewed and improved by, for example, using a quicker algorithm or adding the capability to change times manually.

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Appendix I. List of Publications

List of Publications

No specific publications have been produced within the DAVINCI Project. The list of the technical documents that have been produced is in table below.

These documents are available at the DAVINCI Web-Site (http://www.isdefe.es/davinci1/davinci1.htm).

Type and description of technical deliverables (Title)	Availability C-R-P *	Code
D.1.1 User Requirements and Expectations Survey	P	DAV/NAT/WFR/1/1/1.0
D.1.2 Technical Background Survey	P	DAV/NAT/WFR/1/2/1.0
D.2.1 APTM Process Document	P	DAV/SYS/WFR/2/1/1.0
D.2.2 Description of Generic Scenarios	P	DAV/SYS/WFR/2/2/1.0
D.3.1 Proposed Solution	P	DAV/SYS/WFR/3/1/1.0
D.4.1 Architecture/Model Description	P	DAV/THO/WFR/4/1/1.0
D.5.1 Demonstrator Specification Document	R	DAV/THO/WFR/5/1/1.0
D.5.2 Demonstrator Software User Manual	R	DAV/THO/WFR/5/2/1.0
D.5.3 Demonstrator	R	DAV/THO/WFR/5/3/1.0
D.6.1 Validation Strategy	P	DAV/ISD/WFR/6/1/1.1
D.6.2 Evaluation Plan	R	DAV/ISD/WFR/6/2/1.0
D.7.1 Evaluation Report	R	DAV/SIE/WFR/7/1/1.0
D.7.3 DAVINCI Consolidated Final Report	P	DAV/ISD/WFR/7/3/1.0
*: C = confidential, R = restricted, P = public		

For the "restricted" type documents, an executive summary is available.

Appendix II. Conferences/Presentations

Conferences / Presentations

DAVINCI has been presented at the following forums:

IDENTIFICATION	LOCATION	DATE
Presentation of airport - related EC-funded projects in the 4th Framework Programme.	Brussels (EC)	Dec/1996
Third Interproject Meeting on projects relevant to arrival, departure and ground movement management and planning.	Paris (Alcatel-ISR)	19/11/1997
OPTAS-B Workshop.	Rome (Alenia)	20-21/01/1999
DAVINCI Demonstration session.	Paris (AIRSYS-ATM)	17/06/1999

Deliverable D.7.3
Final report

Public

DAVINCI
Contract No AI-96-SC.1054

Project Coordinator: Isdefe

Partners: DERA
EDISOFT
INESC
NATS
NLR
AIRSYS ATM Gmbh
SOFREAVIA
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AIRSYS ATM S.A.
UPM

Date: 30/09/99

PROJECT FUNDED BY THE EUROPEAN COMMISSION UNDER THE TRANSPORT RTD PROGRAMME OF THE 4th FRAMEWORK PROGRAMME