Final Report

Flagship Project TAMS - Total Airport Management Suite

Version 2.0

Partners:

- Barco Orthogon GmbH
- Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center, DLR)
- Flughafen Stuttgart GmbH (Stuttgart Airport)
- INFORM GmbH
- Siemens AG
- Associated: ATRiCS Advanced Traffic Solutions GmbH
# ACRONYMS

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>A-CDM</td>
<td>Airport Collaborative Decision-Making</td>
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<tr>
<td>ACCES</td>
<td>Airport Control Center Simulator</td>
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<td>ACI</td>
<td>Airport Council International</td>
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<td>ADPS</td>
<td>Airline Driven Preferential Sequencing</td>
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<td>AETT</td>
<td>Actual End of Taxi Time</td>
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<td>AMAN</td>
<td>Arrival Manager</td>
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<td>AOD</td>
<td>Airport Operational Dashboard</td>
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<td>AODB</td>
<td>Airport Operational Data Base</td>
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<td>AOP</td>
<td>Airport Operations Plan</td>
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<td>APIP</td>
<td>Airport Process Integration Platform</td>
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<td>APM</td>
<td>Airport Performance Management</td>
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<td>APOC</td>
<td>Airport Operations Control Center</td>
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<td>A-SMGCS</td>
<td>Advanced Surface Movement Guidance and Control System</td>
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<td>AOBT</td>
<td>Actual Off-Block Time</td>
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<td>ARDT</td>
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<td>ASAT</td>
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<td>ATC</td>
<td>Air Traffic Control</td>
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<td>ATOT</td>
<td>Actual Take-Off Time</td>
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<td>ATWP</td>
<td>Airside Tactical Working Position</td>
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<td>BMWi</td>
<td>Federal Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Technologie)</td>
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<td>CAAS</td>
<td>Civil Aviation Authority Singapore</td>
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<tr>
<td>CDM</td>
<td>Collaborative Decision-Making</td>
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<td>DLR</td>
<td>German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt)</td>
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<td>DMAN</td>
<td>Departure Manager</td>
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<td>E-OCVM</td>
<td>European Operational Concept Validation Methodology</td>
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<td>EADF</td>
<td>DLR DataFusion Prototype (Eingangs-Ausgangs-Daten-Fusion)</td>
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<td>ESARR</td>
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<td>FIDS</td>
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<td>FSG</td>
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<td>GUI</td>
<td>Graphical User Interface</td>
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<td>HFC</td>
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<td>HMI</td>
<td>Human Machine Interface</td>
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<td>National Aerospace Laboratory of the Netherlands</td>
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<td>Operational Concept Document</td>
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<td>Passenger Manager</td>
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<td>Process Integration Platform</td>
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<td>SAD</td>
<td>System Architecture Description</td>
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<td>SAODB</td>
<td>Scenario Airport Operational Data Base</td>
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<td>SAS</td>
<td>Scandinavian Airline</td>
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<td>SYRD</td>
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<td>TAM</td>
<td>Total Airport Management</td>
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<td>TAMS</td>
<td>Total Airport Management Suite</td>
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<td>TAPAS</td>
<td>Total Airport Performance Assessment System</td>
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<td>TMA</td>
<td>Terminal Maneuvering Area</td>
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<td>TMAN</td>
<td>Turnaround Manager</td>
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<td>TOBT</td>
<td>Target Off Block Time</td>
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<td>TOP</td>
<td>Total Operations Planner</td>
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<td>UDPP</td>
<td>User Driver Prioritization Process</td>
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<td>UDPS</td>
<td>User Driven Pre-tactical Sequencing</td>
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<td>XMAN</td>
<td>Tactical tools like Arrival Manager (AMAN), Departure Manager (DMAN), Surface Manager (SMAN), Turnaround Manager (TMAN), Passenger Manager (PaxMan)</td>
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1 Executive summary

1.1 Project objectives

The TAMS project (Total Airport Management Suite) is based on the Total Airport Management (TAM) concept, which was defined jointly by the German Aerospace Center (DLR) and EUROCONTROL. With TAM, the collaboration between stakeholders (airports, air traffic control, airlines, ground handlers, authorities, etc.) is improved in order to enhance efficiency, capacity usage and environmental protection at the airport. It extends EUROCONTROL’s well-known Airport Collaborative Decision-Making (A-CDM) concept by the following elements:

- Joint Airport Operations Plan, which is created, maintained and shared by all stakeholders
- Integration of airside and landside aspects
- Seamless planning
- Airport Operations Control Center (APOC)

The goals of the TAMS project are derived from the socio-economic goals of the German government and the interests of the project’s industrial and research partners.

The following figure provides an overview of the TAMS overall concept.
1.1.1 Overall goals
The overall goals of the TAMS project can be summarized as follows:

- Realize a TAMS Airport Management Suite with a open, modular system architecture
- Adapt existing research prototypes and industrial subsystems to enable one overall TAMS operational and technical concept
- Verify and validate the feasibility of TAMS at the DLR simulation test facilities and quantify operational benefits
- Set up a mobile demonstrator

1.1.2 Contributions to political goals
The political goals:

- Strengthen Germany’s competence in airport operations management systems
- Contribute to the government’s high-tech strategy in the areas of IT and aviation technologies

1.1.3 Scientific and technical goals
The more detailed scientific and technical goals of the project are defined as follows:

- Perform an analysis of as-is airport processes
- Develop an operational TAMS concept
- Develop a joint Airport Operations Plan (AOP) covering airside and landside processes
- Develop tactical landside prediction and planning systems
- Develop pre-tactical APOC tools
- Develop a suitable video wall visualization for an APOC
- Develop stakeholder-specific working positions for an APOC
- Integrate all airside and landside system components via a TAMS integration platform
- Adapt the TAMS simulation and test environment
- Verify and validate TAMS aspects

1.2 Prerequisites for the project
EUROCONTROL and the European Commission have been driving research in air traffic management for several decades. In addition, some national and regional programs such as LuFo (Lufthfahrt-Forschungsprogramm – a German aeronautical research program) perform this work. But the focus of these programs has been primarily on flight guidance and air traffic management aspects from an ATC agent's or a pilot's perspective. Single European Sky ATM Research (SESAR) was started to harmonize all this research to achieve the goals set down in Vision 2020. But here too, the focus — at least initially — has been on 4-D flight guidance. Research involving airport operations has remained a niche topic.

Be that as it may, airports are the nodes of the air transportation network, and aviation is much more than systems supporting ATC agents and pilots. A whole range of operators and stakeholders are heavily involved in airport operations.
After many years of stakeholders optimizing their islands of responsibility, it has become time to consider airport operations more holistically. In the future, only concerted coordination and collaboration between all actors can ensure economical use of resources and a convenient travel experience.

EUROCONTROL, in anticipation of the need for more collaboration between airport stakeholders, founded the well-known A-CDM initiative, which has been implemented at airports in Europe and all over the world.

DLR came up with the Total Airport Management (TAM) concept in the year 2000. The core idea was to go beyond A-CDM information sharing towards joint planning. After some years of basic research, EUROCONTROL joined the TAM initiative. At the time of project start, DLR and EUROCONTROL had already published an initial joint TAM operational concept. This publication was chosen by the TAMS team as the basis for further TAMS considerations.

DLR has a reputation for airport system competence in research, and the organization has prepared airport management system prototypes. When the TAMS project was founded, industry players had COTS products available for certain process areas.

At the request of DLR and Siemens board members, a study was prepared to identify those areas in which results from R&D could be matured to form the basis for new innovations “made in Germany.” The TAM idea was chosen, and a proposal was made for the TAMS flagship project funded by the German Federal Ministry of Economics and Technology (BMWi). During the course of project preparation, a powerful consortium was established, and Barco Orthogon, INFORM, ATRiCS and the Stuttgart Airport also joined the team.

The German government decided to fund this flagship initiative in the framework of its high-tech strategy. TÜV Rheinland was tasked with supervising project execution.

1.3 Project plan and execution

The TAMS project was shaped over a significant period of time during which all targets were agreed upon, all constraints understood, work packages fully described, funding issues clarified, etc. The project started with a letter of intent from BMWi in December 2008. As a formal go-ahead was some months in coming, a “slow” phase was agreed upon in mid-2009 to bridge the time until formal approval was in. Finally, in December 2009 the project could be officially kicked off.

The project was scheduled to run for three years (December 2008 – November 2011) in phases. Because of the slower phase in the first year, a project extension of six months (until May 2012) was agreed upon in the mid-term project review. With this extra time all main goals of the project could be achieved.

In the first and second project phases, Stuttgart Airport and the other TAMS partners carried out extensive as-is process studies based on a professional process description tool. The goal of the studies was to achieve a common understanding of the real airport view of aviation. With this understanding and the given functionalities of the partner systems, an A-CDM gap analysis was carried out. This work resulted in a joint vision of TAMS. Finally, an initial TAMS operational and technical concept was developed – based on the EUROCONTROL/DLR TAM concept – and adapted to industry needs. An initial technical integration of the industrial systems revealed many challenges in an airport environment that could finally be handled. The result of these two phases was an integrated A-CDM-like system. In parallel to the specification and system development work, preparation of the simulation environment was ongoing at DLR.
In the third project phase, the integrated A-CDM was extended by additional functions and systems. Furthermore, the A-CDM was embedded in the DLR simulation facilities to enable closed-loop simulations. Here the simulation automatically executes plans on the basis of rules; master file data and test cases from Stuttgart Airport and aspects from airside at Hamburg Airport were also integrated to model a more complex environment. These plans serve as decision support. The result of this phase was an enhanced A-CDM system, including tactical optimization across stakeholder boundaries. A fully automatic execution of airport traffic could be demonstrated. Although the implementation of an A-CDM system was not an objective of the TAMS solution, this exercise demonstrated that the overall collaborative planning leads to an Airport Operation Plan (AOP) that can be implemented in everyday operation. A further key result was a meaningful visualization of information on a video wall to support contextual situational awareness and specific APOC agents in their individual tasks.

In the fourth phase the overall setup was used for extensive verification exercises, carried out with the individual systems by the industry partners together with DLR. This ensured correct system behavior. In the ensuing validation trials using a simulated scenario, reactive airport management was compared with proactive TAMS joint planning. Furthermore, a mobile demonstrator was set up and presented at Passenger Terminal Expo 2012 in Vienna. The valuable feedback collected at the event rounded out the validation trials. In addition, the industry partners carried out extensive verification exercises with the individual systems. The integrated functionality was first extended by joint what-if capability of tactical systems, which provided integrated decision support capability for an airport’s experts, the national air service provider and the airline operators/ground handlers. Finally, pre-tactical APOC tools, integration between airside and landside tactical tools, and IT supporting coordination and communication within the APOC were added.

All main concept elements of TAMS – AOP, integration of airside and landside, seamless planning, APOC – were realized, integrated and verified. Initial validation runs revealed many valuable aspects that have to be considered in a real TAMS implementation. Finally, validation runs in the DLR simulation environment also showed benefits of the TAMS approach, e.g. improved punctuality of air transportation as well as passenger connectivity.

A subject for a potential follow-up project would be a full-scale TAMS validation at several large European airports with a combination of loop simulation trials (with humans) and field trials. The integrated TAMS system, the integrated simulation environment and the mobile demonstrator would be key aspects for this European-wide project.

1.4 State of the art right from the beginning

As discussed in 1.2, the primary focus of R&D activities to date was on flight guidance aspects (e.g. in projects like “Gate to Gate”). Some work was carried out in surface management of aircraft (e.g. in BETA, EMMA), but it also focused on ATC agents and pilots. EUROCONTROL’s A-CDM was the first approach to coordinate the different airport stakeholders. TAM, a brand-new concept from DLR that was consolidated and published together with EUROCONTROL, described a holistic approach to joint planning.

For modeling and simulating airport operations on airside and landside, projects like OPAL were carried out. But the full integration and ability to include industrial TAM systems were lacking. DLR prepared basic operational concept ideas and achieved some tool development within their FAMOUS project for a Total Operations Planner (TOP), and created valuable baseline input for the TAMS project.

DLR had submitted patents with respect to TAM; Siemens secured the rights to use these inventions within a technology transfer contract. Siemens has also submitted several patents
and protected the brand name “TAMS” in order to document the origin and creator. Patents of third parties were monitored during the course of the project.

1.5 Collaboration with external partners

The TAMS team was a formal construct with contributors from research, industry and users. Nevertheless, it was understood that feedback from a larger airport community would be very valuable in the early states, and therefore significant collaboration was carried out with external partners.

Opportunities to speak to operational experts who might subsequently be TAMS users were used wherever possible. Retired operational experts were hired by Siemens during the specification phase to contribute to graphical user interface (GUI) design aspects. Meetings and workshops with organizations like EUROCONTROL and SESAR were held. Several exhibitions at trade fairs (e.g. ATC Global, Passenger Terminal Expo, Dubai Airport Show, Abu Dhabi Airport Exchange, ATCA), where TAMS partners had booths, were used to present progress and to receive feedback on TAMS results.
2 Detailed description

2.1 Project results and funding usage

The following chapter describes the main TAMS project results following the structure of the TAM concept elements. Also included here is a description of the TAMS concept work, the simulation environment and the validation results.

2.1.1 Progress with TAMS concepts

At the beginning of the TAMS project, DLR and EUROCONTROL had just published a joint, 30-page TAM operational concept document, which set the course for enhancements beyond A-CDM. TAMS delivered a set of consistent documents of several hundred pages in length; the following concepts from numerous technical working papers on integration, verification and project management deserve mentioning:

- TAMS vision
- Operational concept document
- Operational scenarios and business use cases
- Technical concept including architecture and interfaces
- Validation concept document

The TAMS vision document was considered the kick-off for the concept work to align the TAMS partners’ ideas. DLR then successfully coordinated the development of the operational concept. Here a phase-by-phase approach was chosen to complete the living document in a step-by-step approach. The development of the TAMS operational concept was strongly based on the early TAM publication, which was greatly expanded to 200 pages and encompasses the following:

- Stakeholder interests and constraints
- As-is process analysis
- Joint planning in TAMS
- KPAs and KPIs for TAMS
- Roles and interaction with a TAMS APOC

In addition, operational scenarios and business use cases were developed to compare operations with and without TAMS. A comprehensive format similar to the EUROCONTROL A-CDM manual was used.

Stuttgart Airport conducted a series of as-is process analysis studies and explained all details of airport operations management to the TAMS partners. This contribution was a key success factor for the project. Stuttgart Airport's many years of experience with control centers, IT systems, resource management and human machine interaction brought the concept work back on track more than once.

The technical concept, coordinated by Siemens, was also developed in a step-by-step approach with all TAMS partners. The architecture, the communication patterns, the logical data flows and the semantics were jointly developed over a period of more than two years; the result was a very detailed, 200-page document.
The validation concept document was drafted by DLR following the European Operational Concept Validation Methodology (E-OCVM) standard, and it was reviewed and amended by all TAMS partners.

2.1.2 Sharing the Airport Operations Plan (AOP) in an SOA-based integration platform

2.1.2.1 Technological foundation of the system architecture

The TAMS integration platform, developed by Siemens, was built on experience in other logistic domains (e.g. baggage handling, air cargo handling, postal automation and distribution logistics).

Suitable three-tier architecture was chosen with a database layer, an application server layer and a GUI layer. COTS products from ORACLE were selected as a foundation after a careful technology evaluation process.

The architecture is designed with a high level of scalability and availability so that it can cope with a range of non-functional airport requirements, from small airports all the way up to large hubs.

Furthermore, the architecture was tested for its capability to run in a cloud computing environment.

2.1.2.2 Open and modular system architecture for TAMS

The overall TAMS architecture – based on this integration platform – is presented in the following figure.
An enterprise service bus (Airport Process Integration Platform, APIP) provides open interfaces to all TAMS partner systems and connections can be established to further systems. Thus, the TAMS concept is very modular.

The platform provides several interface patterns to enable a smooth integration with further systems. Several subscription-notification mechanisms as well as inventory services are supported.
The data flow and the interface adaptors support a high level of on-the-fly adaptability. This is important in airports operated 24/7 where systems have to be integrated during running operations.

2.1.2.3 Persistence of the Airport Operations Plan

One core TAM concept element is an Airport Operations Plan (AOP) that consistently integrates information across stakeholder and planning time horizons. This integration was realized with the TAMS-capable Airport Operational Data Base (AODB). Comprehensive cooperation with different internal and external airport experts led to the development of a full-blown logical domain model (LDM). This model contains approximately 200 data entities.

All AOP aspects are covered in this model, such as process level, resource level, event level, flight level, traffic flow level and performance indicator level. The constraints of the AOP are also modeled in this LDM.

The business logic around this TAMS-AODB ensures consistency between the data units. The business logic handles standard IATA messages like passenger and load data messages as well as EUROCONTROL A-CDM messages. Messages are automatically parsed and only erroneous messages are drawn to the attention of a human operator at a message clearing desk.

The persistence layer seamlessly tracks all data changes so that at any point in time a clear history of who changed what is available, e.g. to support audit trails.

A-CDM logic is included in this AODB. As such, no extra “magic boxes” are required for information sharing and milestone supervision. The A-CDM concept of EUROCONTROL is even extended to non-standard cases to cope, e.g. with go-arounds or return to ramp cases.

The concept of A-CDM was generalized. The SEAT concept was developed, maintaining full parallel data worlds of schedule, estimate, actual and target timing information. Schedule information is propagated from Scheduled In-Block Time (SIBT) and Scheduled Off-Block Time (SOBT) for all other steps in the full process chain, which leads to the creation of
Scheduled Time Over Fix (STOF) and Scheduled Time Over Departure Fix (STDF). Target times are normative targets in this case, so process durations can always be compared against how long it should usually take. Estimates are integrated through a configurable data hierarchy, so that, e.g. estimates from IATA messages, XMAN estimates, APM and manual input can be aggregated into one best time. Finally, schedule, aggregated estimates, targets and actuals are aggregated into one relevant time, which is what the user should generally rely on.

![Figure 6: SEAT concept](image)

2.1.2.4 Graphical user interfaces to visualize and edit the AOP

Data browsers and editors that access the AOP seamlessly cover all typical airport management processes from seasonal flight plan management via daily flight plan and resource allocation handling all the way to post-processing activities like statistics, reporting and billing.
Figure 7: Seasonal flight planning GUI

Figure 8: Operative flight planning GUI
The GUls are built on rich-client GUI platforms, which support those people who work all the day with the system from a fixed working position. The GUls also feature thin web clients for the many people in the airport premises who use mobile devices to access data.

A special A-CDM view summarizes almost all important flight data in a chart, and the view can be easily used in further landside traffic management applications, e.g. in an airport taxi capacity-demand-matching task.
2.1.2.5  Mobile devices

Mobile computing is a major trend not only in consumer electronics but also in aviation IT systems. Trials were conducted to visualize and enter information into the integration platform through these channels as well.

![Image of mobile device accessing integration platform data]

Figure 11: Sample for mobile device access to integration platform data

2.1.2.6  Data warehousing

The AOP realized by the TAMS platform usually covers the day of operation or several days around the actual date. In order to support statistic and reporting functions, an additional data warehouse was integrated that can easily hold ten years of AOP data from a large airport.

The data replication mechanism is innovative: instead of copying, for example, the day-of-operation at midnight, an incremental replication is realized. This is a key to seamless business intelligence in which the past, the current situation and future plans can be combined seamlessly.
2.1.2.7 Master data management services

Airport IT systems often contain distributed and redundant airport master data. Information about the name and location of airport stands or about aircraft types or worldwide destinations are held in several systems. Centralized management of these data items and suitable data distribution mechanisms can significantly reduce the IT maintenance cost of airports.
In TAMS a centralized AMDM is feasible, and even client applications do not have to be restarted when certain master data are changed.

2.1.3 Joint planning within the Airport Operations Control Center (APOCH)

2.1.3.1 Contextual situational awareness on a central APOCH HMI

The concept and model realization for the central APOCH human machine interface (HMI) was one of the TAMS project work packages coordinated by INFORM. It was created in close cooperation with the other TAMS partners. Content was based on partner input and industry feedback from a variety of users.

The new TAMS capabilities – gain real-time insight; predict arrival, surface and ground-handling turnaround and departure processes on a single and multiple flight level; and issue alerts on irregular operations when joint re-planning between the APOCH partners is still feasible – can be ideally supported by the holistic visualization within the APOCH HMI.

In this sense, the APOCH HMI helps the different APOCH agents at the working positions to participate in the collaborative decision-making process. It provides the interface between operations and mutual planning for approach, departure, runway, apron, the entire ground-handling turnaround chain, and en-route control.

The time horizons of CDM processes within an APOCH range from pre-tactical to tactical. Their effects on tactical tools determine APOCH decision-making. Interdependent, purely tactical decisions directly influence the forecasts used for performance and flow adjustments. At decision-making time, both the pre-tactical plan and the accurate tactical situation need to be visualized with a view to their interdependence on one another.

Aggregated information for the visualization of operational tendencies on a pre-tactical level is deemed to be useful as long as it is accurate; however, this information is not sufficient enough. Due to the high velocity in operational changes stemming from multitudes of parameters that have an impact on one other, a real-time overview of the current operational situation in the air, on the airfield, in ground handling and in passenger flows is essential.

Thus the APOCH HMI should provide good, real-time operational awareness on an ad-hoc level, portray those decisions that are being made by the agents on a tactical level, and indicate performance- and flow-based planning intentions of the pre-tactical time horizon.

The main lessons learned during the APOCH HMI design discussions between the TAMS partners and the additional input obtained from six major airlines, three airports and two ground handling companies revealed that an APOCH HMI should be divided as follows:

- A Static Layout Area with common planning and prediction awareness
- A Variable Layout Area that supports real-time situational awareness – the focus of visualization is subject to changes depending on irregularities
- A Case by Case Layout Area where the processes and results of a joint what-if analysis can be mutually followed and negotiated, when needed
The combination of ideally simultaneous insights into all these operational steering and planning levels and their joint visualization makes true collaborative decision-making possible. The focus is on interdependent collaborative planning and collaborative steering for the experts in an APOC environment. Thus, a flexible HMI layout concept was realized.

On the basis of input and suggestions from the TAMS partners – whose focus is on a highly aggregated and pre-tactical presentation of predicted capacity bottlenecks, implementation of chosen APOC strategies, presentation of determining parameters such as weather, changes in ATC strategies, etc. – the APOC HMI Static Layout Area mainly reflects pre-tactical elements.

Using the additional insights from TAMS partner and interviewed airports, airlines and ground handlers, the Variable Layout Area reflects the tactical real-time situational awareness information elements.

An additional Case by Case Layout Area enables APOC specialists, when faced with irregular situations and developments, to conduct and follow problem-solving what-if analysis to derive the most fitting decisions from both pre-tactical and tactical input. This feature is either enabled on separate video wall space or superimposed on part of the Variable Layout Area.

An example layout used for a presentation of the mobile TAMS demonstrator APOC HMI at the DLR facilities in Braunschweig.
2.1.3.2 Experimental APOC negotiation environment at DLR

The test environment at DLR was used by the partners to not only integrate and demonstrate their systems, but also to integrate DLR's advanced prototypes. DLR implemented and demonstrated tool-supported negotiation within the APOC by employing it’s Total Operations Planner (TOP) advanced pre-tactical planning prototype and corresponding HMI client systems.

The picture in Figure 17 was taken during the demonstration of the negotiation at the TAMS T24 milestone meeting on December 15, 2011. For better visibility, the video wall was used to present the airport airside GUI and the airport landside tools.
The airside agent working positions were equipped with a generic agent GUI using a central negotiation core supported by TOP. TOP calculates key performance indicators (KPIs) of the given traffic situation and the corresponding prediction of traffic development. Furthermore, it performs and shares what-if scenarios to find a common decision in worst-case situations. All of this information is shown in the GUI.

The results of negotiation activities impact other systems at the airport. They require re-planning and the negotiation interfaces show the changed KPIs. For demonstration purposes, several use cases for different situations, e.g. changing airport optimization parameters or planning runway closures, are supported. The activities of negotiation participants, e.g. airport or airlines as well as the moderator, can be shown and the necessary communication channels (voice or messages) can be investigated.

Not only during negotiations are the agents supported by a common overview display: the video wall. The video wall GUI shows aggregated KPIs, tasks and messages. The GUI also features a variable part on which the source of occurring problems can be displayed (e.g. weather radar in case the APOC receives a prediction for adverse weather conditions). Even if the APOC demonstration was done as a centralized APOC, the prototypes can also be used in decentralized APOC experiments. All tools were integrated using the DLR integration platform EADF (DLR DataFusion Prototype).

2.1.3.3 Synchronized decision-making processes

Even if the stakeholders of an airport are gathered in an APOC and are perfectly supported by working positions and superb video wall content, a consensus has to be reached on how decisions are made, communicated and implemented within the APOC.
Siemens developed a solution for a suitable workflow management that can be implemented in central APOC designs as well as in distributed APOCs.

![Figure 18: Workflow-based APOC decision-making](image)

Typical situations that require coordinated action from all stakeholders are identified and documented as workflow templates. An example is a lost suitcase in the terminal building, which would call for the following steps: secure the area, evacuate passengers, if needed adapt stand and gate planning, investigate the suitcase, etc.

These templates are activated whenever such a trigger event happens. IT supervises the proper execution of the workflows and stores the actual workflow together with all related documentation. These data are kept for many years. The activities can therefore be analyzed in lessons-learned workshops and can be used to continuously improve workflows.

For each operator in the APOC a separate task list is maintained, which assists with prioritization. For the central supervisor’s position a special visualization was developed. It dynamically classifies workflows and aids in the selection of which workflows to show on the video wall to increase awareness.

The concept supports the visualization of the prioritized workflows on the video wall as depicted in Figure 19.
An integration of workflow management with communication means like videoconferencing was successfully tested during the PTE2012 exhibition. At the TAMS booth the supervisor position was used to maintain some sample workflows. With just a few clicks, a videoconference could be established to the (simulated) responsible process owner at Stuttgart Airport to discuss aspects of the running workflow.

Figure 20: Videoconferencing triggered from a workflow management system
2.1.3.4 Integrated airport working position

An integrated working position for airport operations management was developed by Siemens.

The solution contains the classical functions of airport operations management like seasonal and daily flight plan management and resource allocation for among others stands, gates, check-ins, reclaim belts and baggage chutes. As such, an airport agent can supervise and modify this part of the AOP from a central position. Information handling is supported by automatic message parsing and clearing functions. The working position was extended by process and performance analysis and forecasting of the APM to allow the agent to anticipate operational problems. This makes a proactive rather than a reactive approach possible. Furthermore, the working position contains lists of active workflows in which the airport agent is engaged. Finally communication means, tightly coupled with workflow management, allow quick coordination with other agents in the APOC or at other locations of the airport. The individual elements are described in 2.1.2.4 and 2.1.6.1.

2.1.3.5 Integrated Airside Tactical Working Position (ATWP)

The tasks of the ATC agent in the APOC are focused on supervising and assuring the optimal utilization of airside resources, like runways, taxiways, etc. Therefore, to improve situational awareness, the ATC agent (e.g. tower supervisor as assumed in the EU-project Episode 3) needs a special working position that provides necessary information about the current and planned usage of the different resources and the situation of the airspace and apron.

The user interface of the Airside Tactical Working Position (ATWP), developed by Barco Orthogon, aggregates relevant information from all system tools. It comprises different views and functions to support ATC agents to fulfill their tasks. Examples include a timeline view to manage capacities and to plan the sequence of flight arrival and departure, an airspace surveillance display, and some novel views that support the tasks of the ATC agent in the APOC. The ATWP is completed by the ATRiCS AirportMap (see 2.1.4.2).

The Air Traffic Flow Management (ATFM) view (Figure 22) provides metrics focusing on demand prediction for ATC resources (sectors, arrival and departure routes, and runways). It supports the ATC agent in determining and initiating adequate flow management restrictions in the case of predicted capacity overloads.
Furthermore, the ATFM view supports performance-based airport operations by calculating and presenting key performance indicators (KPI) (Figure 23), such as throughput, arrival and departure punctuality, ATC slot compliancy, and additional time for ASMA (Arrival Sequencing and Metering Area) and for the taxi-out phase. The latter two have been defined as KPIs for air navigation services and network functions in Europe [European Union: Commission Regulation No 691/2010].

Figure 23: Qualitative KPI view

Figure 24 shows examples of the quantitative views. Diagrams indicate the progression of each KPI value. Performance targets and alert thresholds are indicated as horizontal lines. Furthermore, data series are color coded in accordance with the qualitative view to support the comparison of both result representations. The user is able to decide for which of the KPI(s) a diagram will be presented at the KPI view.
Additional views, like the aggregated A-CDM milestone view (Figure 25) and the pre-departure sequence list, are also included in the ATWP. The A-CDM milestone view provides a monitoring and alerting function in regard to the A-CDM milestones as defined by the European norm for A-CDM [ETSI EN 303 212].

Another new functionality of the ATWP allows the ATC agent to participate in a tactical joint what-if probing, together with other tactical tools – without interacting with and influencing the “real-world” context (see 2.1.4.1) during the probing. With this functionality, all stakeholders can check their considered mitigations. The results and consequences of the action of one stakeholder are immediately visible in the ATWPs “Joint-What-If” view. If all stakeholders agree on a mutual solution, it is possible to activate this solution and put it into operation.

Since the ATC agent must optimize resource management in a proactive manner, a prototype coupling between the User Driven Pre-Tactical Sequencing (UDPS, see 2.1.6.2) was also realized in order to take into account the pre-tactical takeoff times agreed with the airlines. Likewise, the ATWP forwards flow constraints to be applied to arrival and departure capacities to pre-tactical forecast tools.
2.1.3.6 ODS Open Platform

The newly developed user interface of the ATWP is based on Barco Orthogon’s ODS Open Platform. The ODS Open Platform is an HMI integration platform for modular and open operational display systems. Especially its modular architecture makes it possible to integrate various HMI components from different contributors into one homogeneous application. This means that the HMI components have a consistent look and feel, use the same window system infrastructure (share menus, toolbars, etc.), share the same information, and interact with each other.

Using this approach, controller positions can be easily composed of individual HMI components in order to fulfill the required operational functionality.

The underlying software infrastructure of the ODS Open Platform is based upon Java and the Open Source NetBeans Rich Client Platform.

One of the major concepts is to decouple the individual displaying views and the data services from each other. This is achieved via a centralized data model that provides interfaces for data access and event listeners for lifetime and update events.

On the display side, specialized modules for resource managements such as colors and fonts are provided, which can be used to easily configure the overall look and feel of the HMI application. This feature is also provided at runtime via resource editors with an appropriate GUI.

Especially in the context of TAMS, the ODS Open Platform is an ideal framework to integrate various information provided by multiple vendors into a consistent and extendable HMI application.

2.1.3.7 Integrated airline and ground handling working positions

The integrated working position for airline and ground handling management was developed by INFORM.

On the basis of HubControl with its strong, flexible critical path calculation model of all interdependent ground handling processes, two separate Turnaround Manager (TMAN) versions were configured and enhanced – one for the steering purposes of airlines, the other for the steering purposes of ground handling companies.

HubControl provides a complete overview of impending irregularities and exact pre-calculations of upcoming delays – if no corrective action is taken in the interim. It warns and pinpoints the conflict area of an aircraft’s ground handling delay during a timeframe from the present until 24 hours in advance.

Whereas it makes transparent by how much time an arriving flight will be late, it also takes into consideration the chain of events following a late arrival after on-block. Based on the underlying handling process model, the specific aircraft’s load factor and the feedback from the resource level about handling progress in real time, it consistently calculates and updates a possible Target Off Block Time (TOBT). After a final decision about the TOBT’s prediction reliability, the TOBT is qualified to be passed on to the ATC domain by the responsible process coordinator.
If there is malperformance in the ground handling processes, HubControl recognizes it and – if the handling causes a delay – alerts the steering level at a time when corrective action can still be taken.

On a single flight level it consistently calculates the handling process progress and compares it dynamically with remaining buffer times between the handling processes and the scheduled time of departure.

If handling processes or events on a critical path start to be influenced and a TOBT is shifting past the scheduled time of departure, it again issues alerts to the steering level of operations.

The actions of airlines and ground handlers (as well as those of the airport) influence one another and show direct on-time or delay effects for any aircraft turnaround.

The basic idea behind a TMAN is therefore to keep these stakeholders in the same interdependent data model.

The airline’s main objective is to steer its on-time performance for cost and overall airline network performance.
The ground handling company as one of several service providers mainly strives for efficient service delivery to its customer airline(s). Its main objective is to provide its services as efficiently as possible. The steering enablers are:

- Prediction quality as to when resources embedded into the overall process performance flow are going to be required
- Real-time feedback from the resource or resource dispatch level to the overall process level
- Prediction capacity on when processes for specific flights steered by different stakeholders are being planned in conflict with each other. Both stakeholders – each steering common processes focused on a main objective and each working in a specific area of responsibility – influence via their work results a common process data model, which is then provided to the APOC steering level.

![Figure 28: TMAN Airlines and TMAN Ground Handler](image)

**2.1.4 Integration of tactical decision support across stakeholders**

**2.1.4.1 Arrival, pre-departure and departure manager (AMAN/DMAN)**

An arrival, pre-departure and departure manager is a prerequisite used by the ATC agent in the APOC to get an overview of resource utilization and to identify and mitigate potential bottlenecks of airside resources (see 2.1.3.5).

These tools should be configurable to offer conflict-free autonomous planning, which permits automated verification and validation trials.

Barco Orthogon’s OSYRIS product provides an integrated suite of arrival, departure and flow management software for flexible resource utilization. To support planning of arrivals and departures on mixed-mode runways, and to ensure a consistent planning of both arrivals and departures, it was necessary to develop a coupling between the Arrival Manager (AMAN) and the Departure Manager (DMAN).

One focus was the synchronization of both processes with respect to handling external data updates, because the order in which AMAN and DMAN process these data is relevant.
Furthermore, the HMI displaying an arrival and departure sequence – timeline view of the ATWP – had to be synchronized with the planning processes. The result was a coupled system able to create a combined arrival and departure sequence for mixed mode runways, where AMAN is the master and DMAN plans its departures into the gaps left by AMAN.

To enable the capability of changing the arrival and departure rate, e.g. to favor departures over arrivals, time-dependent flow constraints were introduced in AMAN and DMAN. By setting an appropriate arrival and departure flow valid for a particular time interval, AMAN leaves corresponding gaps for departures in the arrival sequence, which DMAN may fill with concrete departure flights.

During the integration of AMAN/DMAN with tools of other TAMS partners, initially AMAN and especially DMAN were typically affected by numerous erroneous and often changing input data. Thus, several checks, restrictions and extensions had to be implemented in AMAN and DMAN, in one case even changing the operational model of the DMAN. Tests with the TAMS partners in the fully integrated TAMS revealed the need to further stabilize the AMAN/DMAN sequence and to enhance the performance of DMAN. Therefore, AMAN and DMAN were enhanced with appropriate changes to become sufficiently robust and reliable.

In order to support a joint decision-making process in the TAMS control room, the involved partners elaborated a detailed and workable application concept. This handles the coordination of creating, editing, rejecting and activating what-if scenarios among the tactical tools. This is a complex task, since the initiator of a what-if scenario can be any of the connected tools (AMAN/DMAN, TMAN, SMAN), and the other tools have to react in an appropriate manner.

AMAN and DMAN were extended by a what-if function, referred to as tactical joint what-if. This function allows the creation of new contexts or “sandboxes” in which tentative changes to AMAN/DMAN settings can be made.

The sandbox data are continually updated with relevant real-world data, as well as changed planning data from the connected tools. The latter can be automatic results from the connected tactical tools triggered by AMAN/DMAN or vice versa. Finally, the sandbox represents all decisions and mitigations initiated by the ATC agent. After acceptance of what-if probing, the mitigations of all stakeholders come into operation.

2.1.4.2 Surface Manager (SMAN)

The ATRiCS Surface Manager (SMAN) is based on an Advanced Surface Movement Guidance and Control System (A-SMGCS) including routing and guidance functionalities. In the TAMS project the SMAN was extended by additional interfaces, prediction and planning capabilities to fulfill the TAMS requirements of an ATC working position in the area of ground movements. The TAMS version of SMAN provides bidirectional interfaces to the AODB, AOP and to the Barco Orthogon DMAN.

With the ATRiCS Advanced Taxi Time Calculation (ATTC), the SMAN improves the A-CDM standard of variable taxi time calculation, both of which are realized by static taxi timetables. The SMAN calculates in real time unimpeded and impeded taxi time durations. The unimpeded taxi times represent the fastest possible taxi time and, in comparison with the impeded taxi time, they represent the taxi delay caused from traffic volume. The TAMS validation shows that the advanced taxi time calculation improves prediction quality.

The ATRiCS Taxi Sequencer generates a 4-D trajectory on the surface, from landing to in-block and from pushback to takeoff. The 4-D trajectory represents a conflict-free and optimized plan that states in which order aircrafts taxi on the ground (see Figure 29). Especially for departure, the Taxi Sequencer supports delivery of an optimized takeoff order
at the runway holding positions. The planning functions are integrated with Barco Orthogon’s arrival/department operations (see 2.1.4.3).

The ATRiCS SMAN provides surface process monitoring by detecting all current events and triggered alerts, e.g. stand conflicts. All generated information, plans and events are stored in a dedicated database and can be display with the ATRiCS Track Data Analyzer to support post-analyzing requirements. The SMAN provides two variations of AirportMap to support the situational awareness: one AirportMap is part of the ATWP for the ATC agent (see 2.1.3.4), and the other AirportMap is a “see only” display as part of the video wall in the APOC (see 2.1.3.1).

The SMAN includes what-if capabilities with all prediction and planning functionalities described above, which can also be used in joint what-if scenarios. This function allows the creation of new contexts or “sandboxes” in which tentative changes to SMAN settings can be made (e.g. alternate preferred routing scheme, see Figure 30).
2.1.4.3 SMAN–DMAN coupling

Furthermore, the ATRiCS Surface Manager (SMAN) was coupled with the Barco Orthogon Departure Manager (DMAN). SMAN provides an advanced taxi time calculation module and, in addition, a taxi-sequencing module (see 2.1.4.2). The SMAN taxi-sequencing module comprises the planning and controlling of the off-block and taxiing processes. With SMAN’s exact data regarding the situation at the apron and on the taxiways, it is able to provide exact taxi durations as well as information about problems like traffic jam situations. Due to this coupling the departure sequence could be improved and stabilized.

2.1.4.4 Turnaround Manager (TMAN)

During the TAMS project, INFORM significantly increased the decision support capability of the Turnaround Manager (TMAN) for stakeholders, airlines and ground handlers.

TMAN was equipped with functions to display the A-CDM progress of EUROCONTROL’s 16 progress milestones. As a result, airlines and ground handlers can work with a clearance process that is embedded in the ATC progress flow and that calculates its own planning adjustments based on these milestones.

This way any airline planner or ground handler can instantly predict where inbound delays are expected, how much delay time will be incurred, and whether there is a chance to recover any of it by special means or procedures. The executing ground handling process dispatcher can see any predicted delays in advance and start making alternative plans at his or her level.

In order to for this to work, the necessary data have to be integrated between AMAN, DMAN, SMAN and TMAN. ATRiCS, Barco Orthogon and INFORM used the “slow” phase – the time before the TAMS project was formally authorized – to integrate these elements. An integration of the ATC and ground handling applications via the TMAN database was created in a manner that, after documentation and demonstration as a project delivery, it could be utilized by the other partners at a later stage.
The integration of all A-CDM relevant processes and milestones within the TMAN could be visualized for TAMS as in Figure 33.

The next step was to identify which arriving flights would carry how many transfer passengers who would be missing their connections due to late arrivals. Using this knowledge, three activities can be started:
1. A connecting flight can be held in a pre-planned manner for a later departure time in order to accommodate the passengers

2. If possible, a faster procedure can be followed to shorten the physical transfer time of the passenger on the ground, for example with a direct wing-tip to wing-tip bus transfer, using electro vehicles within the terminal for transfer, group handling through customs/immigration, etc.

3. A re-booking of misconnected passengers while they are still on the inbound flight can be started instead of potentially increasing further delays in the airline’s network by holding back local connecting flights

When it is known how many passengers may imminently be misconnected, a dynamic cost model can be investigated. Such a model gives coordinators an opportunity to assess the monetary development of an upcoming delay.
If the costs for recovery activities are captured, then there is an opportunity to define an optimal window for holding/releasing flights from an airline’s perspective via an underlying cost model calculation.

![Figure 36: TMAN and the determination of delay costs](image)

When this information is available several hours in advance, the airline planner can start to prioritize ground handling for the flights with arrival delays as well as for the departing flights that are affected by the late arrivals. Real costs are taken into consideration here. The logical next step is to communicate the desired priority decisions to the respective ground handler organizations.

In order to ensure that the requests are manageable, processes may be sped up, services levels reduced (i.e. quick cleaning), and additional resources made available (i.e. extra stairs, additional fueling truck, second catering unit, etc.).

For these situations a Quick Turnaround data model was created on the level of process steering within the TMAN. The Quick Turnaround encompasses feasible short cuts in the process chain of ground handling turnaround.

![Figure 37: TMAN and Quick Turnaround](image)

Without exact knowledge about resource availability at specific times for the respective flights, the TMAN user’s planning can be considered a desired plan only. With feedback from
the resource level regarding availability, however, it can become a joint plan, if feasibilities can be evaluated and agreed upon well in advance.
One of the major enablers for the airline/ground handler turnaround activities described thus far is full awareness of the current and nearer future (4 to 8 hours) for all organizational levels that need to be informed.

To create common situational awareness between these stakeholders, web capability was added to TMAN. With this feature, pertinent situational and planning information is available on a web basis for those who are directly involved in executing passenger services, such as foremen and group leaders.

In the meantime, a virtual airport needed to be set up in the TAMS project. The goal was to create an airport that was as realistic as possible. The resulting virtual airport contains more than 200 anonymous flights from an airport in northern Germany, established and verified handling procedures from an airport in southern Germany, newly created ATC procedures befitting a two-runway airport, and sufficient transfer passenger movements in order to simulate with good reliability. The data from the virtual airport is used for evaluation purposes.

Functional gaps between several tools needed to be closed by parameterization in order to permit semi-automatic validation runs for different scenarios.
When all TAMS suite application elements had progressed sufficiently and the hard- and software for the APOC were made available, the processes of the two TMANs were brought together and made available in two different visualizations on the APOC level.

One Gantt chart displayed combined airline and ground handler process flow progress and prediction, the other a geographical AirportMap including:

- Real-time status of the ground handling progress at the stands and gates
- Movement of all active ground vehicles
- Movement of all aircraft on the ground
- In- and outbound aircraft in the vicinity of the ten miles out radius

The combination of these visualization levels provides a completely integrated situational awareness opportunity for all APOC agents whose focus is ground handling.

2.1.4.5 Joint what-if

At the TAMS T18 milestone meeting in Bonn on May 3, 2011, INFORM together with the partners ATRICS and Barco Orthogon was entrusted by BMWi and TÜV Rheinland to drive forward the R&D activities for tactical joint what-if decision support.

A tactical what-if analysis is the probing of various decision approaches within a closed scenario to evaluate their impact before one of them is taken over into the actual plan or before it is discarded.

A tactical joint what-if is an analysis in which several tactical systems partake jointly. The actions and goals of a joint what-if do not differ in general from those of a simple what-if. However, the processes and procedures had to be synchronized between the systems and correct communication had to be ensured.

Thus, each one of the three XMANs involved was enhanced to include an additional what-if environment alongside its operational environment.
This new functionality of the TMAN, the SMAN and the ATWP allows the APOC agents to jointly participate in a tactical joint what-if probing without interacting with and influencing the “real-world” context. With this functionality, all stakeholders can check their considered mitigations. The results and consequences of the action of one stakeholder are immediately visible in the TMAN’s, SMAN’s and ATWP’s joint-what-if view.

Figure 41: TAMS tactical joint what-if setup

Prerequisites for this joint functionality were an operational AODB and an additional Scenario Airport Operational Data Base (SAODB) provided by INFORM.

The SAODB ran permanently in parallel to the live AODB.

A what-if used actively by only one partner was supported by passive co-runs of all other XMANs.

Figure 42: Tactical joint what-if
The benefits were that a single what-if could be changed to a joint what-if at any time when a passive XMAN started to change its active parameters.

In a single what-if, the active XMAN instantly sees the results of his or her actions within the passive partners’ systems.

All XMANs receive the same data from the SAODB in their “sandbox”; this data matches the available data in the live AODB.

Each XMAN remains the master of the same data fields in the what-if environment, as would be the case in the live environment.

Upon agreement of a joint solution approach, each active XMAN takes over the modified parameters from its what-if environment into its live system.

With this approach of empowering the experts in the three different control domains to jointly evaluate intended or upcoming situations, it becomes possible to predict the impacts and make alternative plans for such use cases as:

- Airline preference evaluation
- Exact timing of runway orientation
- Exact timing of runway closures
- Effects of closing specific taxiways for a period of time
- Effects of delayed end of handling by 20 minutes for the next three flights

![Figure 43: Airline preference impact evaluation by tactical joint what-if](image)

### 2.1.5 Integration of airside and landside operations

DLR landside operations are divided into two parts: The first is the landside part of the simulation environment covering all relevant passenger processes (see 2.1.7). The other part is the DLR Passenger Manager (PaxMan), the main tool to foster integration of airside and landside operations within TAMS. PaxMan is a tool suite that supports the management of processes within the airport terminal on all levels and with a focus on passengers. It supports terminal management by the airport operator, and it is able to provide aircraft operators and ground handlers with helpful information and functionalities for efficient passenger handling.

By monitoring the different passenger processes and general activities at different process points and facilities throughout the terminal, PaxMan is able to predict the Estimated Passenger at Gate Time (EPGT) rather accurately.

PaxMan therefore considers the time frame from Pre-tactical Short Term Phase and Trajectory Execution Phase all the way up to the Post Flight Phase. To comply with the
specific requirements arising from rough and detailed planning all the way to operating terminal processes, PaxMan provides information in two time lines: (1) aggregated predicted passenger flows and (2) utilization of terminal resources in a detailed view related to actual operations. PaxMan architecture and its sub-modules are illustrated in Figure 44 and described in further detail below.

In order to support a decentralized APOC, PaxMan user interfaces (e.g. PaxRadar, Temadis, Queue Observer) are designed to work in a platform-independent environment and can be utilized both on an agent’s working position as well as on mobile devices such as an iPad or a smartphone. This provides users with mobile access especially in disturbance and recovery situations.

### 2.1.5.1 Terminal Management Display (Temadis)

Terminal Management Display (Temadis) from DLR is a web-based application that combines diverse information from the PaxMan system. Temadis also renders control of different process points and PaxMan subsystems, and thus represents an important part of its HMI. Depending on the various requirements of users or user groups, different views and control permissions can be provided.

The main elements of Temadis are the Localizer and Tool Status. The Localizer provides a quick overview of the different process points in an AirportMap as well as their status. By clicking on a specific resource, detailed information can be accessed, e.g. resource
utilization, queue lengths, handling rates, planned staffing, etc. Changes in the planned resource allocation can also be entered here.

A search function provides for quick access of detailed information, e.g. for a specific flight and all related resources involved.

Figure 45: Temadis user interface

The Tools Status shows the current state of all PaxMan subsystems and the active scenario. Some tools can be directly accessed and started from here, and the state of the simulation updates can be monitored (see Figure 46).
2.1.5.2 PaxRadar

PaxRadar is an innovative tool to visualize a large amount of information in a compact layout. PaxRadar shows the current state of all planned flights and related passengers at an airport within the upcoming ten hours (see Figure 47). Each circle represents one flight, and the size of the circle correlates to the number of passengers booked for that flight. The segment in which a flight is placed on this radar represents the gate for which it is planned. As time moves on, the flights (circles) move from the boundary (ten hours to off-block) toward the center of the radar, whereby the center point is the present. In the inner circle the time horizon is five minutes to off-block.

By clicking on a circle, detailed information is provided for the respective flight. An overview of the status of the flight’s passengers is provided, which also shows the respective rate of completion at the different process points (check-in, security, boarding). This especially helps in judging whether passengers will reach a flight on time. The information gathered and shown in PaxRadar is also used for the forecast (see 2.1.5.7).
2.1.5.3 Queue Observer

Queue Observer monitors queues at each open task station. The algorithm takes the coordinates of passengers as input data. Cameras (especially with the help of the sensor simulation described in 2.1.7) are installed in relevant areas of the microscopic simulation and deliver the required data for the queue algorithm.

The evaluation of the input data is performed by a greedy algorithm. The first step assigns all observed persons to exactly one task station by a minimum distance. The second step searches the queues beginning with the coordinate of the task station as a base coordinate. If the nearest person to this coordinate is within a pre-defined range, that person counts to the queue. To examine whether further distant persons are within the range, the next base coordinate is now the one of the last passenger in the queue. If no more passengers are within the range, queue calculation for this task station is done.

The determined queues can now be used to assess the level of service and to provide decision support concerning the opening of additional task stations. They can also help to reduce costs by closing task stations with low usage.
The visualization PaxWall fosters situational awareness for decision-makers working at an airport. The base display is a terminal map that uses geo data. Bottlenecks causing long queues are indicated on this display. As the visualization is web based, it can be accessed with any device supporting a web browser with common functionality, even mobile devices.

A simplified view of the PaxWall is designed to be displayed on a video wall. Figure 48 gives an example with a bottleneck at terminal T1. The alert is indicated by the red area.

![Figure 48: Simplified PaxWall display for a video wall](image)

The standard visualization (see Figure 49) of the PaxWall is more detailed; it is designed for devices with possibilities for interaction. A user can zoom and scroll within this map to gain more detailed information on a bottleneck.

![Figure 49: PaxWall display with user interaction](image)

Each task station (check-in, security lane, border control and gate) provides graphical hints about its current queue state as follows:

- **Closed task station**
- **Short queue at a task station**
- **Queue size is normal**
2.1.5.4 Security Agent

Security Agent is a simple decider module to open and close security lanes automatically. Decision-making is based on the queue calculation by the Queue Observer (see 2.1.5.3). For simplification it is assumed that there is always enough staff to open additional lanes. This module incorporates several constraints so that reality-based decisions can be made:

- Wavering on a decision to open and close security lanes is not recommended. This can be prevented by introducing two thresholds. If the average number of persons waiting at security lanes of one terminal exceeds the open threshold, additional lanes are opened. If the average number falls below the close threshold, lanes are closed.
- A security lane should not be closed shortly after it has been opened. A minimal open time in minutes reduces expensive short time duty of security staff.
- Staff needs a certain amount of time to open a security lane. There is a minimum delay between the decision to open a lane and the time when operations can start at the lane.
- The opening and closing times of security lanes have to respect a time slot of 15 minutes. This slot takes the working times of security staff into consideration.

2.1.5.5 Stamps

STAMPS (Stream-based TAMS-PaxMan Synchronizer) is an integrated PaxMan tool that runs in the TAMS broadcasting network. STAMPS receives, processes and stores the TAMS simulation time distributed by a central time manager (master clock). The STAMPS objective is to keep PaxMan synchronized with the airside TAMS system. The simulation time messages are sent in xml format.

The workflow of STAMPS consists of:

1. Receiving the simulation time messages
2. Extracting the simulation time content
3. Converting this date string into another date string compatible with PaxMan
4. Storing this converted data on the PaxMan database

STAMPS is provided by a GUI in order to support a comfortable control (start/stop) and monitoring management (see Figure 50)

In addition, STAMPS provides an integrated time sender tool that simulates the TAMS simulation time sender. This tool was developed for testing purposes.
2.1.5.6 PAXU

The Passenger and Airport Data Exchange Unit (PAXU) is used to manage the data exchange between landside and airside systems in TAMS. The central TAMS integration platform provides the PAXU with an initial flight plan and updates for this flight plan (for example stand or TOBT changes). Using these changes, the PAXU generates update events for the tools inside the PaxMan suite and the landside simulation environment TOMICS (see 2.1.7.2). Output from PAXU is the current processing data of simulated passengers at the airport with all current and relevant landside data. Also, the predicted EPGT is sent to the TMAN via the PAXU.

2.1.5.7 Forecast

The PaxMan provides a forecast of the expected status of passengers in relation to respective flights. It is important to be able to judge the probability of having all passengers booked on a flight at the right gate in due time, especially if changes occur or specific decisions have to be taken on a total airport level.

For this purpose PaxMan provides a forecast functionality specifically designed according to the principles of a system dynamics simulation. Depending on the actual planned TOBT for each flight, this module allows for a very quick and yet reliable forecast on how many passengers will be at the gate on time and when the EPGT can be expected.
Figure 51: Structure diagram of the PaxMan forecast model

The system dynamics simulation is operated as a service and automatically reacts to flight plan updates. As soon as an update is filed to the PaxMan, a new forecast run is triggered in order to check the differences and consequences. The new estimates are also based on the current status of all landside systems, resources and passenger status. The most important source of information is the PaxRadar (see 2.1.5.2) and the Security Agent (see 2.1.5.4) from which the actual resource planning is acquired.

The main synchronization value with airside processes for the forecast module is the TOBT, which is used as a basis. If a TOBT does not yet exist, the SOBT is used instead.

2.1.5.8 Flight Information Display System (FIDS)

The FIDS employed in TAMS is a Siemens product in use, e.g. at Stuttgart Airport. The system was adapted to TAMS' needs and combined with the integration platform. A FIDS is at the core of an airport's dynamic passenger guidance. Appropriate FIDS displays are installed at dedicated locations inside the terminal building. Generally arriving and departing flights are presented there, often together with check-in counter, boarding gate and baggage reclaim information.

Advanced FIDS solutions supplement this basic flight information with additional signage for travelers, for example, to direct transfer passengers to the connecting gate or to provide more timely information (gate opening time, next info time). But in any case, the accuracy and reliability of all FIDS information depend on the process quality of its data sources.

With TAMS, more precise information is available to the passengers through FIDS. If, for example, reliable gate opening and boarding times are provided to the passengers, they may spend more of their idle time in restaurants or shopping areas, thus increasing the airport owner's non-aviation revenues. Last-minute gate changes are avoided with passengers hurrying to the new gate and arriving too late or even not at all.

Taking into account additional information from the TAMS context, even more benefits might be achieved:

- Current queue lengths and resulting waiting times at various checkpoints can be taken into account for dynamic passenger guidance, which helps level out the throughput of all checkpoints.
- Critical flights that depart shortly can be allocated to a fast lane at the checkpoints. As a result, these flights will not be delayed further by passengers who are stuck in the queues.
Having more information about a passenger, for example if he or she has already passed some checkpoints, unnecessary waiting times can be avoided. The gate can be closed earlier if there is no chance that missing passengers will show up.

The route taken by passengers through the airport is changing. Passengers become increasingly an active part of business processes. Enhanced security measures require the active participation of passengers. Only well-informed passengers can effectively support lean and fast processes.

2.1.6 Pre-tactical forecasting and planning

Two types of APOC tools – forecasting and automatic planning – were developed by Siemens.

2.1.6.1 Airport Performance Management (APM)

Airport Performance Management (APM) is a forecasting tool to enable proactive airport management. It analyzes the recent past and the current situation, and based on this information makes predictions for the next hours.

The APM covers different levels of information aggregation holistically and consistently, as described in the original TAM concept.

Process level data for each rotation are the foundation of the APM. In a configurable time window, the APM creates, maintains and deletes process chains for each arrival-departure pair. The process chain contains the classical schedule information like SIBT and SOBT – as well as calculated pseudo-schedules for all other processes (like a STOF, Scheduled Time Over Fix) (cf. SEAT concept described in Figure 6).
In addition, the APM calculates normative target times for all processes. As such, an analysis can be made to uncover the reasons for a delay. A proper distinction between an imported delay and an airport-caused delay is possible.

A straightforward traffic-light concept guides the user’s attention to the critical process time deviations. Green, yellow and red are self-explaining; white stands for “too early.”

As the APM contains models for all individual processes, the holistic chain is maintained for each flight. Special processes such as de-icing and pushback are integrated as well. In general, the same principles are applicable to passenger processes.

The APM has a data hierarchy that is able to cope with manual data input (usually highest priority), automatic messages and tactical XMAN data. Therefore, it integrates the whole chain – from entering the Terminal Maneuvering Area (TMA) up to leaving it. Whenever airport operators want to improve data quality for a certain process, they can do so by integrating, for example, an AMAN for the arrival process.

In order to allow for a drill down into turnaround details for diagnostic purposes, an interface between APM and several TMANs (several ground handling companies at one airport possible) was designed based on the well-standardized XPDL language.

In contrast to simple process considerations, on a flight-by-flight basis the APM is also capable of analyzing the traffic flows with capacity-demand-mismatch analyses. This function is based on the technology transfer know-how obtained from DLR. The APM calculates the impact of insufficient capacity to the individual processes (cf. Figure 54).
To effectively support APOC agents in their decision-making processes, a what-if feature was added to the APM. The agent can enter hypotheses on the future of arrival and departure rates, and the APM instantaneously provides an overview, as in Figure 55, of the impact on the process chains of all flight rotations.
Finally, the APM makes an online calculation of numerous KPIs relating to traffic. This important information is displayed on a video wall to enable performance-based management in an APOC environment. Figure 56 shows how the APM displays a configurable number of KPIs like punctuality, throughput, passenger waiting minutes, etc. in a spider diagram for the last hour, the current hour, and the upcoming hours. Furthermore, the main constraints affecting airport operations are presented. The sequence of green, yellow and red boxes visualizes how the additional dwell time of the airport will evolve.

Discussions with potential users showed that flight information and processes need to be displayed graphically, e.g. on a video wall. Therefore, solutions were developed to make full use of the geographic information systems (GIS) included in the integration platform. It turned out that it is relatively simple today to visualize airspace and the ground situation using GIS (cf. Figure 57).
2.1.6.2 User Driven Pre-Tactical Sequencing (UDPS)

The UDPS developed by Siemens is a derivative of the TOP. The traffic prognosis developed for the APM is re-used to have a do-nothing baseline overview of the predicted situation. This do-nothing solution is calculated for a configurable time horizon of several hours up to a few days.

It is presented to the airspace users with a special GUI. They can therefore see where they are in the queue and what delays they will most likely experience. The airport maintains the full overview; the airlines only see their own flights and perhaps those of their alliance partners. The flights of competing airlines are kept anonymous.

A collaboration mechanism between the airspace users moderated by the airport is a permanent task. While time is running, airlines can shuffle their own flights (in coordination with the network, of course), cancel flights if absolutely necessary, and implement optimization proposals from the UDPS.

All activities that an airline operator can perform are linked to a bonus/penalty system. In cooperation with a large airline and in parallel with the TAMS project, detailed gaming rules are under further scientific investigation.

2.1.7 A unique integration and test environment at DLR

The integration and test environment consists of two main components. The first is the full airport process simulation suite, and the other is the hardware setup for the integration. For this purpose a local network has been set up, completely separated from the DLR company network and with VPN access for all partners. This made testing and integration very efficient, as partners could access their systems – which were physically located at DLR in Braunschweig – from their own offices. Integration tests were mainly conducted via teleconferences and only milestone testing events required the physical presence of all partners in Braunschweig.
The entire system has been installed in DLR’s Airport Control Center Simulator (ACCES), which provides a number of operator working positions and a large video wall to ensure common situational awareness. For TAMS demonstrations the operator working positions were connected to the partner systems, and a selected set of displays was linked to the video wall using DLR’s video wall management system and following the ideas laid out in the HMI concept document developed in the project.

The other main component of the test and integration environment is a simulation suite capable of replicating all relevant processes at the airport. The main processes are the flight operations (arrival, taxi and departure), the turnaround process and the passenger movement through the terminal. For all of these processes previously existing simulation components were re-used, adapted to the project’s needs and extended where necessary. The main tasks were linking these components together to an airport simulation suite and allowing fully automatic simulation runs. Here the simulation followed the output of the tactical planning tools. This is normally done by human operators, i.e. by ATC agents and pseudo-pilots controlling the flights. For the TAMS validation these human operators had to be simulated. The result is a truly unique simulation suite that is capable of delivering traffic following the planning outputs (arrival and departure sequencing, etc.) of the tactical tools. In a full TAM suite, where the tactical tools are also coupled with pre-tactical planning, pre-tactical planning result also have to be simulated automatically.

The following paragraphs detail the main simulation components.

2.1.7.1 Arrival, taxi and departure processes

The simulation of aircraft movements (arrival, taxi, departure) is performed by NARSIM, an air and ground traffic simulator developed by the National Aerospace Laboratory of the Netherlands (NLR). This simulator has been adapted to allow a completely automatic controlled traffic flow. Special procedures, e.g. for holding patterns, have been developed. The main challenge was to automate the tasks normally performed by ATC agents and pilots. For the arrival process this required that the simulation ensure on-time arrival of incoming flights based on planned landing times specified by the Arrival Manager (AMAN). This has been achieved by using DLR’s research AMAN to simulate the ATC agents. Normally the human controller would give commands to the aircraft to establish the desired sequence and landing times. DLR’s AMAN contains a very precise 4–D trajectory predictor and is capable of generating command advisories that can help controllers to achieve a higher landing time precision. For TAMS, the DLR AMAN was fed with the Estimated Landing Times (ELDTs) calculated and planned by Barco Orthogon’s AMAN, and the command advisories were computed to achieve the landing times fed directly into the simulator. This approach resulted in landing time errors of typically just a few seconds.
For the taxi and departure processes the human controller function was implemented in the Surface Manager (SMAN) developed by ATRiCS. The ATC autocontroller module developed for this purpose generates taxi commands and computes taxi routes, which the simulation can then follow. Conflict situations are avoided by a stop-bar system, which can also be switched on/off via commands by SMAN. These commands cause the simulated aircraft to halt or continue the taxi procedure.

### 2.1.7.2 Turnaround processes

The turnaround process is simulated by TAMODES, a simulation module developed in house by DLR. TAMODES is programmed in MATLAB/SimEvent and models the turnaround process in form of an event-based simulation. For the TAMS project the underlying process model was carefully aligned with the model used by the partner INFORM in their Turnaround Manager (TMAN). Special interfaces were designed so that TAMODES can communicate with TMAN directly, although TAMODES has been seamlessly integrated into the simulation environment. However, this allows TMAN to have some direct influence on the turnaround process (e.g. quick turnaround for specific flights).

Within TAMS trials, TAMODES was used in two modes of operation: The first is the real-time simulation, which simulates the turnaround process steps as they occur. This simulation sends actual process start and end times to TMAN, which keeps track of the turnaround process and can show warnings if delays occur. The turnaround process for a given flight is started when TAMODES receives the actual in-block event from the simulation. An important part of the turnaround is of course the boarding process.

Here the passengers (PAX) are simulated by the TOMICS simulator, described in the following section. It was decided that all communication between TAMODES and the
passenger simulation be routed over TMAN, as TMAN needs this information and it allows TMAN to terminate the boarding process when passengers arrive too late. When the aircraft is ready for boarding, TAMODES sends a boarding start event to TMAN. This event is forwarded to the passenger simulation as well, and the passengers move from the gate area into the airplane. The passenger simulation continuously informs TMAN of the number of boarded and missing passengers. When all passengers have boarded, TMAN sends a boarding completed event to TAMODES, which then completes the turnaround process and sends an aircraft ready event back to TMAN.

This implementation allows an automatic algorithm (required for the validation experiments) that terminates boarding when passengers are too late. A set of rules and criteria has been defined to decide when to abort boarding, providing a simple version of an airline agent’s handling behavior.

The second mode of operation is a prediction mode. Here TAMODES computes estimated process start and end times, looking several hours ahead into the future. These estimates simulate ground resource management systems connected to TMAN. Hence TMAN can make use of high-quality prediction of the turnaround processes and take limited resources into account.

The DLR GAP (Gate Allocation Program) stand and gate management tool was integrated into the environment to dynamically allow for stand/gate planning and re-planning.

ATRiCS supported the DLR test environment with an ATC autocontroller including the functionalities of automated routing, clearances and stop-bar switching.

2.1.7.3 PAX processes

The DLR test environment comprises a comprehensive and detailed simulation of all relevant landside processes with a focus on the passenger. This also includes the arrival pattern differentiated by the mode of transport used to reach the airport. Thus there is an interface where varying conditions in ground access (e.g. a delayed rail connection or a traffic jam on the freeway) can have an immediate effect on the simulated airport terminal processes.
TOMICS simulation software was used to model passenger behavior on the airport landside. This software was specifically developed by DLR in order to model individual passenger movements in transport nodes in a so-called microscopic simulation. A number of improvements were needed to meet the requirements of the PaxMan system. This simulation runs in the background and communicates only with newly created tools. This ensures an easy migration path from an experimental environment to reality.

For TAMS a specific model was set up by means of an elementary structure of components from Hamburg Airport and Stuttgart Airport. All passenger movements are simulated by a permanent time-step-related calculation of direction and speed as well as the assessment of likely conflicts in a defined space.

The TOMICS integrated SensorSim tool was set up and used to simulate state-of-the-art sensors to get information about traffic flow and emulate the imprecise information provided by today’s sensors in a real environment.

To ensure communication between airside events like gate changes etc., to initialize passenger simulation and to synchronize air and landside simulation, another tool called RealSim Connector was developed. This tool scans events in the PaxMan database and translates them into adequate instructions for each simulated “person.” When during simulation a passenger passes a process step, such as a check-in counter, a security lane or a terminal gate, the tool reports such events back to the PaxMan database.

Main links into the airside processes are established with the Stand and Gate Manager (SGMAN), where gate allocation needs to be synchronized with the passenger flow, and with the TMAN, where the TOBT is adjusted also according to the passenger status.
2.1.8 Key TAMS results

2.1.8.1 Use cases and benefits for different stakeholders

As a basis for the development of functionalities and systems to enable the implementation of a Total Airport Management System, the TAMS operational concept document (OCD) was created under the lead of DLR. The TAMS OCD [2] promotes a new airport management philosophy, whereas the project’s approach for this philosophy is presented from a high-level perspective. Furthermore, it includes a description of how the various systems of the TAMS partners interact to build the TAMS industrial variant of the depicted approach.

In addition to the TAMS OCD, an assorted selection of operational scenarios and business use cases [3] were prepared to explain in more detail the application of the industrial tool suite within this new management philosophy. To demonstrate in practice the functionality of the TAM concept elements, the operational scenarios exemplarily highlight different situations that can occur during everyday operations at an airport. The selected scenarios exemplify a variety of events at an airport occurring ad-hoc or already predicted in advance – on the landside or airside – during everyday operations or under special circumstances and with an impact on all airport processes. The operational scenarios set the framework for selected scenarios, providing a sketch of the situations and the views of how the situation might develop. To get a brief glimpse of the described and mostly known situations, all descriptions are exemplified with the project’s Generic International Airport (GIA). Each scenario includes a comparison between the management of the respective situation with and without the TAMS solution employed. As such, the benefits of implementing a TAMS industrial system suite can be derived.

How – in this case the GIA’s – operators and stakeholders will solve specific operational problems, as described with the operational scenarios, is presented with an additional level of detail in the business use cases. Business use cases are a series of interactive steps either between humans or between a human and the corresponding TAMS APOC support system. All business use cases are linked to several operational scenarios and provide detailed information on how TAMS components and procedures enable problem solving.

The following operational scenarios have been created [3]

- CLOSED TERMINAL AREA
- DE-ICING AND WINTER SERVICES
- CAPACITY DEMAND BALANCING
- CLOSURE OF NEIGHBOURING AIRPORT
- STRIKE (ENTRY AND EXECUTION PHASE OF STRIKE)
- RECOVERY SUBSEQUENT TO STRIKE (RECOVERY MANAGEMENT)
- QUALITY OF SERVICE

These have been complemented by the following business use cases [3]

- UPDATE SERVICE LEVEL AGREEMENT
- PLANNING OF CAPACITY FOR DAY OF OPERATION
- MANAGEMENT OF AN ADDITIONAL ARRIVAL FLIGHT
2.1.8.2 Selected results of the TAMS validation campaign

The TAMS project has defined a set of validation goals and hypotheses, following the E-OCVM. During the project goals have been refined and adjusted, according to the project’s progress and orientation.

The focus of the validation campaign was on the assessment of the benefits of the coupled airside and landside assistance and management applications that were developed within the project.

Therefore, the system behavior with all coupled applications was compared with a baseline setup. In real-time, unmanned simulations that have been conducted in the DLR ACCES APOC simulator environment, the human influence was eliminated by including automated decision-making processes. Several scenarios that include airside and landside bottleneck situations (e.g. passenger security screening, arrival and departure peak exceeding available capacity) have been used.

All activities concerning TAMS validation are documented within the TAMS Validation Concept Document [5] and the TAMS Validation Report [6]. Only the management summaries of the results in these documents will be presented.

The results show a comparable amount of handled traffic while retaining to a realistic level of slot compliance. The performance indicator “Readiness Punctuality” (deviation of the actual ready time of an aircraft against the scheduled off-block time) showed a statistically significant reduction of about 112 seconds on average for each flight. This seems to offer an opportunity to reduce buffers and potentially increase the utilization of an airport’s capacity.

Due to the coupling of airside and landside systems, the number of departures suffering delays greater than 15 minutes was significantly reduced. Due to the master-slave behavior of arrival and departure management, no statistically significant difference with arrival traffic was observed.

A central goal was to reduce emissions by coupling planning and decision support applications. A central performance indicator to show this effect is the engine running time (total amount of time the engine of a departing aircraft is kept running after going off-block and before takeoff). A statistically significant reduction in the overall engine running time by an average of about 32 seconds for each flight was measured, proving that less fuel consumption and fewer emissions can be realized.
Additional performance indicators such as waiting time at runway, which refers to the time a flight spends waiting with engines running at the runway holding position and until takeoff, and off-block waiting time, or waiting time at the stand or parking position without engines running, are used to support the results.

A statistically significant decrease of the waiting time at runway of about 35 seconds on average per flight, and a statistically significant increase of the off-block waiting time of about 53 seconds on average per flight, further prove the expected shift of the waiting time from the runway/taxi way system toward the stand or parking position.

Beside these improvements in flight handling on the airport airside, the number of passengers catching their flights on time was significantly increased statistically from the already high level of 90.6 percent to 97.3 percent.

With the obtained results it was possible to confirm the main validation hypotheses and prove that the TAMS solution subjected to the validation trials has the potential to deliver benefits for all stakeholders involved.

2.2 Financial summary

The total project budget of the TAMS project and the share between the partners was agreed upon when the project started. The overall budget was not fully utilized due to constraints in the participating companies and requests from the funding organization. Though significant budget cuts compared with the initial quotation were taken, all main goals of TAMS were achieved. In detail, some aspects had to be streamlined and reduced in their planned extent to cope with these changing constraints. The extension of the project duration also contributed to efficiency gains because dependent work packages could be executed sequentially.

2.3 Implementation perspectives

The TAMS implementation perspectives are considered solid. All industry partners will undertake subsequent marketing and sales efforts to bring TAMS results into real-life solutions at airports. The implementation of A-CDM is ongoing worldwide and is paving the way toward TAMS while establishing the prerequisites like a collaboration culture between airport stakeholders.

Furthermore, there is a certain consensus among the TAMS partners to jointly address the market, as a full team or as sub-teams.

Leading world airports like Dubai International Airport have already announced their intention to go for TAM in order to make full use of their scarce airport resources. In Europe as well, the big hubs appear to have plans to install TAM concept elements like central APOCs.

2.4 External progress for state-of-the-art solutions

Obviously the world around TAMS did not stand still for the last three years. It can be observed that the TAM concept gained significant momentum. A TAM symposium organized by HOCHTIEF AirPort in Budapest recently has shown that more and more airports and airlines (!) are embracing the TAM idea. On the R&D side further initiatives were started. The SESAR project is now taking TAM into account and is expected to make use of the TAMS results in order to not reinvent the wheel. Senior managers convinced by TAM are passing the idea on to young professionals.
2.5 Dissemination of results

Considerable efforts were made by all TAMS partners to make other researchers and users aware of the TAMS projects and of preliminary results:

- Several press releases were published
- Presentations were given on several occasions (e.g. ATCA 2009, ATC Global 2009 and 2011, INFORM GroundStar User Conference 2009, A-CDM Coordination Group Meeting 2010 at EUROCONTROL headquarters in Brussels, HOCHTIEF AirPort TAM Symposium in Budapest 2012, PTE2012 in Vienna)
- A TAMS website was maintained (www.tams.aero) by DLR
- A scientific TAMS conference including a demonstration was prepared for PTE2012 (but reduced to a demonstration due to budget constraints)
- ATC global was used in the years 2009, 2010 and 2011 to interact with others
- The Siemens Airport Center was used to present TAMS aspects to users
- A final meeting including a demonstration was conducted

A mobile TAMS demonstrator was set up by all partners using the Siemens Airport Center as a workbench. The mobile demonstrator gives an example what a TAMS APOC could look like. Working positions for airport, ATC, ground handling and airlines were created. A video wall was configured to show typical TAMS content. The TAMS integration platform runs in the background and connects all systems.

Figure 60: TAMS results and a technical demonstration at PTE2012
3 Project success assessment

3.1 Contribution to political goals

The TAMS R&D project definitely strengthened the position of the involved industrial players, as they are now in a position to bring new concepts, features and systems into product development or directly into a customer’s development projects. The involved industrial companies can either bring their contributions to the world market individually, as sub-teams or as an overall TAMS team. This is a way forward for Germany to play a leading role in the delivery of IT solutions for airport operations management.

Furthermore, added value was created in terms of new validated concepts. The efficiency and quality of airports can be improved by TAMS. TAMS seems to be technically and operationally feasible, though it is recommended that further validation studies be done to understand the full potential of TAMS.

DLR again has proven to be the leading European R&D organization capable of contributing to novel operational concepts and providing integrated airside and landside simulation environments where industry partners’ systems and DLR’s own research ideas can be tested efficiently.

For Stuttgart Airport as well, the TAMS project was a success: insights into the latest R&D trends were obtained and checked against already existing business processes and IT systems.

On a European scale, the TAMS results should be carefully considered in the context of SESAR.

3.2 Scientific and technical results

First of all the TAM concepts, published by DLR and EUROCONTROL a few years ago, have been substantiated. The derived TAMS concepts (operational and technical concepts) are now more down to earth and viable from an industrial perspective. The TAM concepts therefore pave the way for a quick implementation of TAMS.

It has been shown that TAMS can be built based on existing industrial systems that are already in use all over the world (e.g. XMAN). These systems only need to be upgraded to be used in TAMS. It is also necessary to integrate these systems properly with a TAMS-capable platform as well as some additional novel subsystems (e.g. APM, APOC video wall).

The technical feasibility of the TAMS approach has been proven by all the prototyping and integration efforts. A TAMS system, consisting of about 15 subsystems, has been integrated in a three-year R&D project.

TAMS has also created a TAM validation concept following the standard E-OCVM processes. The validation itself showed that TAMS provides benefits in terms of punctuality and passenger connectivity. Taxi times are shortened and the time with idling engines in aircrafts is reduced. As these results were already obtained in a midsize airport scenario with moderate traffic demand, it can be expected that the gains are even greater in more complex airport scenarios.

3.3 Implementation plans

All industry partners offer their products and expertise on the world market. Interested customers should get in touch directly with the partners’ sales contact.
If customers are interested in obtaining a more or less full TAMS solution, whether for an existing system or for a completely new implementation, the TAMS consortium is capable of implementing a TAMS solution worldwide, led by Siemens as the general contractor.

If further R&D studies based on the TAMS results are desired, DLR is the right point of contact; DLR would potentially coordinate such activities.

3.4 Lessons learned during the project

Obviously many lessons were learned in the three-year TAMS project. First of all, a more streamlined plan would have benefited the very ambitious and complex project. The overall goal – to arrive at new concepts via the development of industrial systems and the outcome of validation results – was too comprehensive for a three-year project. It would have been better to have a five-year program with clear project steps and sufficient time in between for thorough review and plan revision.

Furthermore, it would have been better to have more user involvement – from airports, airlines, ground handlers and ATC. Though the TAMS team received excellent support from Stuttgart Airport, further input from other stakeholders, such as from airports of different sizes and perspectives, would have been valuable.

An approach that was successfully carried out in the EMMA project within the EU FP6 program included several test sites. A team of users and industry partners applies a prototypical implementation at each site, following a joint concept and test plan, but with different industrial approaches. It would be advisable to revert to such an approach instead of implementing solutions from all industrial partners at a single site.

3.5 Presentation possibilities for potential users

TAMS developed a large-scale mobile demonstrator that was featured for the first time at the Passenger Terminal Expo 2012 in Vienna. This demonstrator can be used to demonstrate – and possibly to evaluate – TAMS at customer sites. The demonstrator can be moved to further exhibitions, too. With a bit of effort the demonstrator can be adapted to other airport scenarios.

The TAMS mobile demonstrator started small with a TAMS demonstration system that focuses on the tactical planning systems developed by ATRiCS, Barco and INFORM. It has been shown on several occasions with positive resonance from airport stakeholder experts.

Some TAMS documents have become public documents, which are made available for interested parties. Upon request, presentations of concepts, implementations and results can be obtained.

3.6 Adherence to cost and time plan

The overall project stayed in the total cost plan and most of the partners kept within their budgets. The project started with a letter of intent and a slow phase in the first year until all contracts could be settled. Therefore, it is a bit difficult to compare the course of the project with a time plan. In contrast to what was stated in the letter of intent, the TAMS project duration had to be extended by one year. According to the official funding notice, the project was concluded on time.
4 Project fact sheet
see extra document attached
## 5 References

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