TOTAL AIRPORT MANAGEMENT
(Operational Concept & Logical Architecture)

Version **1.0**

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Total Airport Management

DLR

TAM Document

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1. Executive Summary

Airports are seen as constraints to growth in the future air transport system. In the context of a doubling of traffic by 2020, increased investment, development and research will be needed to support continuous improvement in airport throughput, efficiency and punctuality with continued safety considerations. Airport processes must be fully integrated within the Air Traffic Management (ATM) system and capable of interacting with other system components in order to be aware of the priorities of aircraft operators and the constraints of the air transport network in order to optimally fulfil the airspace users' needs when making decisions.

As a first step towards this evolution, all essential airport processes from passenger check-in to aircraft turn-round must work collaboratively with the common goal of ensuring that each departure meets its agreed 4D-trajectory. Agreement between air and ground on the 4D-trajectory, based on precise target take-off and target arrival times, not only increases the efficiency of the ATM system but also that of the airport itself.

Airports are the nodes of the air transport system. A performance-based airport is needed as a pre-requisite for a future performance-based ATM system. Therefore future concepts aim at an integrated airport management, where all major aircraft operator, airport, aerodrome ATC and ground handling processes are conducted using a single data set. This is embodied in an Airport Operations Centre (APOC) where operators constantly communicate and co-ordinate, develop and maintain dynamically joint plans and execute those in their respective area of responsibility. Different possible APOC-implementations are expected, ranging from a distributed virtual APOC to a high-tech physical APOC, even with new operator roles.

The core information basis of Total Airport Management is the Airport Operations Plan (AOP). The AOP is firstly an en-route-to-en-route-conversion of the Network Operations Plan (NOP), enriched by airport specific data. It ranges from agreed airport performance targets, hard and soft constraints of the different stakeholders to a detailed event-resource-usage description enabling the airport to be operated as a time-ordered system. Different implementation options of the AOP exist, ensuring as well the commercial interests of the stakeholders. As the AOP is for sure a result of a dynamic and repetitive layered planning process of several stakeholders, sufficient processes have to be designed to efficiently (and effectively) achieve this joint plan. The APOC facilitates the generation, discussion, commitment to and maintenance of such an AOP. The processes outlined in this document for an APOC are based on some proven principles of distributed complex C^4I (command & control) system approaches.

The TAM approach integrates existing optimisation support systems. These have been developed in the past to assist the human operators in their individual workflows. E.g. arrival, departure and surface management tools have already demonstrated that they can lead to improved safety and efficiency. But it is only when they evolve from today's situation where they act as individual support tools and become components of an integrated airport information architecture that they can act as holistic decision-support tools for all airport partners.

This document, which is the result of a joint initiative between DLR and EUROCONTROL, is to be seen as the initial definition of the Total Airport Management (TAM) operational concept and the logical architecture of an APOC in the future. Compatibility with previous and ongoing work in DLR and EUROCONTROL is ensured where possible. It is envisaged that the initial concept will be further developed and validated, e.g. by performing human-in-the-loop simulations within SESAR or in related activities. Stakeholder feed-back is more than welcome!

2. Introduction

2.1 Purpose of the document

Airports are seen as bottlenecks of the future air transport system. DLR and EUROCONTROL have been leading many R&D activities that have led to significant improvements of the safety, throughput, weather independence and efficiency of airport operations. Samples are A-SMGCS, XMAN, CDM, etc. On this basis a joint initiative was started in spring 2006 to develop the initial operational concept of future airports, integrating all the previous work into one holistic approach – called Total Airport Management. The operational concept was shaped in several workshops making use of results of previous work like the CARE innovative study on TAM, the OATA work, the C-ATM / K-ATM[1] work and the CDM Task Force. This document summarises the findings of the joint initiative between DLR and EUROCONTROL. It will be seen as actual definition of the Total Airport Management (TAM) concept. It is envisaged that this concept will be further developed and validated by performing human-in-the-loop simulations e.g. in SESAR and Episode-3. Feedback from airspace users, airports, ANSPs, industry, academia and other organisations is highly welcome!

After an overview about the "Current Situation and Trends at Airports and resulting Limitations" (see 2.2) reference material for the Future Air Transport Operational Concept will be presented (see 2.3).
Chapter 3 deals with the Approach of TAM showing the reader objectives and benefits (see 3.1), the definition of the temporal and spatial scope of TAM (see 3.2) and the explanation of the methodology used to describe TAM (see 3.3). Furthermore, in chapter 3.4 "Human Centred Design", the human role in TAM will be depicted and possible implementations of TAM will be presented (see 3.5).
Chapter 4 deals with the logical and functional architecture of TAM. First ideas about the Airport Operations Plan (AOP) as a dynamic joint plan will be presented in chapter 4.1 and the dynamics of the AOP explained in chapter 4.2. The functional architecture of TAM will be clarified in chapter 4.3. whilst the operator role in an Airport Operation Centre (APOC) will be depicted as one possible implementation of TAM in chapter 4.4. The co-ordination and communication in an APOC will also be introduced in a first approach in chapter 4.5.

2.2 Current Situation and Trends at Airports and resulting Limitations

Today in many airports, operational decisions are often made with a limited knowledge of the most pertinent data. In addition, decisions by a given actor are often taken in isolation without reference to other actors who may be impacted by such decisions. Addressing these shortcomings individually brings small improvements but in order to improve the whole complex set of issues, it is necessary to follow the principles of **Airport Collaborative Decision Making (CDM).**

Airport CDM is embedded in the ATM operational concept as an important enabler that will improve efficiency and punctuality. The CDM elements have been **developed through airport trials** and are now being widely implemented at many major European Airports. Implementing CDM can take time, as often it **transforms many of the communication policies and procedures** that have historically dominated the airport operations environment changes; however, now that Airport CDM requirements are becoming standardised through the work of EUROCONTROL, IATA, ACI, EUROCAE WG69 and the European Commission and as improved data becomes available then the full effect on the network will be seen.

[1] Within the joined initiative „Kooperatives Air Traffic Management" (K-ATM, funded within the German aeronautical research programme) a consortium consisting of an airport (Frankfurt), an airline (Lufthansa), the German ANSP provider (DFS), system manufacturers (Thales, delair), Airbus and different research institutes (DLR, universities) is working on solutions towards a cooperative planning mechanism which allows an optimal use of air traffic system ressources in bottle-neck situations. The work focuses on traffic processes around the major hub airport Frankfurt.

The basic foundation of Airport CDM is to have **improved information sharing and data quality**. It is important that the **right airport partners** get **accurate data** at the **right time** in the **right place** in order for them to make decisions while working together. This will lead to a better use of resources, partners being able to make preferences, improved punctuality and predictability. The accurate and accessible data is also used for post analysis, which is an increasingly important factor in order to measure success and learn from situations.

The CDM concept is realised in the airport environment by the implementation of defined operational processes and technical systems.

Initially, flight plan information is checked against the airport slot data and correlated. Here basic errors such as matching of the flight identification, destination and aircraft type can be identified, and through the raising of alarms to the aircraft operator these errors can be corrected at an early stage.

Arrival estimates can be improved through Flight Update Messages (FUM) which are provided by the CFMU. The FUMs calculate the estimated landing time at the destination using radar and environment data and can be sent up to 3 hours before landing. The landing estimates can then be updated more accurately by local radar sources and tools such as Arrival Manager (AMAN).

AMAN builds an arrival sequence based on flight plans and radar information and assigns an absolute or relative arrival time at the runway threshold or other significant waypoints. It can predict a conflict free trajectory for each aircraft, taking into account actual runway configurations, weather conditions, and aircraft performance data, which results in an assigned arrival time.

Latest developments will include adaptation of the arrival's schedule, considering any ATC control action, even if this action deviates from the proposed plan. Furthermore, the controllers will be able to transmit to the pilot via voice or data link the appropriate trajectory and guidance instructions which include features for conformance monitoring, conflict detection, and real-time conflict resolution.

The integration of AMAN with other controller decision support tools such as Departure Manager (DMAN) and wake vortex prediction systems will provide a smooth and efficient inbound flow whilst maintaining an optimum runway utilisation and taking into account preferred aircraft operator and TMA noise sensitive trajectories.

The on-block time, which is essential for partners to be able to start to predict stand allocation and factors affecting the turnaround process, can then be calculated by adding the taxi in time to the accurate prediction of arrival time that comes from the AMAN.

The position and movement of aircraft at an airport can be tracked by **A-SMGCS** which can provide

- situational awareness to airport partners (e.g. flights often get blocked during the taxi-in phase and Aircraft Operators and Ground Handlers can see exactly where they are)
- Data such as actual landing, on-block, off-block and take-off times.
- Taxi time prediction
- Alerts, alarms, and warnings

During the **turnaround phase** the CDM Interface can show partners the progress of a flight with updates of the Target Off-Block Time (TOBT). An accurate TOBT is essential for partners to be able to plan stand allocation, pre-departure sequence and take off order. Events such as late boarding and flights that will not be able to conform to their TOBT will cause alarms to be raised prompting partners to update the TOBT.

The **departure phase** can be semi-automated using tools such as sequence planners, Departure Managers (DMAN), and Surface Manager (SMAN). Humans are still involved in the loop as they have the ability to update TOBTs and refine the sequence to meet with the current operational situation. DMAN assists controllers by

- Harmonising the operations of different working positions.

- Handling the growing number and complexity of departures, whilst also considering arrival traffic (specifically in mixed mode operations or crossing runways).
- Maintaining maximum operational runway capacity, slot compliance and minimising taxi-out delays.
- Helping to make optimum use of the available airport capacities by reducing unnecessary delays on stands, on taxiways and at departure runway holding points.
- Providing an accurate and constantly updating Target Take-Off Time (TTOT).
- Reducing the time a controller spends on planning.

A TTOT is important because it can be used to calculate and predict flight profiles. This has a big impact on the network regarding the planning of sector capacities. Until recently, accurate TTOTs have not been available to the CFMU, instead they had to use the EOBT plus an often inaccurate default taxi out time. However, the introduction of Departure Planning Information (DPI) Messages will provide the CFMU with increasingly more accurate take off estimates from -3 hours up until take-off.

At most international airports the runways are used at least temporarily in **a mixed mode operation**, so controllers have to handle arrivals and departures on the same runway simultaneously. The integration of management systems AMAN and DMAN can be achieved in two ways:

- The first one is to integrate AMAN into DMAN (or vice versa). The idea is to extend existing management systems with new functionalities, because both planning tools use the same information like flight plans and runway occupancy times.

- The second one is to add a co-ordination tool to the existing management systems. This tool is the only connection between AMAN and DMAN and receives and distributes all relevant sequence information. The idea is, that the co-ordination tool takes both sequences of the planning systems and merges them to one sequence for all runways in mixed mode operation. The co-ordination tool is not a part of one of the management systems, so different kinds of AMAN and DMAN could be connected.

Both approaches are based upon a set of rules, controlled by parameters like actual and predicted flows, aircraft types, estimated target times, runway occupancy times and weather conditions for the merging process, which regulates the arrival and departure flows. The objective of this co-ordinated connection between AMAN and DMAN is the maximum utilisation of existing runway systems, reducing number and duration of flight and ground holdings without raising the workload of the controllers at the same time.

Improved **forecasting of meteorological conditions** means that it is now easier to predict a change to the normal operating capacity of an airport and this information is used by partners working in a CDM cell to make preferences and critical decisions in order to maintain an efficient operation. These facts are being distributed more and more via specific websites or email in order to keep all partners informed.

ATM improvements over the past decade have had significant impact on reducing and/or stabilising delays due to ATC. However, since air traffic is expected to continue growing, new concepts and systems are required to avoid additional congestions and delays.

While the arguments above are valid for the ATM system as a whole, the following additional characteristics are valid to varying degrees for airports:

- A lack of collaborative tactical to strategic planning between ATM, airport planners, handling agencies, aircraft operators and national airport co-ordinators, resulting in less than optimum use of scarce airport airside capacity[2],
- Limited facilities for real-time data sharing between ATM, meteorology, airports and aircraft operators (including ground handling), resulting in inflexible responses to real-time events and changes in the users' operational requirements,
- The inability to fully exploit the potential for efficiency and capacity gains offered by modern aircraft avionics,
- Environmental limitations and requirements that can heavily impact the airside airport capacity[3],
- The long lead-times for introducing improved and/or new systems in aircraft and ATM.

To solve the mentioned problems a new conceptual approach for the planning and the controlling of an airport is needed.

2.3 Future Air Transport Operational Concept

This chapter presents the reference materials for the future Air Transport Operational Concept, focussing on the role of the airport and airport operational processes, i.e. the Airport Operational Concept.

As the overall Airport Operational Concept is already fully described in the EUROCONTROL medium-term Airport Operational Concept document [1], only a short summary will be provided below.

The EUROCONTROL medium-term Airport Operational Concept document constitutes a visionary description of airport operations for the medium-term timeframe (i.e. deployable from 2012 onwards). The future Airport Operational Concept described in this document is the result of the convergence of the OCD/CONOPS developed by OCA and the Airport Operational Concept developed by the C-ATM consortium.

The main element is the emphasis on the ATM layered planning used as the baseline for breaking down all airport operational processes ranging from the strategic phase (months ahead of the day of operations) down to the execution of the flight. This concept will address the interactions between airports, aircraft operators, air traffic management and airport operators in order to free or create airport capacity and operational effectiveness and efficiency in the interests of combating delays, increasing the level of safety and minimising cost and environmental impact.

The benefits that can be expected with such Airport Operational Concept are the following:

- Improved safety in airport operations, especially in runway operations;

- Better predictability of the overall traffic flow at all airports, so that aircraft operators can operate more reliable flight schedules;

[2] In theory, there are sufficient airports and runways in Europe to take us well into the future. However, market forces dictate the usage pattern and therefore the main airports will continue to be bottlenecks in the air transport system. The forecast traffic growth will exacerbate the congestion problem at the busiest airports which in turn will probably impact the traffic distribution pattern. Regional airports are becoming more important in this process. So, congestion may well spread to airports where this problem does not yet exist. This, if not addressed in time, will further upset schedules, degrade the service to the travelling public and have additional environmental impact.

[3] Environmental considerations become increasingly important in airport operations & Air Traffic Management (ATM) changes. Advances have been made in ICAO Standards leading to reduction in new aircraft noise and emissions. However, more advanced ATC procedures, flight operational techniques and in the longer term new infrastructure and technology are required to minimise noise and emissions to the absolutely unavoidable. However, even this will not provide the solution when they are not combined with efficient land-use planning around airports and long-term national and regional/communal strategies to safeguard both the economic and the environmental interests of society.

- Optimised arrival and departure rates at all airports in respect of their specific airside infrastructure, so that constrained airports will be able to function at optimum throughput for long periods;

- Sufficient flexibility to accommodate real-time events in day-to-day airport operations with minimum effect on these operations;

- More efficient arrival and departure flows at major airports through systematic application of current best practices, agreed “new procedures” and new technology;

- Environmentally suitable and acceptable operations.

Total Airport Management is an airport-implementation option for this future Air Transport Operational Concept.

3. Total Airport Management Approach

Total Airport Management (TAM) considers the airport holistically as one node of the overall air transport network (Figure 3-1). In order to ensure an overall Quality of Service (QoS) of an airport to the customers and to the air transport network, TAM concentrates on the initial strategic and pre-tactical planning phases using the most accurate information available, followed by the monitoring (and when required, reactive planning) of the tactical working process.

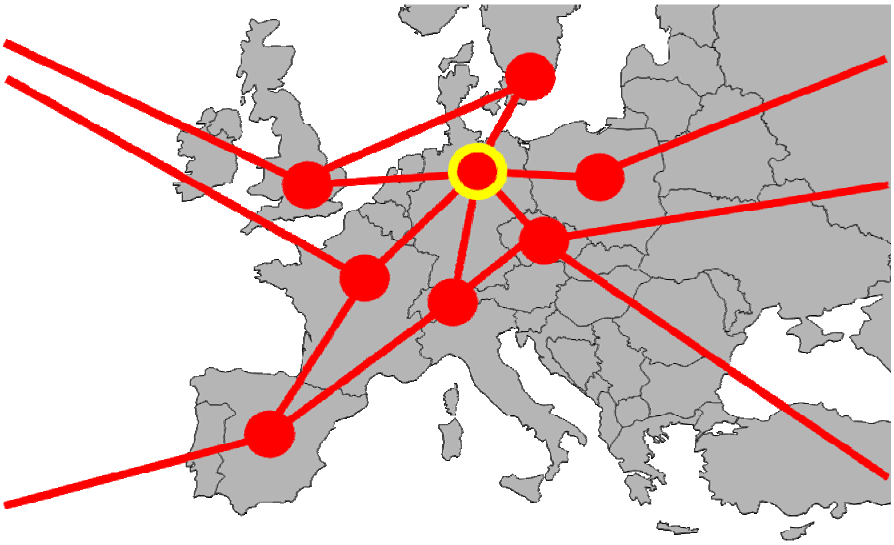

Figure 3-1: A schematic view of the air transport network in Europe

3.1 Objectives and expected Benefits

As TAM is part of the Future Air Transport Concept mentioned in 2.3, it also contributes significantly to the benefits described. In detail, the following main objectives and benefits are expected from TAM:

Objectives:

- More dynamic and more responsive ways to incorporate priorities of customers – the airspace users - and a fair and transparent means of handling competing interests at one airport
- Performance-based airport operations in order to enable a performance-based ATM system
- Improved predictability of the behaviour of the system “airport” within the air transport network, i.e. increased prediction look-ahead-time and reduced variability of schedules compared to today, in order to give the network more time to pro-actively manage the air transport and to become more stable and robust.
- More equal performance of different airports with respect to each other, measured by one common set of performance indicators, the airport to agree with other stakeholders and the ATFCM on a guaranteed QoS with respect to these indicators – a QoS Contract (QoSC).
- TAM to provide ways to handle degraded situations in the most appropriate way to ensure that the QoS is fulfilled as far as possible

Benefits:

- Due to improved predictability available resources might be used in an optimised way and overcapacities can be reduced or prevented.
- Situational awareness of predicted events will increase customer satisfaction (aircraft operators and passengers).

- Better understanding and more transparency of co-operative negotiation and decision making for all stakeholders can be expected.
- Conflict solutions with better acceptance by the different stakeholders are possible.

It has to be stated clearly that this QoS contract does not imply a certain way of implementation, organisational structures or technical support systems to the individual airport. It is completely up to the airport how to ensure the QoS contract with the network, so a huge variety of implementations of TAM will be possible – ranging from working with a pencil and a sheet of paper at very small airfields, to the installation of a command and control centre type facility with huge computer support for a large airport.

The general task of Total Airport Management is to break down the promise to the network, the QoSC, to individual activities of all the stakeholders, actors, operators and individuals.

3.2 Scope

The execution of decisions at the ad hoc level is not part of TAM. Due to time and competency enforcements, ad hoc decisions are and will be made in the Operation Centres, but the outcome of these decisions have to be taken into account in TAM (see Figure 3-2). The extension of TAM is limited to one single airport but with influence on other TAMs, other airports, and the whole ATM.

TAM also gives the opportunity to realise a new way of communication. The stakeholders will get an impression about the processes and problems of other stakeholders and will be aware of upcoming problems concerning different external circumstances (e.g. weather conditions). In a CDM process they will work and decide together about solutions and depending on the airport, decisions will or might be made in a kind of central "head office" or decentralised system (see chapter 3.5). Further the concept of TAM will enable the development of automated planning tools to help the stakeholders in achieving a better level of performance. The scope of TAM can be described in different ways, in a temporal and a spatial way.

In a temporal scope TAM extends from the strategic phase down to the pre-tactical and tactical phase (see Figure 3-2). In this figure the red dashed TAM-line expresses the temporal range of TAM while the APOC (Airport Operation Centre – see chapter 3.5) depicts a physical realisation in the strategic, pre-tactical and partly tactical phase. The ATC operation centres existing today, aircraft operators etc. work mostly only in a tactical time horizon.

Figure 3-2: Hierarchical view of centres and actors within their appropriate time window

Definition of the strategic phase
The strategic phase encompasses the time horizon of planning tools that work on the performance and the flow level only and have only assumptions (normally based on experience) available for the planning of the air traffic (schedules). Today the strategic phase typically starts after the slot conference and ends seven days before the event.

Definition of the pre-tactical phase
The pre-tactical phase encompasses the time horizon of planning tools that work on the performance, flow and event level making use of early estimates of parameters such as meteorological and potential capacity shortfalls whilst taking into account the predicted state of the air traffic (schedules and estimates). Today the pre-tactical phase typically encompasses the time from seven days before the event until the start of the tactical phase.

Definition of the tactical phase
The tactical phase encompasses the day of operation up to the ad hoc level (see [1]). This phase makes use of detailed weather and other pertinent operational information, whilst taking into account the most recent information relating to the state of the air traffic (schedules, estimates and actual times). TAM does not encompass the time horizon of planning tools that work solely on the event level (e.g. AMAN, DMAN, …) and create managed (automatically planned) times for events. These times are used as fixed events for further calculation of management processes.

In the **strategic phase** the detail of information for planning is lower (compared with the pre-tactical and the tactical phase) and results in a rough planning of a future flow according to the time schedules of the flights and the known capacity under "normal" circumstances (twice a year at the IATA Schedule Co-ordination

Conference the average capacity of the runway system will be used for the co-ordination of arrival and departure times). In this phase several scenarios might be developed in advance of changing constraints, such as wind direction, bad weather, early arrival of trans-continental flights etc.(due to experiences).

Due to further information in the **pre-tactical phase** e.g. about the weather activities might concentrate on the development of strategies and predefinition of performance and flow targets. These activities will depend on the quality of data, predictability and probability of occurrence of events.

With the approach of the flight event (**tactical phase**) planning activities might be intensified and become more precise caused in the increase of the quality of information. In advance of e.g. capacity shortfalls flights could be speeded up, decelerated, temporarily held at the departure airport or as a last resort be cancelled. But at the same time the variability in planning decreases with the decrease of possible influences on certain flights. In this phase as well the Operation Centres of ATC, Aircraft Operators, Airport and independent Ground Handler (if available) are mainly involved.

Figure 3-3 describes the spatial scope of TAM. Depending on the quality of data predictability and probability of occurrence of events, as mentioned above, the horizon of TAM might be stretched to the en-route area and - especially by taking short haul flights into consideration - also to surrounding departure airports. Therefore the connection and potentially the overlapping responsibilities between TAM and ATM need to be determined. Landside operations such as check-in, security check etc. have a direct influence on airside operations. Late passengers due to operating delays may lead to deviating boarding times, as may events such as the closure of a Gate or of parts of the Terminal (e.g. due to unattended baggage) influence operations at all.

Landside operations are part of TAM in order to cope with the influence on airside operations. This document does not yet cover this, but it will be addressed in a later version of the TAM-OCD.

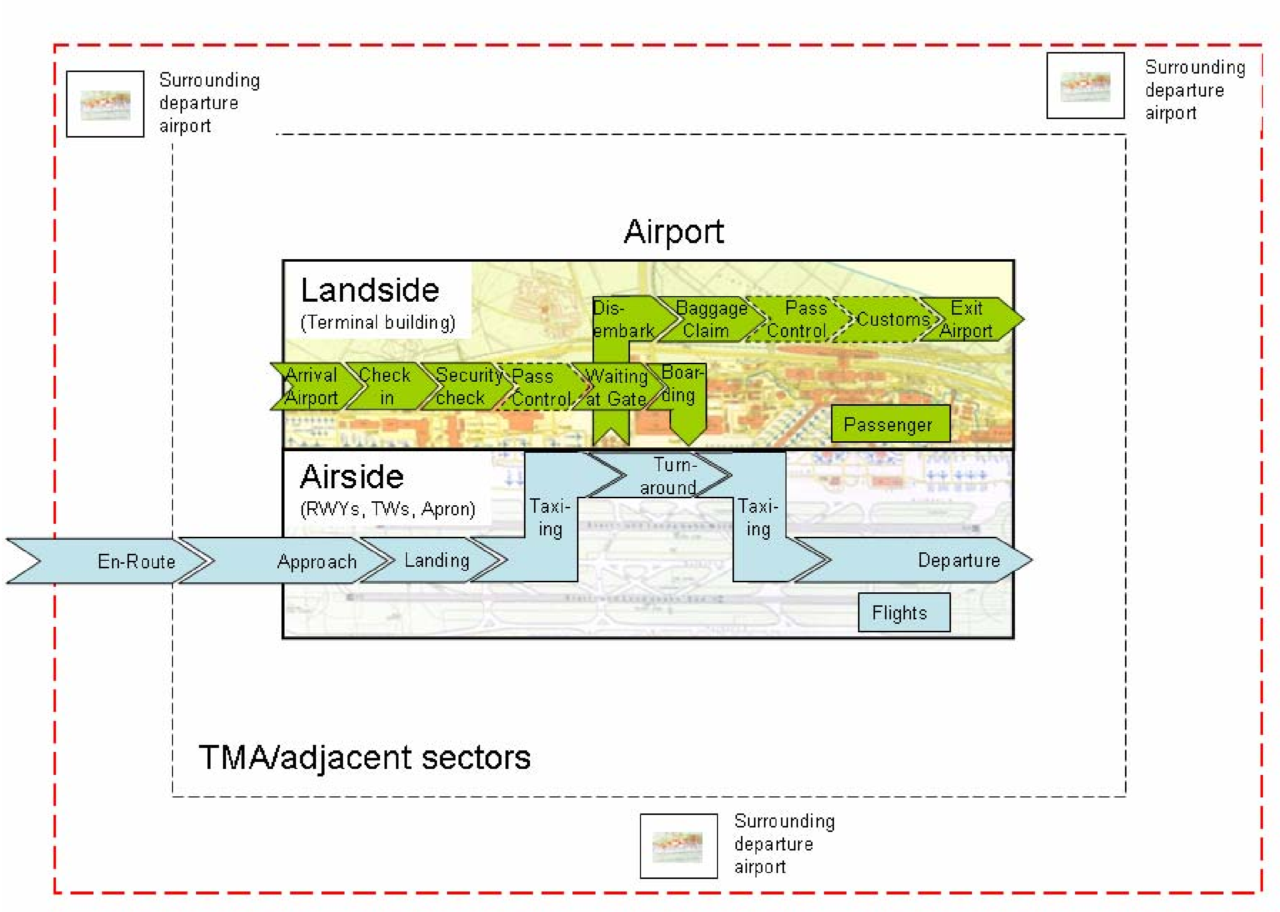

Figure 3-3: Spatial scope of TAM

3.3 Methodological Approach to describe TAM

The approach for TAM is the development of a hierarchical structure for an optimised reaction e.g. on predicted capacity shortfalls, an over-demand or lack of punctuality. TAM can also result in an optimised traffic flow during “normal” conditions and increase the punctuality or throughput (e.g. runway system, taxiways, stands). In this way TAM includes an overall macroscopic view with necessary filtered airport information concerning the overall flow, demand and capacity.

The basic hypothesis is that an airport can be considered as a system-of-systems that could be best managed to fulfil the objectives mentioned in a hierarchical “guidance and control” style. This hypothesis is supported by the insight that big commercial enterprises and large military operations are in all cases managed in such a way.

A methodological approach to how to describe such guidance and control functions was described in the AGARD report AR325 in 1995 [2]. Figure 3-4 shows how a guidance & control loop is running on one level. It is triggered with an overall task, objective, instruction, request, etc.

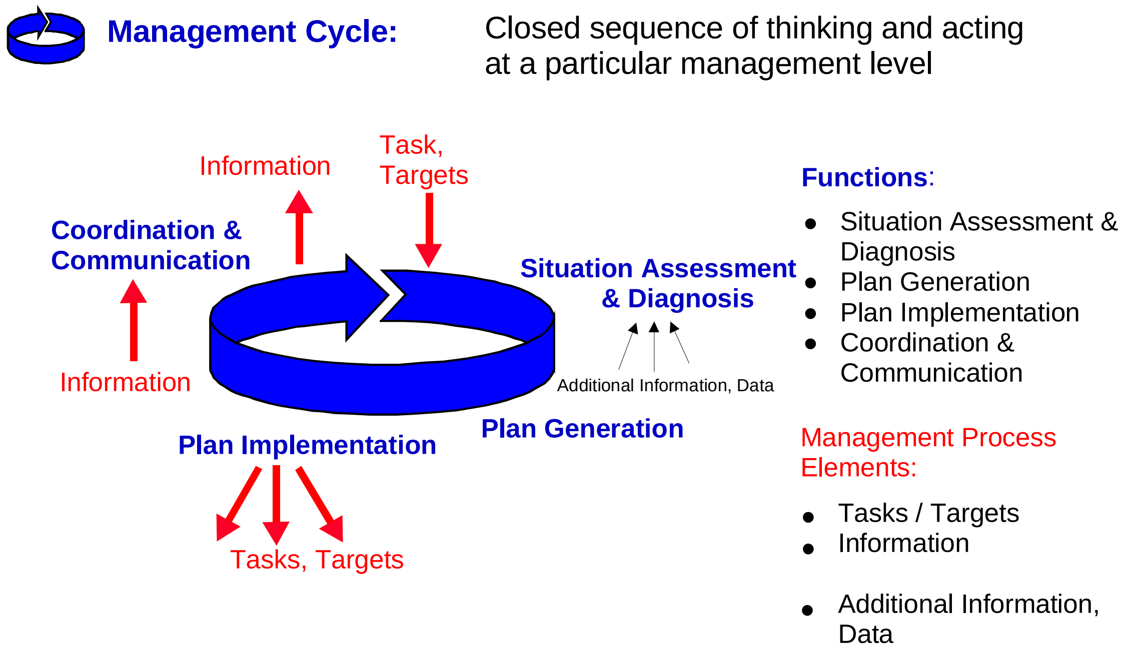

Figure 3-4: Management cycle at a particular management level

Functions
The first function is the *Situation Assessment & Diagnosis* of the situation with respect to the given objectives.

The second function *Plan Generation* is planning, producing a set of more detailed objectives and instructions (or commands) that in total would ensure the achievement of the overall objective of the loop, based on the assessed initial situation.

The third function *Plan Implementation* is preparing tasks and targets which will usually be given to several lower level guidance & control loops. These lower level loops should give feed-back and commitments to these instructions.

The fourth function *Co-ordination & Communication* is the analysis of the feed-back of the lower level loops (success of implementation of tasks and targets).

Actions (Management Process Elements)
Situation Assessment & Diagnosis usually comprises some information fusion tasks in order to bundle information from different sources and to put them into a context appropriate for the guidance and control loop being considered. Tasks and Targets, which are prepared during the Plan Implementation, will be communicated to lower level guidance & control loops or will be received from upper level guidance & control loops. Information from the lower level guidance & control loop about the result of the implementation will be received and communicated. Also information about the success of the implementation of tasks and targets communicated from the upper guidance & control loop will be sent to this upper loop.

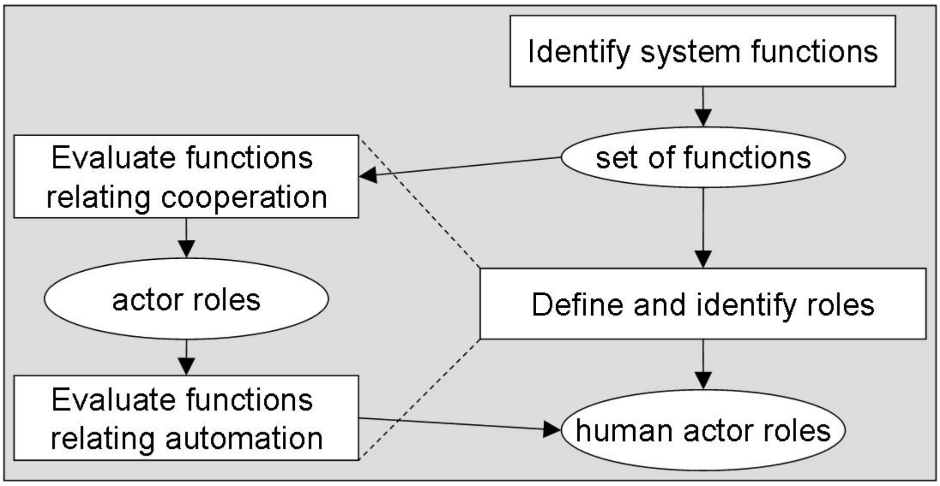

Figure 3-5: Methodical approach for role allocation

Method
On the basis of the control loop approach, TAM-functions on different hierarchical levels will be identified. Levels are oriented on the time horizon and the quality of information processing. As a first step the functions on the different layers will be allocated to one stage of the control cycle model [2] (see Figure 3-5). In a second step the definition and identification of potential roles in TAM follows. This step includes the evaluation of co-operation between different stakeholders in TAM. At the third the allocation to automated system or human will be identified (see Figure 3-6) as proposed in [15]. In discussion with domain experts, workflow sequences using operational scenarios and use cases will be designed [9]. After formalisation initially with a development of operational scenarios and use cases and later in executable models (e.g. Coloured Petri Nets, [11]) the workflow sequences will be simulated, analysed, and discussed.
The models should help to discuss the work flow sequences with domain experts. Possible actor roles in TAM and distribute functions between human and machine can be defined. For this the relation between the control cycle model and the four stage model of information processing for a qualitative allocation of level of automation will be established [4].

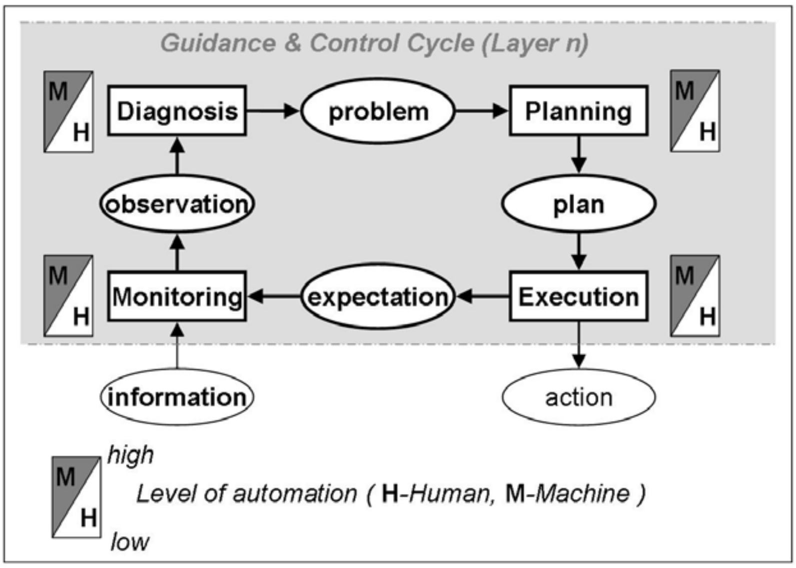

Figure 3-6: Relation between Guidance and Control Cycle and Level of automation scheme (evaluate functions relating automation)

Function allocation
The term task allocation is sometimes used interchangeably with function-allocation [5], [6]. The term 'task' is used for functions that are assigned to the human [13]. Task allocation will be used to refer to work design decision dealing with the distribution of work across multiple human actors. A function that is intended to be assigned to a machine will be referred to as an automated function. The allocation of functions should be implemented in an early phase of the design of a human-machine system. By the specification of the functions the human-machine system must consider its intended working context. The output from allocation of function is a specification, at an appropriate level of abstraction, of the functionality of the sub-systems that will be required. In chapter 4.4 the potential allocation of tasks and the identification of the associated human roles are described.

Scenarios and Use Cases
In terms of the development of a Total Airport Management (TAM), the function allocation between human actors and future assistance systems (for example planning systems) could be realised by the design and use of scenarios. Scenarios describe the behaviour of users and the future system, interaction between the two, and the wider context of use. Scenarios also aid the analysis of multiple aspects of a complex problem more or less simultaneously on a qualitative level.

Use cases describe the system's behaviour under various conditions as the system responds to a request from one of the stakeholders (the primary actor) [9]. So we have a more detailed representation of the work flow. The developments of use cases in a simple natural language have to be the first step of a translation into an important formal model. A very important fact for understanding the work of complex systems is the development of executable models for concurred and distributed systems. There is the exclusive possibility to analyse and evaluate system architectures in early design phases. Models assist the analyst to articulate the complex and dynamic nature of interaction between important elements of a future system. Use cases responds protecting the interests of all stakeholders.

By using executable models the investigation of effects of a certain task distribution on actor activity during different phases of a procedure becomes realisable. Alternative flows with different function allocations could be represented for communication and discussion with domain experts. Furthermore formal models supply mathematical analyses methods (linear algebra, graph theory) and consistency, achievability and safety analysis [14]. Within the OATA project from EUROCONTROL scenarios and use cases are developed which might be applicable utilised for the development of TAM. These scenarios and use cases can be found in the ConOps document which will be updated and extended due to the AAM project [7].
Taking these general ideas as a background, the approach to define the TAM concept and logical architecture is:

1. Identifying the guidance & control loops and their overall level architecture.
2. Identifying the concrete meaning of the functions and actions of the individual loops.
3. Identifying meaningful packages and instances of the TAM concept including the work share in each function between human and automation.

The concept has to be validated in simulation in order to prove the designed architecture and the proposed work shares.

3.4 Human Centred Design

In the TAM concept the main focus can be located in the design of the common decision making processes of actors from different stakeholders. Based on the stakeholder interests potential conflicts should be identified and concepts for conflict solution should be found.

The definition of the human role in TAM and the resultant interaction of actors is a theme for the collaborative decision making process. The creation of TAM will permit the generation of a global information picture derived from a number of local information sources. Aspects are the integration of local information into a global picture or the kind of intermediation between human actors of different organisations with respect to their different goals and intents. Expected benefits of co-operative working and decision processes in TAM could be:

- possibility of direct verbal communication and discussion
- representation of information by means of common used displays
- common computer aided simulations
- transmission of planning orders, action proposals or action instructions
- better negotiation and solution of conflicts and communication of interests

Function based role allocation

The human role is an aggregate of tasks that a human actor performs. Responsibility and accountability are substantiated in an actor's role. Responsibility is defined as the fact of being in charge of a certain job or task, facing the situation in case of an abnormal functioning in the process in which the actor is involved [16]. The role of human actors is based on tasks (see chapter 4.4) and functions (see chapter 4.3), which are identified for TAM with respect to the actors interests and objectives. Current tasks of different stakeholders on the airport could be mixed with new tasks due to new allocations of the responsibilities in the future. Changing tasks and the amount of responsibility assigned to human actors may lead to role transitions. The new tasks may have an impact on the perceived congruency between an actor's self-concept, expectations of his organisation (subsystem) and expectations of the airport system as a whole.

The role concept is a useful approach for further reasoning about human requirements and function allocation. In analogy to [12] three important role types are defined:

- supervisor
- individual operator
- team member

These roles overlap and are highly interdependent. Concerning TAM the interdependencies and overlaps between team members and supervisors take a central area of interest.

Aspects

This current approach accounts for the human actor's role in an early state of system design process. A holistic view of the human-machine system includes an active involvement of human actors into system control activities. The reduction of distance to the control process can be taken into account and thus avoid ending up in a passive monitoring role for the human actor.

In [8] seven main interacting factors are identified for evaluation of task sharing between human and machine in further work environments:

- Trust,
- Situational awareness,
- Team performance,
- Skill changes,
- Workload,
- Recovery from system failure and
- Error analysis

From the view of human factors the most important aspects are:

- To respect the collaborative decision making philosophy
- To pay attention to the active decision-making role of human actors
- Improvement of situation awareness
- Guarantee of actors´ trust in TAM
- Balance the workload of the actors

Collaboration, Interaction and Communication between actors of different stakeholders
The collaboration and communication between different stakeholders are a main aspect in the TAM. The Interaction between actors of different stakeholders should follow the CDM philosophy [10]. Advantages are:

- Information is shared between appropriate actors
- All parties know constraints
- All parties are able to react to constraints
- Decisions are made by the most appropriate actors

For the actors involved in the management process, a common information base and knowledge is necessary. Further, the necessary specific information and knowledge for each actor depending on his specific role, has to be identified.

Decision-Making
The decision making process is a pro-active cognitive process, in which one action sequence is selected from a set of different alternatives. The decision making process can include different levels of human information processing for description of skill, rule, and knowledge based behaviour [12].
For a common decision process in system management, allocation of responsibility, accountability for decisions and allocation of support functions are of central significance. Full situational awareness is the basis for optimum decision making.

Situation awareness
The identification of an actors' role including allocation of tasks and working procedures is linked to the consideration of situation awareness. In [3] three levels of situation awareness are identified. On the first level key elements of the situation are identified. In the second level comprehension and integration of information takes place, and in the third follows the projection into the future.

Trust in the TAM system
Important factors for trust in the system are the reliability and usability of those support systems which are included in TAM as well as those factors representing the quality and availability of information. On the other hand, actors may be tempted to show complacency effects as a result of automation which may be critical in certain system states.

Workload of the human actors
The management of airport systems in the future will seek recourse to an increased number of automated tools and technologies. Many of those automation tools will be developed with the intention of reducing the workload of human actors.

3.5 Possible Implementations

Total Airport Management should be scalable and adaptable for different sizes of airports, because not every airport needs the complete technical complexity of TAM. On some airports parts of TAM are already available and have merely to be connected to a global management system. On other (primarily smaller) airports some parts like operation centres have to be completed or added if the entire functionalities of TAM are to be implemented.

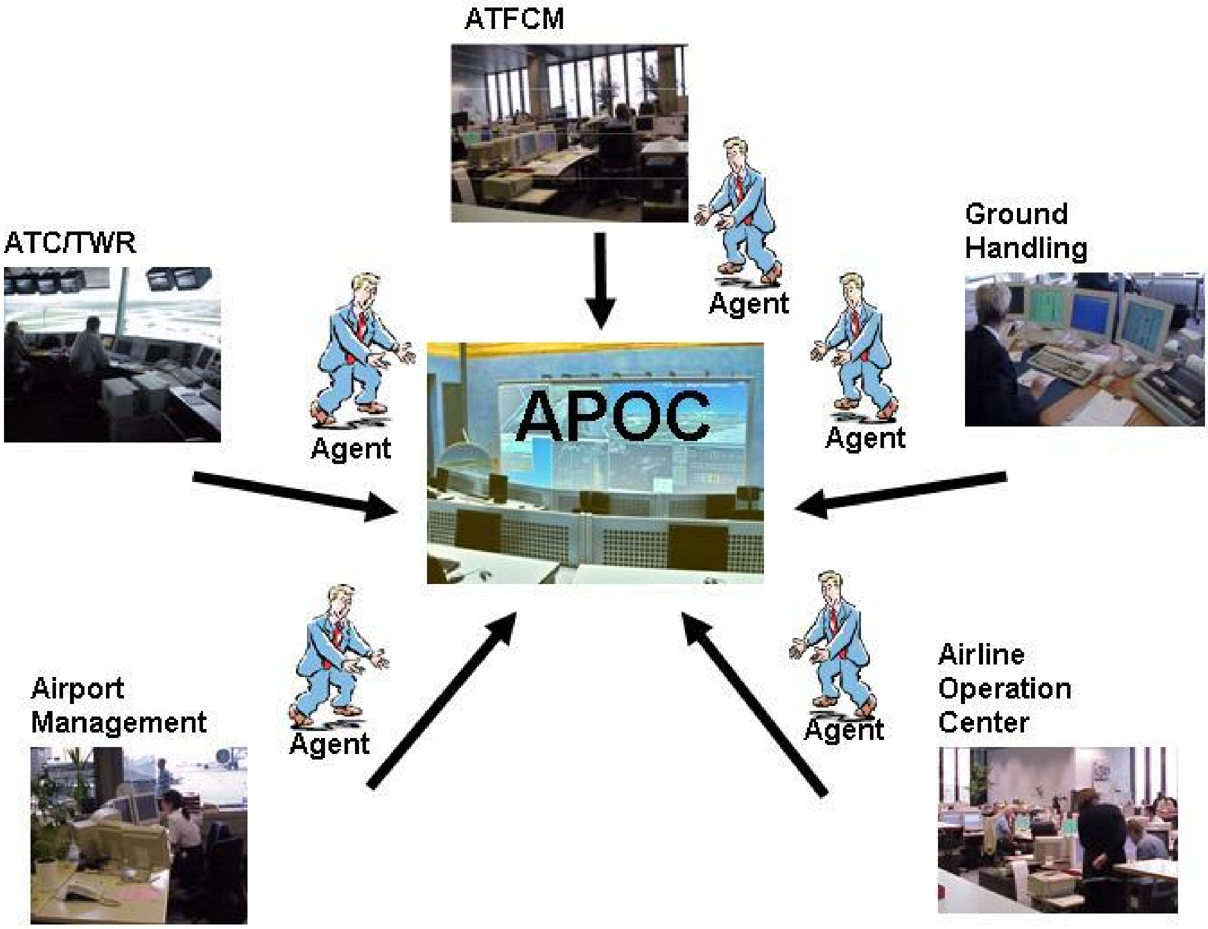

Figure 3-7: agents working in the Airport Operations Centre

The central tool of TAM is the Airport Operation Centre (APOC) where representatives of all stakeholders involved work (Figure 3-7). This APOC has two major functions: first all relevant information of the airport, air and land traffic, ground operations, weather conditions and so on are collected, monitored, and analysed in the centre. This information is appropriately prepared for displaying to give the executive staff aids for ad hoc and tactical decisions to operate the airport and air traffic in an optimum manner (Figure 3-8).

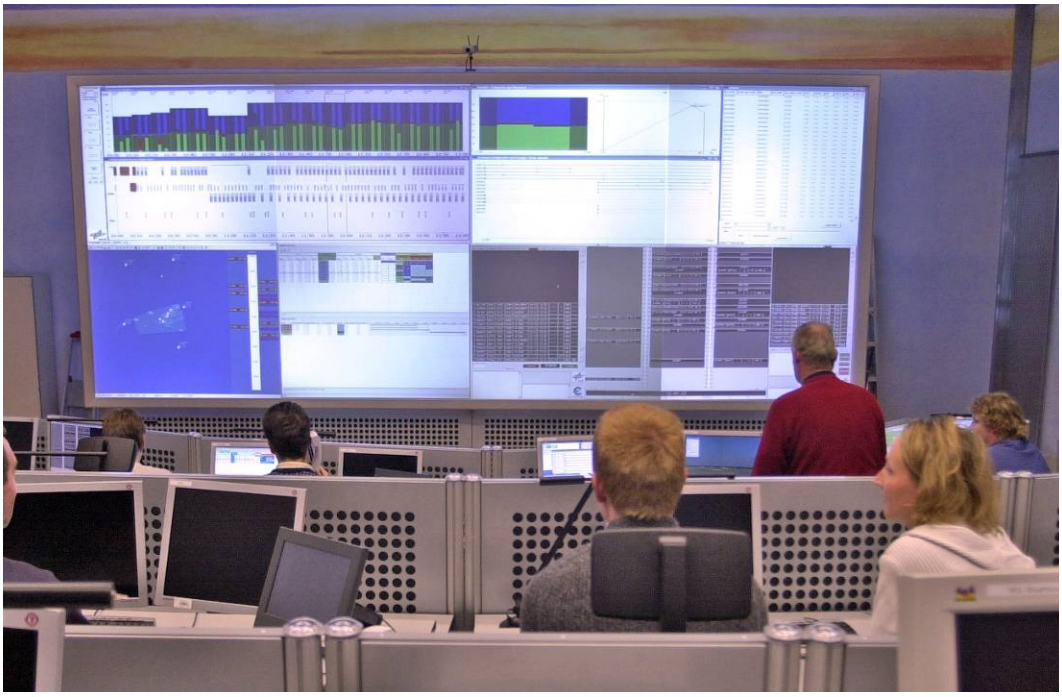

Figure 3-8: The DLR experimental Airport Operations Centre in Brunswick (Germany)

Second the APOC should be equipped with planning and simulation tools for pre-tactical and in some cases strategic planning. In doing so the amount of technical systems and tools should be adjusted to the complexity of the airport infrastructure and the volume of daily air traffic. Connecting existing technical tools and integrating them into the global concept, TAM will enable the development and the implementation of automated planning tools to help the stakeholders in achieving a better level of performance. TAM will provide both a concept for a communication and an information platform for all stakeholders involved at a given airport thereby enabling each participant to take decisions in the most enlightened manner in line with the objectives of CDM. Essentially an airport operation centre can be considered as “centralised” or “de-centralised”.

Centralised APOC

The “centralised solution” of an APOC requires one room in which all relevant information will be merged and displayed. Every stakeholder or its agent receives a workplace with online access to its operation centre to share information and to ensure upcoming decisions.

The central solution contains a complete APOC with considerable technical equipment for real-time analysis, planning, and simulation of large international airports. In this way all stakeholders involved share the same information simultaneously and have the ability to make harmonised decisions. They will be aware of potential problems and in the CDM process they can develop and co-ordinate solutions at an early stage.

De-Centralised APOC

The “de-centralised solution” for an APOC requires no single airport operation centre. Instead of this the operation centres of the local shareholders are connected with online access to the available data pools for monitoring, planning, and simulation tools. Only for urgent decisions with far-reaching effects will deputies of the joint partners take part in a meeting and come together. The financial and the technical effort for the de-centralised solution might be less than for a centralised one, but at the expense of complicated communication feasibilities and the lack of overview.

Another variation might be a virtual APOC: The technical equipment is shared on the existing operation centres of ATC, aircraft operators, or airport. With the aid of a network all relevant information such as actual traffic situation, planning, and ad hoc decisions are exchanged between the connected partners. In this way the technical aid for all stakeholders is available without building a physical airport operation centre.

Theoretically, a **virtual reality APOC** with direct connections between the stakeholder’s agents would be conceivable. The boundary conditions would be probably the same as in a real APOC, but every connected agent sits physically in his local operation centre and has access to relevant data and planning and monitoring tools as in an APOC. In the virtual APOC room an agent has the possibility of discussing and sharing information with connected partners visually. In this environment he will be able to demonstrate the influence of parameter changes on the actual or expected arrival and departure flow and adjusting the subsequent proceedings.

APOC by Hand
The smallest system for regional airports might be one existing operational centre which is equipped with additional technical tools for monitoring and planning. Normally capacity reduction and delays are negligible problems on these airports (except smaller aerodromes on typical touristy destinations like islands that are highly frequented during summer seasons), so airport operators need support for their daily business rather than for pre-tactical and strategic planning.

Remote APOC
Another solution for very small airports might be the outsourcing of the APOC and its functionalities to a larger (hub-) airport. However, this solution requires a reliable digital network and the non-restrictive data handling between the partners and stakeholders involved.

4. Logical Architecture

The basic idea of TAM is the development of a common airport management structure for all stakeholders. The individual and direct contact between the representatives of all stakeholders enables a collaborative decision making process supported by all stakeholders. This approach introduces a holistic view of the airport management processes underlying a common information data base for all stakeholders. In Figure 4-1: the physical and functional view of the APOC is depicted.

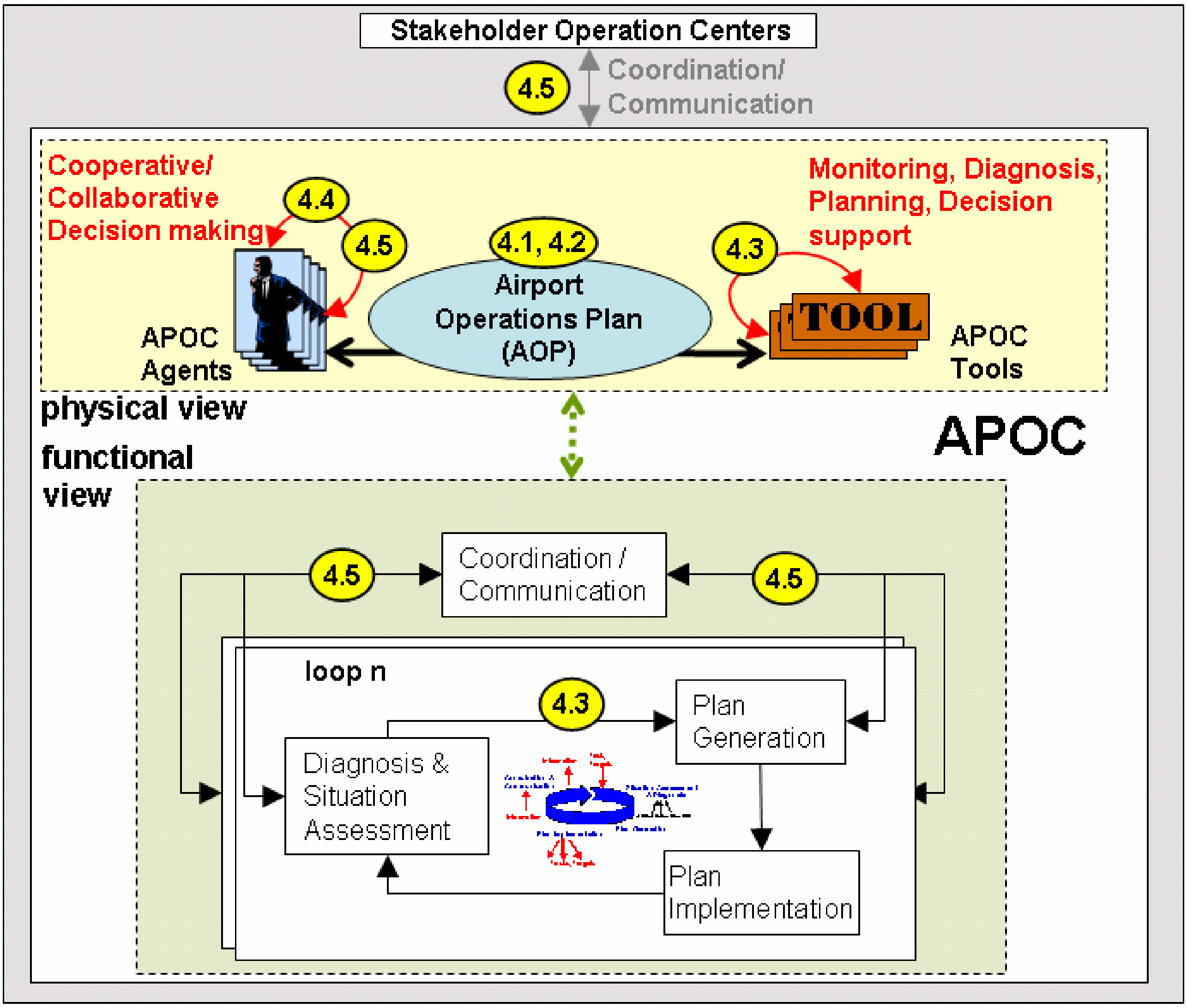

Figure 4-1: Overall diagram for TAM logical architecture

In the physical view the shared information base named Airport Operations Plan (AOP) includes all planned data on different levels of granularity and it will be described in chapter 4.1. Agents as representatives of all airport stakeholders work together on the same knowledge base (AOP) and will be supported by different kinds of tools (Monitoring, Planning and Diagnosis). In the working process different functions are filled out by human agents or support tools.

The functional view represents the kind of management functions, their organisation and logical connections with each other.

The management process follows the Control- and Guidance approach introduced in Chapter 3. For functional purposes the management process can be described by hierarchical organised loops. The main inner loop functions are the same for all cycles and are named Diagnosis & Situation Assessment, Plan Generation and Plan Implementation (Figure 4-1: , functional view). These functions will be introduced in detail in chapter 4.3. In a function allocation process, functions will be identified which are suitable for automation.

In the next chapter (4.4) tasks will be derived and allocated to the stakeholder representatives (agents) by analysing the identified functions. The tasks identified will be considered as collaborative decision making processes. The role allocation to the different APOC - Agents into the decision making process depends on the tasks identified. Contingent upon time horizon and the kind of information processed, different cycles can be identified (Figure 4-1, functional view).

Communication intra APOC and between APOC - Agents and stakeholder organisations (Operation Centres - OCs) is explained in chapter 4.5. In the functional view communication and co-ordination is represented as a link between the different management cycles.

4.1 Airport Operations Plan (AOP)

The AOP firstly is the conversion of the NOP to an airport centric “en-route to en-route” view. Additionally it adds further levels of detail to the pure conversion result, down to target times for all airport processes. The NOP (Network Operations Plan) is the overall data structure, described in the EUROCONTROL medium-term Airport Operational Concept document [1], giving the holistic overview on the status of the overall air transport network (or at least of the European part) and how operations are to take place.

The core idea of the AOP is to have one dynamic joint plan to which all stakeholders are fully committed (Figure 4-2). The AOP therefore has to take into account the partly diverging interests of the stakeholders at an airport and it has to be the result from a (the main) collaborative decision making process. As this joint plan is only of value if the stakeholders can trust that the others will also follow this plan, suitable (market) mechanisms have to be established so that each stakeholder has a vested interest in adhering to the plan.

The AOP might be handled in a central airport data base with full access by all stakeholders or in a distributed fashion, where e.g. only the NOP conversion is accessible by all stakeholders and the detailed process plans of each stakeholder are maintained by the individual stakeholder separately.

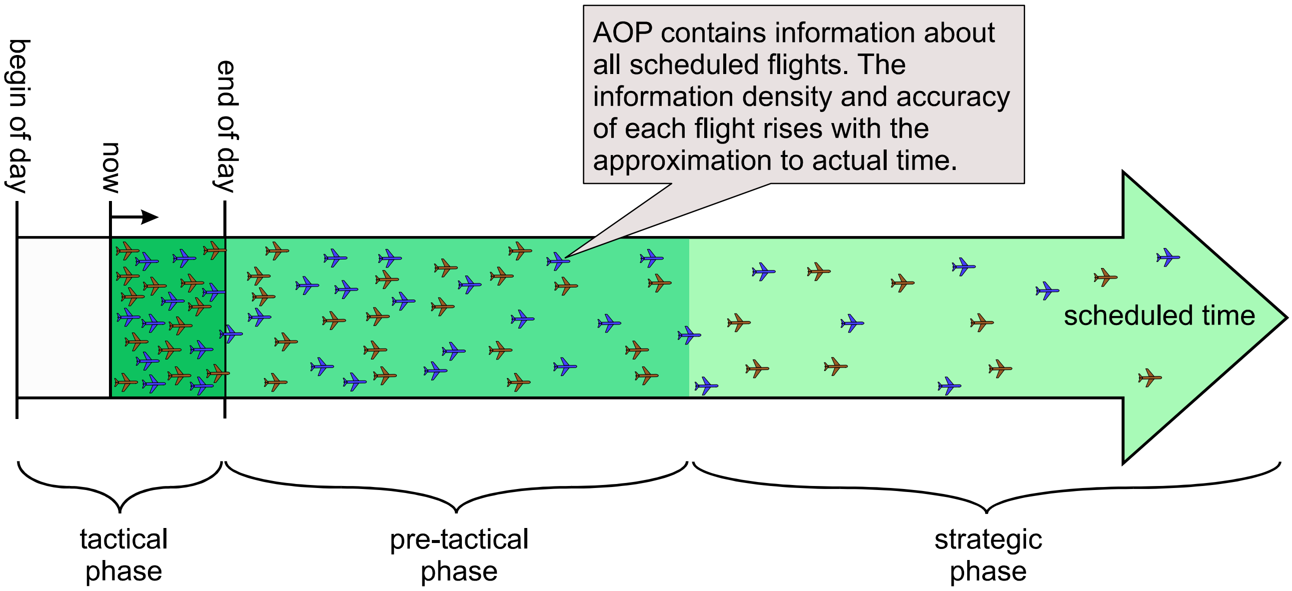

Figure 4-2: The AOP divided into sections for the tactical, pre-tactical, and the strategic phases. Every aircraft symbolises the amount of confirmed information

The AOP is divided into the three sections tactical, pre-tactical, and strategic phase. The boundaries and the period of validity of these phases may vary, because they may be relocated step-wise or sliding. This depends on airport size and airport organisation structures. The AOP contains information about all scheduled flights, symbolised in Figure 4-2 by blue aircraft for departures and brown for arrivals. Every flight is associated with estimated target time, which will be replaced or completed by confirmed target times. The information accuracy and density of each flight rises with the approach of actual time, marked with “now” in Figure 4-2.

NOP and AOP have to be maintained in a consistent way, as the aggregated AOP can be considered as a part of the NOP. Sufficient means of ensuring consistency have to be established.

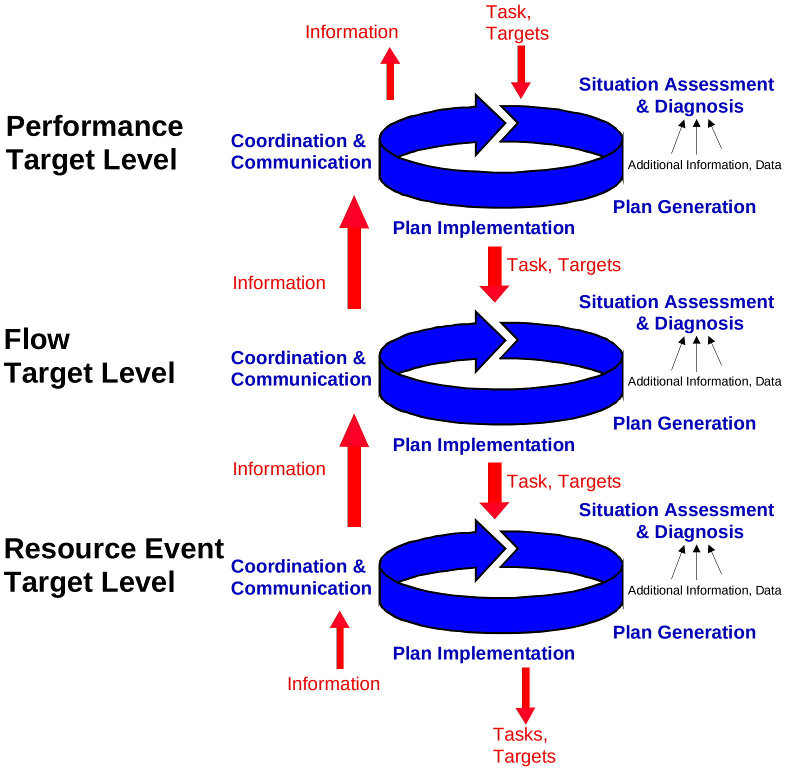

Figure 4-3: In view of TAM guidance and control loops can be allocated to three different levels

As in chapter 3.3 represented, guidance & control loops and resulting level architecture of TAM have to be identified. In this document, three main target levels are differentiated (Figure 4-3): The performance target level, the flow target level, the resource event target level.

The following table gives an overview concerning the different data items that are contained in the AOP. It has to be noted that the listed data items are not all included during the full life cycle of the AOP in always the same data quality or granularity. Some items are included a long time before the flight operation is executed, some furthers are added and some data items are becoming more precise during refinement of the AOP.

	Parameter	Comments
Performance-Targets		
	Punctuality (t)	Following IATA definition, 15min criterion
	Throughput (t)	Aircraft (or Passengers) per time
	Emission (t)	Gaseous and Noise
	Cost / Efficiency (t)	
	Predictability (t)	
	Stability of Operations (t)	Robustness, flexibility to cover stochastic disturbances by buffers
		Safety is not compromised nor weighted in any case; therefore it is not a parameter to be set.
Flow-Targets		
	Capacity (t)	
	Demand (t)	
	Flow (t)	
	Queue (t)	
		All these parameters can be considered or planned for the airport, for arrival/departure, for individual airport resources (RWY, TXWY, Apron,…) or a combination of these possibilities.
Resource-Event-Targets		
	Resource-Config-Targets	E.g. RWY in mixed or segregated mode,
	Operation/Flight Targets	E.g. target time to complete boarding, locations are bound to the target times to associate target times with the resources to be used. Can be converted into a resource usage view

Figure 4-4: AOP targets and constraints

The explanation of the three target levels that are shown in Figure 4-4 is as follows:

The **performance target level** represents a trade-off agreement between the stakeholders on the key performance indicators of the airport operations. This Quality of Service (QoS) agreement has to be co-ordinated with the ATFCM, too. These parameters are functions of the time. The performance parameters reflect the interests of the stakeholder. On an economical view, reduced costs, increased throughput and increased efficiency are important for all of them. A better predictability, stability in operations and punctuality improves the Quality of Service and therewith the satisfaction of the customers (for the aircraft operators and finally for the passengers). With the increase in air transport and the advance of urbanisation around existing airports environmental aspects become more and more important as well.

A compromise between throughput and punctuality has to be found. Furthermore, a compromise between throughput and emission issues could one day be necessary for environmentally restricted airports. These compromises will usually be set to default values, agreed on a long term basis – as is the case for the punctuality target today inherently included in the published co-ordination capacity of an airport. For the more short-term part of the AOP, this trade-off might be re-negotiated due to constraints that could not be taken into account in the longer term planning earlier. For example, a shortage in capacity due to runway closure might lead to a new compromise between punctuality and throughput towards throughput, in order not to cancel too many flights. Or in a situation that the environment is already suffering from too much exhaust due to special weather situations, emission might temporarily get a higher weight than throughput.

The **flow target level** inherently includes all information on the availability of airport resources. For example, runway availability, expected weather, and other factors can be combined into a runway or airport capacity prognosis. The same is applicable to other resources, e.g. a terminal with a certain set of stands has a capacity that can be predicted to cover cases where some stands are closed due to maintenance. The expected demand and how it flows through the airport system can be compared with the individual capacities to assess the individual flows through the individual resources and to assess the resulting queues. The flow plan of the AOP is the solution to make best use of the available resources via controlling the flow by selecting appropriate resource usage strategies over time, by assigning available resource capacities appropriately to the demand etc. This part of the AOP directly takes into account the performance level of the AOP as a soft constraint.

The **resource event target level** of the AOP uses one standard en-route-to-en-route process model for each aircraft and each passenger and piece of baggage to further detail the planned flows into target times for each process step. For each object on the airport the target times and the object to resource relations are set up. This can also be done in several stages, first associating only the most important resources to the aircraft – e.g. the stand – resulting in a rough taxi time estimate. When refining the plan later, weather and operational configuration of the airport will be known and therefore further assignments will happen, e.g. approach route, runway and taxi route. Further, the target times for all resource usages are set. Perhaps the target times may be target time windows in the long term planning, evolving into crisper target times when the operation comes closer. Remark: For building this event level plan, existing planning systems (XMAN) will be re-used.

Static constraints limit the search space for the generation and refinement of plans. They can also be used to explain drafted plans. They ensure too that only operationally meaningful plans are generated. The following table gives an overview of which constraints could be necessary and should be stored as supplementary elements to the AOP. Some of this information is required for arrival and departure managing or is the result of this planning:

Airspace structure	Noise or military restricted areas
	SIDs and STARs
	Flight sectors
	High mountains or buildings in the vicinity of the airport
Airport structure	Airport topology with runway and taxiway structure, stands and gates
	Dependencies between aircrafts and runway configurations, because at some airports, heavy or fully-loaded aircraft cannot use every runway
	Minimum handling times for ground processes

Figure 4-5: Static constraints included in the AOP

Further some **dynamic constraints** - which are not foreseeable in the very long run - will be needed in the AOP. A distinction has to be made between hard and soft constraints. Hard constraints are those that must not be violated e.g. due to safety regulations. Soft constraints are strong wishes from stakeholders to be respected during planning unless they are impossible to fulfil. Two categories of dynamic constraints are identified: resource availability constraints (e.g. temp. RWY closure) and resource dependency constraints (e.g. if this RWY is used then that RWY must not be used). Depending on airport, aircraft operator, and other participants, there are innumerable dynamic constraints, so only examples are given here to show the different constraint categories:

- Aircraft A cannot depart before 10:00 (earliest off-block)
- Aircraft A cannot depart earlier than 40min after landing
- Aircraft A must depart before aircraft B
- Runway 18 will be blocked from 12:00 to 12:20 because of snow removal
- Gate A17 closed today due to maintenance.

4.2 AOP Dynamics

The AOP is of course a dynamic data set. This includes both the initial creation and any adaptation of the plan. The introduction of different planning phases, strategic, pre-tactical, and tactical, results in a fragmentation of the AOP. Considering any point in time (termed as now), the strategic plan affects an interval from now to the end of the planning period (termed as planning horizon), e.g. the end of the season. The pre-tactical plan however will not affect now but any time of the next *n* days, i.e. starting with the first hour of tomorrow's operation and ending with the last hour of *n*-1 day after tomorrow's operation. The (active) daily tactical plan will affect now and any time of the current day's operation. At a certain time there might also be a daily tactical plan for tomorrow available which is non-active.

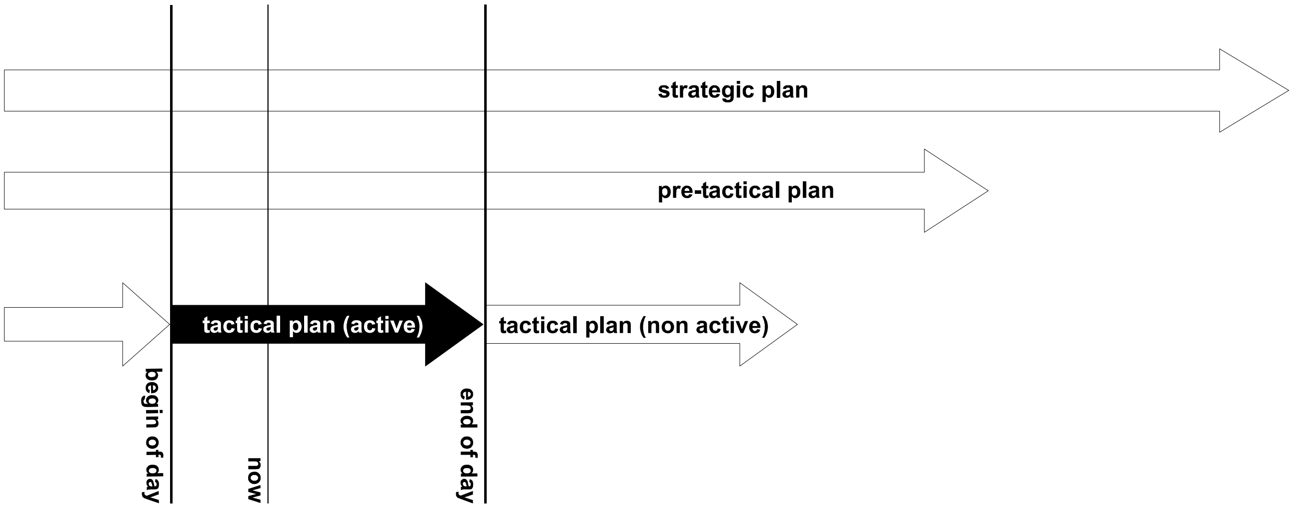

Figure 4-6: Life-cycles of strategic, pre-tactical, and tactical (active, non-active) plans

A fragmentation of the AOP as described above immediately suggests a set of consequences:

1. The active daily tactical AOP should contain all relevant planning information so far available for current (daily) operations of an airport.
2. The frequency of plan updates should increase from strategic to tactical level.
3. Any upper level planning should be considered as some kind of framework for the next lower level planning.
4. Some plan changes on the tactical level have an influence on the pre-tactical planning level, so feedback from tactical to pre-tactical phases and in particular on occasions to the strategic phase is necessary.

On a generic description level both initialisation and refinement of the plans can always be regarded as event-driven, since any scheduled or periodic triggering may be described by time-events. However, in order to enhanced transparency these two mechanisms will be characterised as clock-driven, where as the term "event-driven" then is used for a triggering which is caused by any change of relevant data. The data change may be induced by new external information, user interactions, internally generated data, e.g. as a result of a monitoring process.

The strategic AOP of a season will be initialised directly after the bi-annual slot conference. The time of a pre-tactical AOP initiation has to be agreed among the TAM decision makers. Plan updates of both the strategic as well as the pre-tactical plan will be performed at a decision maker's request and on unforeseen events, which have an influence on the long-term planning. Revisions of the pre-tactical plans might have an immediate influence on the tactical planning.

The different levels within the AOP are associated with different planning horizons as shown in the following figure. The higher levels usually carry out a rough planning that looks further into the future than the detailed plans that are more short-term in nature.

Figure 4-7: Planning horizon of the AOP

The maximum planning horizon time is six months into the future, associated with the seasonal planning of co-ordinated airports in the slot conference. Levels in the AOP affected are the performance level (trade off between punctuality and declared capacity), traffic flows and cornerstones for the target times.

The next refinement step could be triggered by availability of initial weather and infrastructure forecasts some days before the day of operation, setting new constraints to further detailed planning. Levels affected would be the flow level resolved to individual airport resources and plans concerning detailed events.

The shortest term planning horizon time would affect the refinement of event times and relevant trajectories of objects.

4.3 Functional Architecture

Four main functions describe as depicted in Figure 4-8 the functional TAM architecture. First a survey of the existing airport traffic situation and its analysis is needed. On that basis all further discussion and planning takes place – e.g. in the APOC, while the planning is enhanced by the automatic planning algorithm that the system has to provide. On the basis of the plan generated and after the commitment to it by the stakeholders, a new AOP is generated and sent to the ATFCM, which will combine relevant data for the network into the NOP and distribute it to the participating airports.

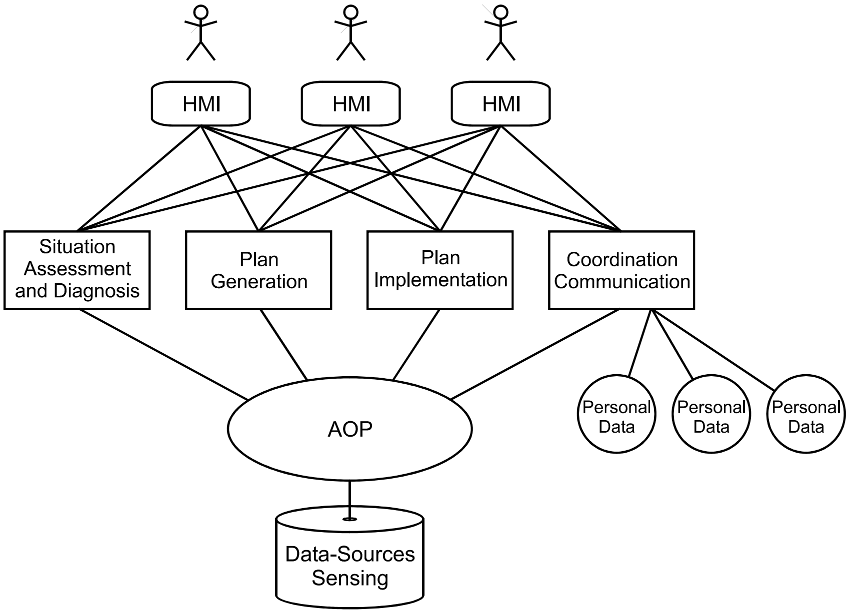

Figure 4-8: Functional architecture of TAM

The agents inside the APOC (or connected to it) are directly interconnected with one system for situation assessment and diagnosis, plan generation, plan implementation, and a co-ordination and communication module. These systems have dedicated lines to the AOP. External data-sources provide the AOP with current information.

All management and guidance processes can be described by control cycles, which include analysis and planning components. The analysis process (Figure 4-9, brown boxes) consists of sensing, monitoring and diagnosis as sub-processes and the planning process (Figure 4-9, green boxes) is composed of plan generation, plan selection and activation. Process input information and resulting information are represented by ellipses. The arrows show the logical flow direction. The grey network in Figure 4-9 describes the connection with the higher and lower cycle.

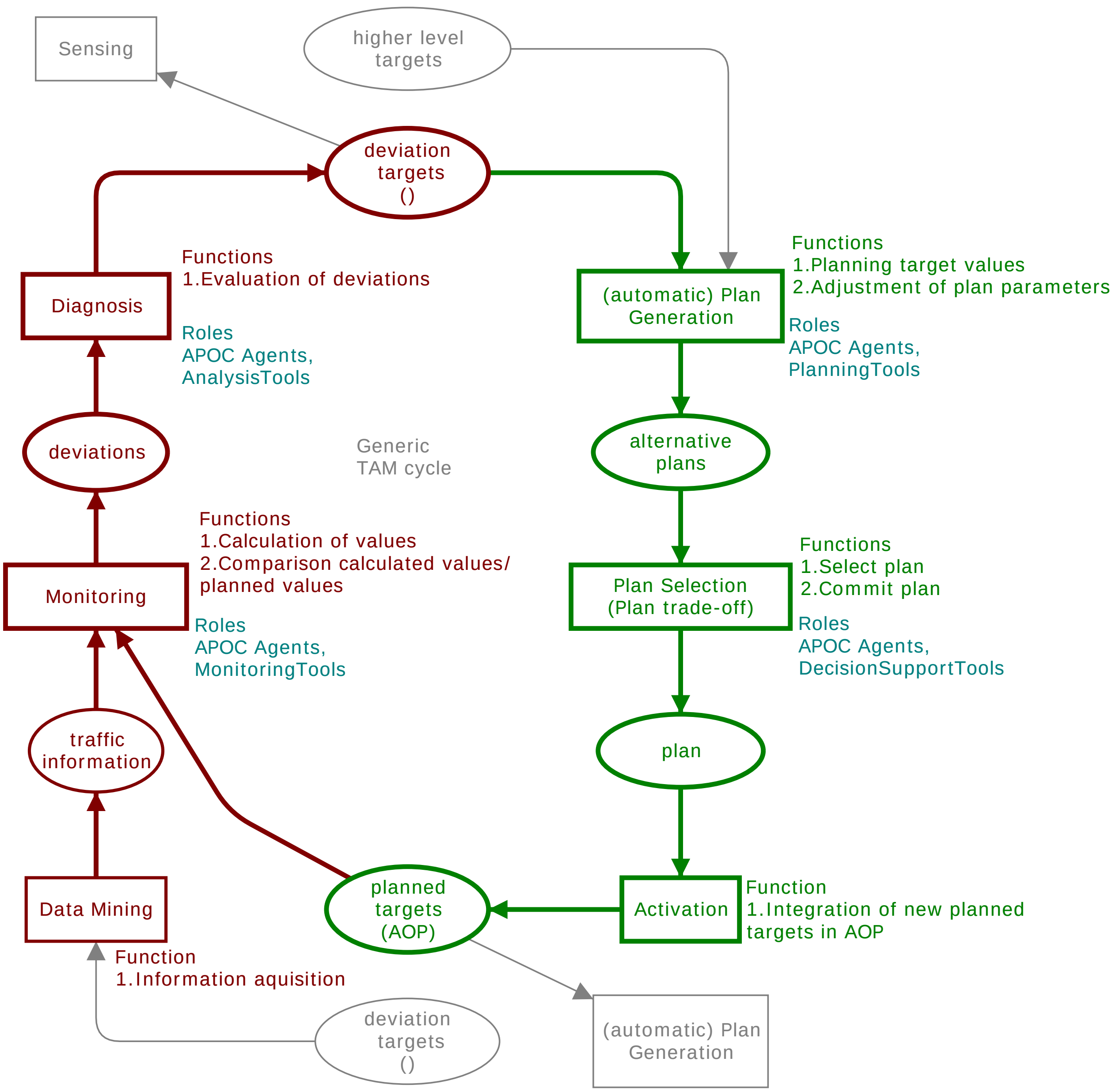

Figure 4-9: Generic TAM loop. The three different types of loops in Figure 4-3 (performance, flow, and event) could be described with the same generic structure which is represented in this figure

The logical planning flow (green part of Figure 4-9) in the generic cycle could be described as follows: The Plan Generation is carried out based upon higher level target values and detected deviations from inner cycle targets. The result can be a tentative plan with new target values. Through the Plan Selection the choice of the *plan* occurs which should be active (either to take place of the old active plan or the new tentative plan, that is the alternative plan). This process includes the negotiation and commitment between the different stakeholders. In the Activation process the new planned targets will be integrated in the current plan.

The analysis flow (brown part of Figure 4-9) starts with sensing of information of the next lower cycle. This traffic information could be actual and predicted process data and constraints on different aggregation levels. By using this information, higher aggregated information will be calculated and compared with the planned target values. Identified deviations are evaluated in the diagnosis process. Deviations from target values as results of this process close the cycle and trigger the plan generation.

Situation Assessment and Diagnosis
To enable a CDM process between the stakeholders it is necessary to achieve a common situation assessment in order to ensure common situation awareness. Situation Assessment and Diagnosis can be divided into the sub-processes Data Mining, Monitoring and Diagnosis.

Data Mining, as the first step of situation assessment, is the collection of the necessary data from the System Wide Information Management (SWIM) and the airport network (airport SWIM). Which data is needed and how this data is collected may differ from airport to airport. The data from different sources have to be collected and to be brought into one consistent status. The sources of data can be of three different categories:

1. data deriving from the ATFCM Network Operation Plan (NOP):
    a. flight plan
    b. flight update messages (FUM), including early off-block information at the departure airport
    c. slots for departing aircraft
2. data deriving from stakeholders at the airport (including meteorology):
    a. actual and predicted capacity (runway, taxiways, stands & gates, GH)
    b. small modifications to the flight plan which aren't already included in the NOP
    c. information from the local planning systems
    d. radar data
    e. actual weather and weather forecast
    f. data from A-SMGCS sensors concerning
    g. dynamic restricted areas (e.g. snow removal)
    h. dynamic airspace configuration
    i. restrictions based on operation mode
    j. dynamic restrictions in operation mode selection
    k. preferences from the stakeholders concerning events[4]
    l. warning levels for alerts[5]
3. constraints which change rarely and thus can be seen as static for short term planning:
    a. topography
    b. airspace topology
    c. ground topology

Depending upon the size of the airport and the fulfilment of the quality of service respectively all or just a subset of the listed data might be needed. There might even be data that is needed for a given airport which is not included in the listing yet.

The Monitoring begins with the calculation of compound data like the length of queues (e.g. on-block and departure) and the average times (e.g. taxi in and taxi out time) for events. Other necessary compound data are the demands. The data is derived from the estimates in the flight plan, the radar data, the A-SMGCS data and the target times from the tactical systems.

There might be two outcomes of the sub-function for the survey of the performance targets: Either there is no deviation from the performance targets, thus no diagnosis or new planning is necessary, or there might be a deviation from one or more of the performance targets in which case new planning has to be done.

The Diagnosis function includes a valuation of the deviations ascertained during the monitoring. This includes the raising of alerts for predefined conditions, the determination of the source of deviation and an

[4] The preferences from the stakeholders might include priorities for single flights, preferred times of departure and so on. These preferences are dynamic and can change from one planning interval to the other. A balance has to be found for the adjustment of these preferences concerning the prioritisation and how fast or how often they might change, e.g. to prioritise one flight the aircraft operator has to de-prioritise another flight.

[5] The stakeholders will have to reach agreement on the adjustment of the warning level for alerts. For example, alerts could be raised because performance targets are missed by a certain percentage. The value for this percentage would be the warning level for the alert.

estimation of their impact on the predefined performance targets. A further sub-function of the diagnosis is statistical analysis.

The values for the warning levels will be checked first. If a calculated value exceeds the value for the warning level, an alert is activated. For all alerts raised, the source of the deviation has to be identified, thus a solution to the problem can be found. The alert has to be displayed with a connection to the source of the deviation to the decision makers.

For each deviation, its impact has to be estimated to allow an assumption of the measures that might have to be taken.

Statistical analysis is needed for performance monitoring to enable the controllers in the APOC to judge the outcome of their actions. Furthermore the system must enable post analysis for later performance reviewing. Advanced systems might possess the ability to learn automatically from the post analysis.

Plan Generation

After new or updated information is available, the AOP plan generation process starts with an automatic planning. If stakeholders adjust the constraints and therewith the actual parameter set of the last planning process manually, a recalculation of the affected parts of the AOP is launched. After Plan Generation with manual parameters, all stakeholders or their assigned agents choose between the actual and the tentative AOP and then have the option to activate the varied plan or not.

The automatic AOP generation is triggered by events like new or updated information. Planning target times of events takes flows as constraints into account and creates sequences considering agreed rules. The rules are divided into fixed and changeable rules. All rules have to be harmonised between all stakeholders involved. In combination with events the change of parameters by agents or AOCs also starts a new plan calculation. After Plan Calculation this tentative AOP has to be agreed by all participants affected before it becomes active. This adjusting process has to meet the standards of a collaborative decision making process, so it might be that some postulations of stakeholders are more in the nature of wishes. During this adjusting process, all agents have to be given the possibility of changing their priorities and personal constraints several times to react to new inputs by other agents or AOCs. For this procedure it would be helpful if each individual agent gets the technical opportunity for direct communication and co-operation. In this way all participants get the possibility to initiate an alternative plan.

During the plan generation and co-ordination process, the actual AOP is still active and all new information is considered. To meet the latest changes, the complete recalculated and harmonised plan will not be the new actual AOP, but only the rules which lead to the new plan will apply to the next automatic AOP generation. If it is impossible to find an alternative plan taking latest events into account and matching all interests at the same time, the actual rules and consequently the active AOP will not be changed.

The automatic planning process is an optimising process regarding all actual preferred parameters. This leads to only one best fitting plan, which makes it unnecessary for the stakeholders to choose between two or more alternative plans. Thus the APOC helps all participants to meet the quality of service.

After or during the automatic planning process of the AOP[6], all stakeholders or their substituting agents involved and authorised in the APOC have the possibility of changing parameters for plan calculation. These parameters are variable constraints of the planned AOP like departure or arrival order, runway or gate assignment, or turnaround times. Every stakeholder has the possibility of changing parameter values in his local calculation and planning system and to watch the influences on flight sequences, turnaround processes and stand allocation. The local planning tools plan on the basis of the actual traffic situation and upon agreed constraint parameters. Only the parameters of the off-line input are changed in the local system parameter

[6] The course of action described in this subsection refers to the tactical planning phase, where – because of the lack of time – proper collaborative decision making with requests and discussion is no longer feasible.

set, so only the stakeholder in front of the planning tool sees the influence of his work (and – of course – all partners connected and authorised by the stakeholder). If the changed value shows the desired results, the authorised agent has to ask all other partners in the APOC for permission to change one or more parameters which will have an influence on the next AOP planning process. For this co-operation and co-ordination a set of rules should be defined to simplify and to speed up the decision process. Furthermore, established rules help to direct the behaviour between the stakeholders to meet the performance target "quality of service".

Plan Implementation
After the automatic planning process with the altered constraints the new plan is displayed in the APOC for agreement of the agents. This request might be automatically generated and distributed. In this case the stakeholders or their agents have the possibility of accepting or rejecting the petition. The agents examine the solution concerning the overall performance targets and the performance targets of the stakeholders in the APOC. Either they agree upon the plan or they make new inputs. If they deem the given result insufficient, the agents might change the priorities and constraints to make adjustments to the automatic planning process. Otherwise they agree to the plan and distribute it to the stakeholders in particular to the Airline Operation Centres (AOC). The APOC - Agents have the possibility of creating a tentative AOP to present it for acceptance by the tactical Operation Centres at the airport (tower, apron, …). They are limited in their choice concerning the selection of the plan: either they agree upon the AOP with the altered constraints and the plan can be actuated or they make new inputs for priorities and constraints and send them to the APOC. The new priorities and/or constraints may not trigger ad hoc a new planning process; they are more in the nature of soft constraints (wishes) that will be considered as soon as a new planning process is started. The decision as to when the input of the stakeholders is taken into account is up to the actors in the APOC, but normally they will be encouraged to satisfy the wishes of the stakeholders if possible. If the requested parameter value change is rejected, but the change request is important for one of the partners, the APOC supervisor should be involved. He tries to mediate between the request maker and the objector. If it is not possible to agree on constraint variation, the last agreed plan parameters will be maintained.

Comparing active, tentative, and if applicable alternative plans, the APOC - Agents and AOC stakeholders have the possibility of accepting or rejecting the new planning constraints. The AOP is recalculated with the new and co-ordinated parameter set. This procedure matches the splicing of alternative and active plans. In a next (maybe automated) step the AOP is compared with the actual NOP. If there are changes regarding the NOP these modifications have to be implemented into the NOP and verified to avoid inconsistencies between AOP and NOP. The result is saved in the AOP database and distributed as the new and active airport operation plan to the Network Operation Plan of ATFCM and all connected system tools.

Communication and Co-ordination
Communication and Co-ordination proceed between the agents representing the stakeholders in an APOC and between the agents and the operation centres. In the first case they might discuss predicted traffic situations and probable reactions to them or the realisation of individual wishes; in the second case they co-ordinate and inform the operation centres how planned and agreed tasks will be implemented.

To describe how it might work in detail, the explanation of the tasks the agents might be responsible for and the introduction of the roles of the different agents is needed. Section 4.4 addresses this topic with the example of an APOC. In section 4.5 the communication and co-ordination based on the results of section 4.4 are explained.

4.4 Operator Roles and Decision Making

Intensive communication between aircraft operators, ATC, airport and other stakeholders is decisive for the success of co-operation in the management process of an airport. A main idea of an APOC is attaining the best possible co-operation through direct communication between the different stakeholders through their APOC representatives. Future advantages of this central CDM approach are located in possibilities for a faster reaction to critical traffic situations arising and a better consideration of customer wishes. Furthermore each representative stakeholder will have a better awareness of the objectives and interests of the other stakeholders, due to their individual contacts.

Following the TAM approach, all APOC operators use shared information and a joint plan - the AOP. The improvement of the general situational awareness supports a better quality for the collaborative decision making process. All parties know the constraints and are able to react to them. Especially the local contiguity of operators offers one chance to take priorities of one's neighbour into account. The specific information and knowledge necessary for each operator to perform his tasks depending on his specific role could be identified.

Figure 4-10 shows the fundamental roles of agents and the supervisor in an APOC.

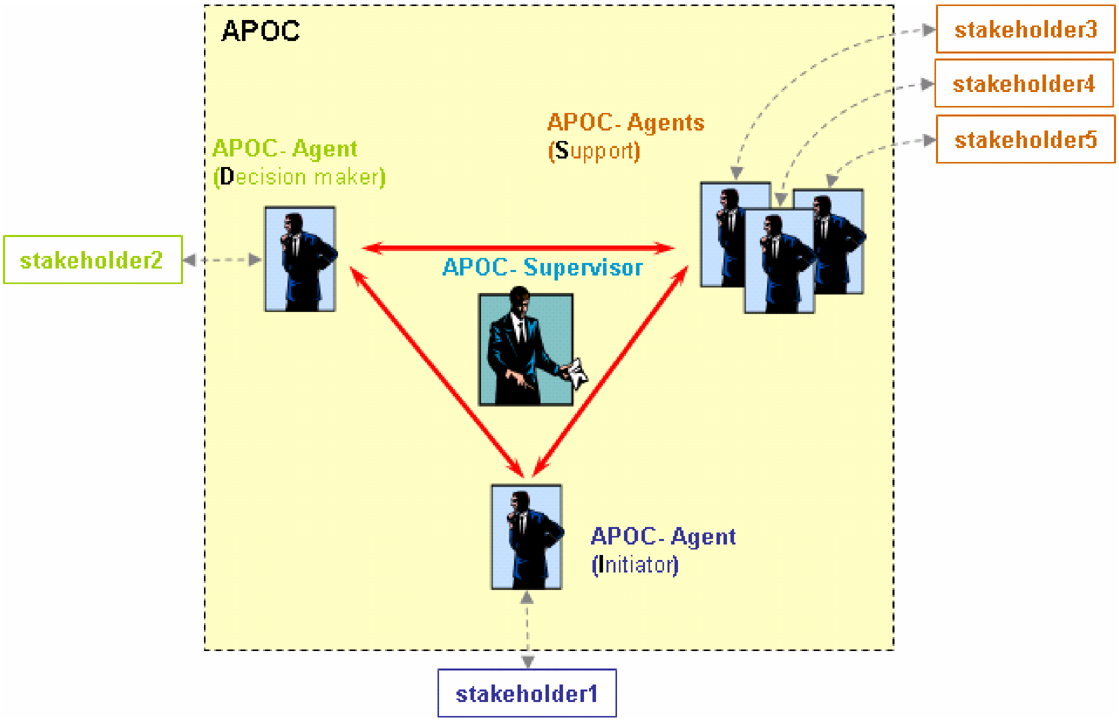

Figure 4-10: Fundamental roles of the agents and the Supervisor in an APOC

Initiator
One agent expresses the wish to modify the AOP (e.g. after consultation with the stakeholder he represents).

Decision Maker
He is responsible for the implementation of a decision. The allocation of decisions to the agents could be derived from today's procedures or is assigned to the agents who are probably responsible for decisions due to their field of duties. The agents might not make all the decisions by themselves, but as representatives of the stakeholders in the APOC, they will have the responsibility to make the decisions which will be executed by the staff of their company.

Support
Other agents, representing stakeholders whose operations can be influenced by the decision, might give supporting information and accept and commit the preferred option provided by the decision maker agent.

Supervisor
The supervisor has the primary role of a co-ordinator and moderator and he controls the compliance of defined rules. He also might act as a conciliator.

All airport stakeholders can be represented in an APOC by agents, working at working positions. Depending on the airport size the number of working positions could vary. APOC - Agents as representatives of the stakeholders take into account stakeholders' goals and interests. Identified working positions are ATFCM-Agent, ATC-Agent, Airport - Agent and Ground Handling - Agent (Figure 4-11). With respect to oppositional interest and goals of different aircraft operators, more than one Aircraft Operator - Agents is conceivable.
Dependent on processing tasks, the APOC - Agents have different roles as decision maker (D), decision supporter (S) and decision initiator (I). The APOC - Agent roles are defined around this set of tasks for every working position.

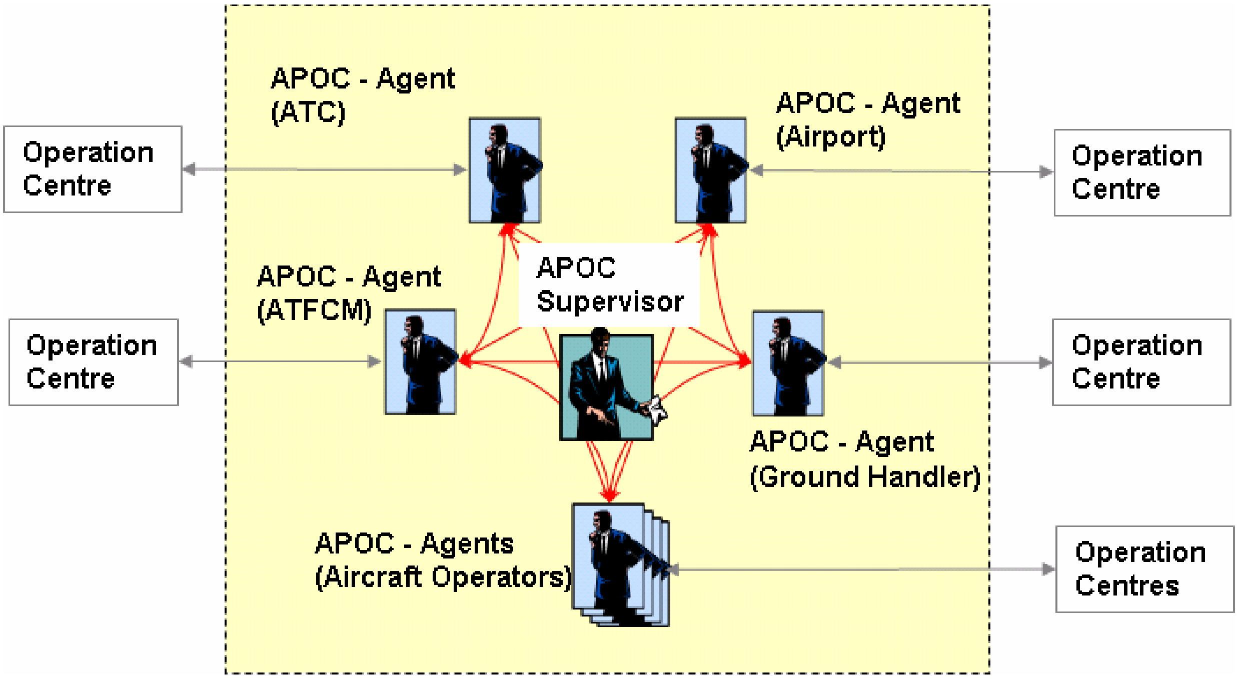

Figure 4-11: Representation of identified working positions in APOC

The APOC Supervisor is not only a role depending on the processing task. It can also be a working position, if the moderation and conflict solution are conducted by one person. Following the goals and interests of the agents on APOC, working positions are defined and resulting roles in the decision making process are represented by:

ATFCM - Agent
The interest of the ATFCM - Agent is to maintain optimum utilisation of sector capacities and avoid sector overloads in all decision making processes. Resulting tasks are identification and negotiation of influences on the NOP which result from possible changes in the AOP.

ATC - Agent
One of the interests of ATC is to guarantee the safety of the air traffic in the manoeuvring area. This could include the reduction and limitation of load on the airport resources, e.g. taxiways. Furthermore ATC should take into account the enhancement of service quality such as wishes of aircraft operators.

The agent is responsible for intended ARR/DEP flow, change of runway utilisation, predictable inhibition of a runway and changes of the direction of operation. In all tasks, other APOC - Agents are involved and the decision making process should be collaborative. The ATC - Agent has to support the task capacity prediction and prioritisation/ de-prioritisation of flights. He has to be informed about the stand and gate allocation and about inhibitions of a runway by an Airport - Agent.

Aircraft Operator - Agents
Aircraft operators are interested in stability and regularity of operations to guarantee the passengers punctual flights and guaranteed transfers between connecting flights. They want to improve the irregularity management such as prioritisation and cancellation of flights (to adjust demand) and they want to increase the efficiency. Aircraft Operator - Agents basically will have a view on several flights in detail. A lot of decisions and requests will be met at this level. But they also will be incorporated in decision making processes concerning performance and flow targets of airport operations. Aircraft Operator - Agents are responsible for prioritisation and de-prioritisation of flights. They initiate and support intended ARR/DEP flows and initiate slot allocation at the departure airport, set target times, change of runway utilisation, predictable inhibition of a runway, change of direction of operations by request.

Airport - Agent
Enhancement of punctuality and improvement/optimisation of the utilisation of available resources are main objectives of the airport. The airport is also interested in the optimisation of operations with improved utilisation of available resources. The Airport - Agent is responsible for predictable inhibition of a runway and monitoring stand and gate. He initiates and supports predetermined ARR/DEP flow and supports predicted airport capacity, set target times and prioritisation and de-prioritisation of flights.

Ground Handling - Agent
An objective of the Ground Handler is to guarantee resource availability and keeping the conditions for turnarounds agreed with the Aircraft Operators. The Ground Handler also wants to optimise the utilisation of the ground equipment and staff. In the decision making process the Ground Handling - Agent fills the role as supporter. Hence the Ground Handling - Agent supports predicted airport capacity, set target times, monitors stand and gate, prioritisation and de-prioritisation of flights.

APOC Supervisor
The working position supervisor and role supervisor could be realised by one person. The main interest is to conciliation of conflicts between agents with the objective of reaching consensus decisions with respect to the interests of all stakeholders. The APOC supervisor is responsible for providing the predicted airport capacity. In all decision making processes he can intervene and moderate in supporting the decision making process. The APOC supervisor must be a neutral person and the salary should be paid from the stakeholders.

4.5 Co-ordination & Communication

Co-ordination AOP and NOP
The co-ordination between AOP and NOP is quite straightforward and will be possible thanks to the CDM processes that characterise the establishment and maintenance of the AOP.

When the AOP is for the first time established, the corresponding CDM process involves the ATFCM entity. The first AOP will be validated only if no ATFCM constraint is violated, i.e. if it is consistent with the NOP.

The same will apply when the AOP is updated at some point in time. The validation of a modification at the AOP level will involve the ATFCM entity which is still part of the corresponding CDM process. Again, the update of the AOP will be validated only if it is consistent with the NOP (no ATFCM constraint is violated).

Co-ordination intra APOC
With respect to role allocation in the previous section, the logic behind co-ordination of tasks will be introduced. In the decision making process, the stakeholders will also be involved through the agents.

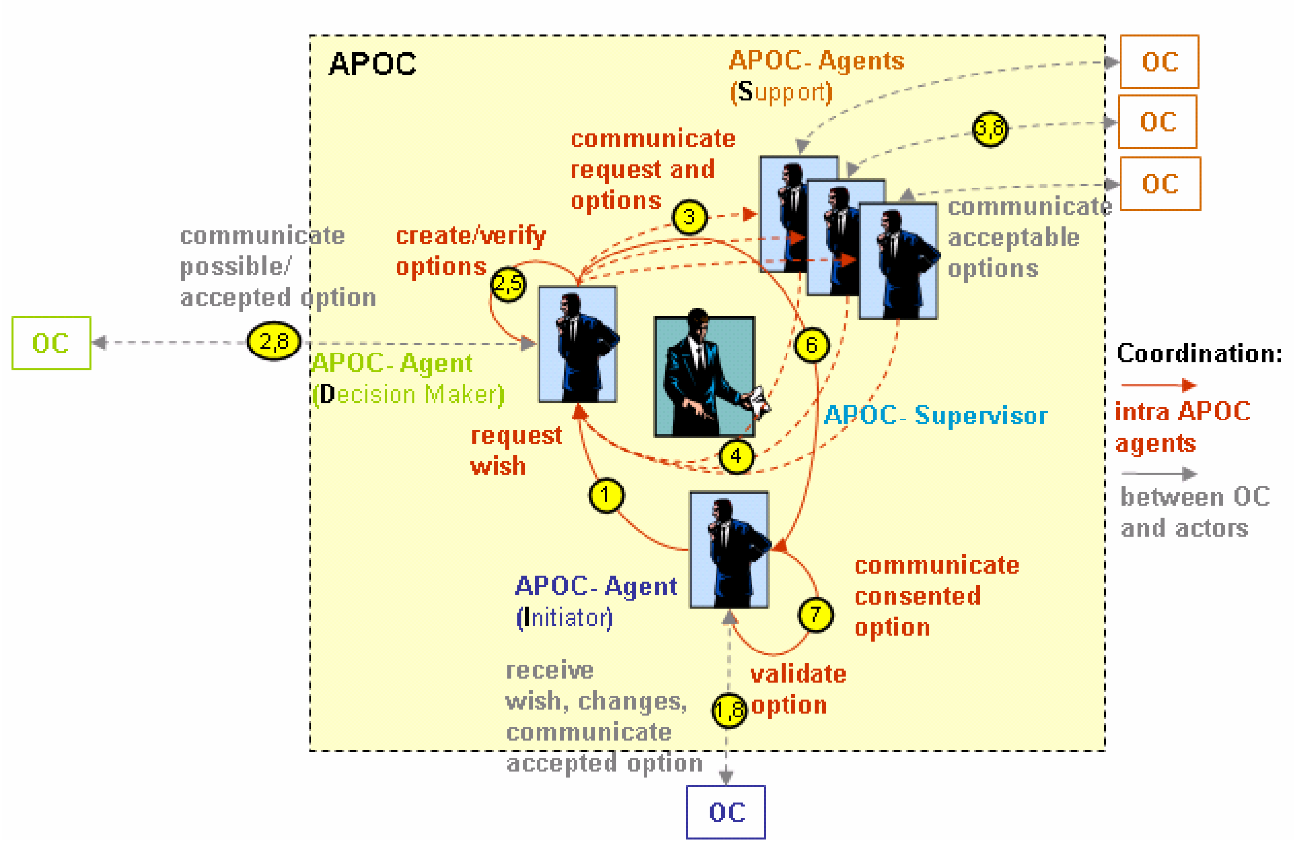

Figure 4-12 Moderated collaborative decision making process

In this variant (Figure 4-12), there is enough time available to consider and discuss the various options with respect to the different interests of stakeholders. Methods of game theory can be used.

(1) An APOC – Agent (Initiator) is aware of the predicted traffic situation (situation assessment & analysis) and wants to request a wish (due to his own experience or after having consulted the company he represents) from another APOC – Agent who is responsible for the decision (e.g. Aircraft operator wants to change target times, ATC decides about the realisation).
(2) The APOC – Agent (Decision Maker) develops possible options after having consulted the company he represents. He also might be able to find options on his own (plan generation).
(3) The APOC – Agent (Decision Maker) presents the option to other APOC – Agents (support), who must agree with the developed options.
(4) The APOC – Agents (Support) provide the APOC – Agent (Decision Maker) with their agreement/disagreement (e.g. about stands and equipment available).
(5) After getting all necessary information the APOC – Agent (Decision Maker) chooses the best option and verifies it (Plan Generation).
(6) The APOC – Agent (Decision Maker) provides the APOC – Agent (Initiator) with the verified option.
(7) The APOC – Agent (Initiator) validates/rejects the verified option.
(8) The decision will be communicated to the stakeholders e.g. by phone (Plan Implementation). It is also feasible that agreed changes might be provided to the stakeholders automatically via the AOP (open issue).

Moderated by the supervisor, advantages/disadvantages will be discussed and acceptable compromises for parties will be sought. This process can be supported by what-if tools which consider evaluations based e.g. on game theory.

In a different variant due to time constraints the decision might need to be made much faster. In this case possible options given by the decision maker are limited. In such a variant the role of a supervisor might have to be dispensed with.

Co-ordination APOC and Operation Centres

Different decisions met in an APOC need the agreement of the companies the agents work for. It cannot be expected that every agent in an APOC knows all the internal procedures and that all responsibilities will be delegated to him. He needs to co-ordinate possible decisions with persons responsible for the execution, as far as today's structures will still exist in the future.

Depending on the task, the agents might explain the anticipated situation to the persons responsible in the OCs. The agents can provide them with possible solutions they might agree on or they themselves provide the agents with possible solutions due to internal rules. It is also feasible that both need to discuss different alternatives, that they assess advantages and disadvantages. In this way the agent can provide the responsible person in the OC with additional information, about concessions of other stakeholders/agents or possible disagreements, respectively.

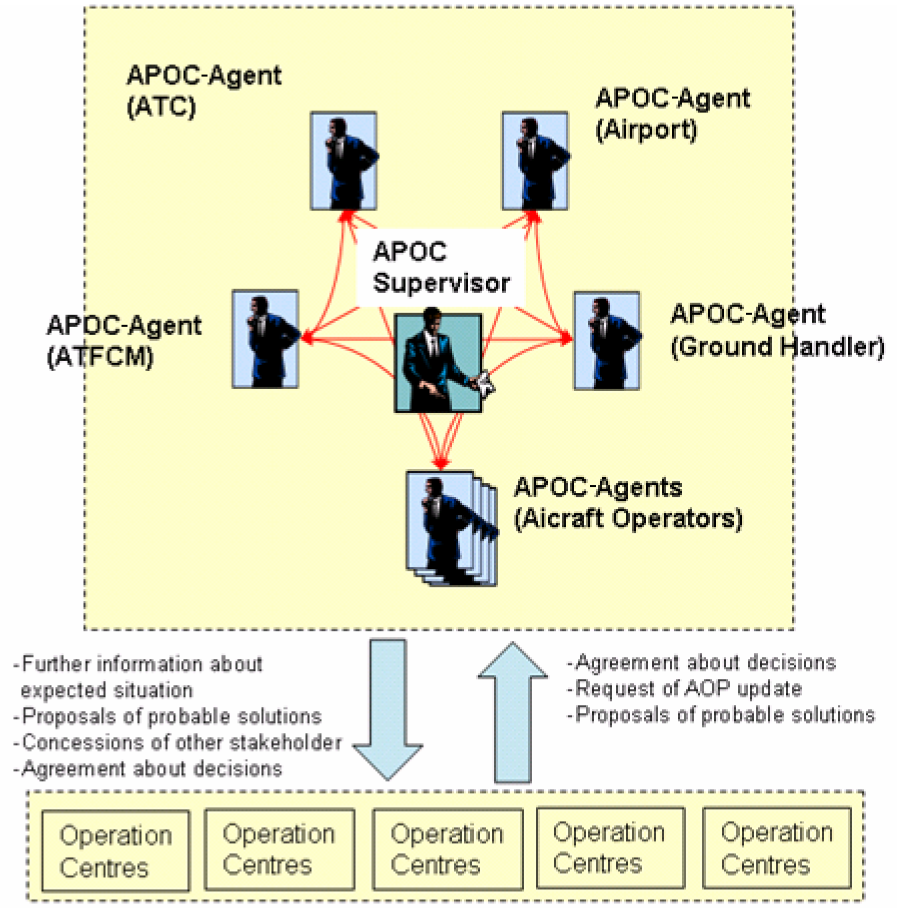

Figure 4-13: Communication between APOC - Agents and stakeholders (OC)

Depending on the airport, if a control centre is available the communication between APOC and OCs might produce conflicts between the control centre and OCs due to possible divergent instructions. In this case, communication between APOC, control centre and OC must be established and the tasks divided.

5. Annex

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5.2 Acronyms and Abbreviations

A/C	Aircraft
A-SMGCS	Advanced Surface Movement Guidance and Control System
AAM	Airport Airside Model
ACC	Area Control Centre
ACI	Airports Council International
AMAN	Arrival Manager
ANSP	Air Navigation Service Provider
AOC	Airline Operation Centre
AOP	Airport Operation Plan
APOC	Airport Operation Centre
ARR	Arrival
ATFCM	Air Traffic Flow and Capacity Management
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATM	Air Traffic Management
ATS	Air Traffic Services Authority
C-ATM	Co-operative Air Traffic Management
CDM	Collaborative Decision Making
CFMU	Capacity Flow Management Unit
CNS	Communication, Navigation, Surveillance
CTOT	Confirmed Take-off Time
CWP	Controller Working Position
DEP	Departure
DMAN	Departure Manager
DPI	Departure Planning Information
EUROCAE	European Organisation for Civil Aviation Electronics (regulatory agency for certifying aviation electronics in Europe)
EUROCAE WG-69	Workgroup of EUROCAE for the standardisation of CDM
EIBT	Estimated In Block Time
EOBT	Estimated Off Block Time
ESC	European ATM Systems and Convergence
FP	Flight Plan
FUM	Flight Update Message
HMI	Human Machine Interface
IATA	International Air Transport Association
K-ATM	Kooperatives Air Traffic Management
NOP	Network Operation Plan
OC	Operation Centre
OC	Operational Concept
OCA	Overall Concept and Architecture (activity of the ESC Business Division)
OCD/ConOps	Operational Concept Document (OC provided by the OATA project)
QoS	Quality of Service
QoSC	Quality of Service Contract
RWY	Runway
SAM	Slot Allocation Message
SID	Standard Instrument Departure
SIT	Slot Issue Time (SIT1 is the time when the CFMU issues the SAM)
STAR	Standard Arrival Route
SWIM	System Wide Information Management
TAM	Total Airport Management
TMAN	Turnaround Manager
TOBT	Target Off-block Time

TOP	Total Operations Planner
TTOT	Target Take-off Time
TWR	Tower Control (normally: ATC for RWY and inbound traffic)