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# Table of Contents

**REVISION HISTORY** ................................................................................................................................................................. 5  
**AUTHORS** ............................................................................................................................................................................. 6  
**TABLE OF CONTENTS** ............................................................................................................................................................ 7  
**TABLES** .................................................................................................................................................................................... 9  
**FIGURES** ................................................................................................................................................................................... 9  

## 1. EXECUTIVE SUMMARY .......................................................................................................................................................... 11  

## 2. INTRODUCTION ................................................................................................................................................................... 13  
### 2.1. MOTIVATION ................................................................................................................................................................. 13  
#### 2.1.1. Global Trends and Forecasts ....................................................................................................................................... 13  
#### 2.1.2. General Operational Problem ................................................................................................................................... 15  
### 2.2. STATE OF THE ART .......................................................................................................................................................... 19  
### 2.3. FURTHERMORE EXISTING GAPS ................................................................................................................................. 22  

## 3. APPROACH OF TAMS ............................................................................................................................................................ 25  
### 3.1. BACKGROUND ............................................................................................................................................................... 25  
### 3.2. VISION ................................................................................................................................................................................ 26  
### 3.3. SCOPE ................................................................................................................................................................................ 27  
### 3.4. GOALS ................................................................................................................................................................................ 30  
### 3.5. INSTRUMENTS FOR ACHIEVEMENT OF GOALS .......................................................................................................... 32  

## 4. CONCEPT OF AIRPORT OPERATIONS WITH TAMS ........................................................................................................ 37  
### 4.1. PRINCIPLE OF THE AIRPORT OPERATION CENTRE (AOP) ....................................................................................... 37  
#### 4.1.1. Possible AOP Implementations ..................................................................................................................................... 38  
### 4.2. AIRPORT OPERATION PLAN (AOP) ................................................................................................................................. 41  
#### 4.2.1. Required Static Data ..................................................................................................................................................... 42  
#### 4.2.2. Data for Incorporation in an AOP .................................................................................................................................. 42  
### 4.3. KEY PERFORMANCE INDICATORS ................................................................................................................................. 43  
### 4.4. ALERT MANAGEMENT ..................................................................................................................................................... 50  
#### 4.4.1. Types of Alerts ............................................................................................................................................................... 51  
#### 4.4.2. Management of Performance Alerts ............................................................................................................................ 51  
### 4.5. ROLES OF AGENTS ........................................................................................................................................................... 58  
#### 4.5.1. Functional Roles ............................................................................................................................................................ 59  
#### 4.5.2. Interaction between AOPC and “the Outer World”. ........................................................................................................ 65  
#### 4.5.3. TAMS Collaborative Airport Planning ....................................................................................................................... 67  
#### 4.5.4. Fairness within the CAP Process .................................................................................................................................. 71  
### 4.6. APOC WORKING POSITIONS ......................................................................................................................................... 72  
#### 4.6.1. APOC Video Wall .......................................................................................................................................................... 72  
#### 4.6.2. Agent Working Positions .......................................................................................................................................... 75  

## 5. IMPLEMENTATION OF TAMS CONCEPT ....................................................................................................................... 81  
### 5.1. TIME PHASES IN TAMS .................................................................................................................................................... 81  
### 5.2. A-CMD IMPLEMENTATION .......................................................................................................................................... 83  
#### 5.2.1. Implementation ............................................................................................................................................................ 83  
#### 5.2.2. Enhancements .............................................................................................................................................................. 87  
#### 5.2.3. Future Prospects .......................................................................................................................................................... 87  
### 5.3. OPERATIONAL REQUIREMENTS AND CORRELATED SYSTEMS ................................................................................ 88  
#### 5.3.1. Data Management ....................................................................................................................................................... 89  
#### 5.3.2. Operational Management ........................................................................................................................................ 93  
#### 5.3.3. Performance Management ....................................................................................................................................... 100  
#### 5.3.4. CDM-process and Joint What-if (chapter 4.5.3) ............................................................................................................ 105  
#### 5.3.5. Strategy Capability ..................................................................................................................................................... 107
5.4. VIDEO WALL ........................................................................................................................................ 108
5.5. AGENT WORKING POSITION ............................................................................................................. 112
  5.5.1. Airport Agent Working Position ..................................................................................................... 112
  5.5.2. ATWP as Part of ATC Agent Working Position ............................................................................ 113

REFERENCES .................................................................................................................................................. 115

ABBREVIATIONS ........................................................................................................................................... 123
Tables

TABLE 4-1: DEFINITION OF KPIs WITHIN THE ATMAP FRAMEWORK ................................................................. 46
TABLE 4-2: SAMPLE OF KPIs FOR TAMS .................................................................................................................. 48
TABLE 4-3: A-CDM MILESTONES AND BORDERS OF POSSIBILITY WINDOW ................................................... 50
TABLE 4-4: INFLUENCE OF DIFFERENT STAKEHOLDER AGENTS ON KPAs ................................................... 61
TABLE 4-5: RESPONSIBILITY OF STAKEHOLDER AGENTS FOR CAP RELATED RESOURCES ......................... 63
TABLE 5-1: POSSIBLE NEW LANDSIDE MILESTONES ....................................................................................... 88
TABLE 5-2: ACISP CAPABILITIES ......................................................................................................................... 90
TABLE 5-3: INFORMATION OF SGMAN CAPABILITIES ...................................................................................... 96

Figures

FIGURE 2-1: INTERESTS OF STAKEHOLDERS ........................................................................................................ 16
FIGURE 2-2: PROCESS CHAIN OF AIRPORT PROCESSES ................................................................................... 18
FIGURE 3-1: SESAR ATM LIFE CYCLE [35] ........................................................................................................ 28
FIGURE 4-1: KPAs AND KPIs DEFINED IN THE ATMAP FRAMEWORK .......................................................... 45
FIGURE 4-2: KPAs DEFINED IN THE ATMAP FRAMEWORK AND POSSIBLE INTERPRETATION OF LANDSIDE KPIs . 47
FIGURE 4-3: PREFERENCE AND POSSIBILITY WINDOW [23] ........................................................................... 53
FIGURE 4-4: PREFERENCE AND POSSIBILITY WINDOW FOR PUNCTUALITY (TOP), FLOW (MIDDLE) AND
PERFORMANCE TARGET (BOTTOM) [23]. ............................................................................................................ 54
FIGURE 4-5: HANDLING OF PERFORMANCE ALERTS ....................................................................................... 55
FIGURE 4-6: EXEMPLARY PREFERENCE AND POSSIBILITY WINDOW ON EVENT LEVEL .................................... 57
FIGURE 4-7: IMPLEMENTATION OF DECISIONS MADE IN THE APOC .......................................................... 66
FIGURE 4-8: SCHEMATIC REPRESENTATION OF AN APOC VIDEO WALL ..................................................... 73
FIGURE 4-9: APOC VIDEO WALL EXAMPLE ...................................................................................................... 73
FIGURE 5-1: AIRPORT CDM FUNCTIONAL GROUPS [28] ................................................................................ 83
FIGURE 5-2: A-CDM MILESTONE APPROACH [27] .......................................................................................... 84
FIGURE 5-3: SPIDER DIAGRAM FOR QoS ............................................................................................................. 101
FIGURE 5-4: DISPLAY OF CDM-RELATED PROCESS TIMES BY APM ................................................................ 101
FIGURE 5-5: DESIGN DRAFT FOR FLOW LEVEL KPI DISPLAY ......................................................................... 104
FIGURE 5-6: VISUALIZATION OF INTENDED APOC STEERING ....................................................................... 110
FIGURE 5-7: VISUALIZATION OF INTEREST OVERLAP ...................................................................................... 110
FIGURE 5-8: VISUALIZATION OF JOINT WHAT-IF .............................................................................................. 111
FIGURE 5-9: APOC HMI LAYOUT – COMBINED VIEWS ...................................................................................... 112
1. Executive Summary

TAMS is a Research & Development project under the funding of the German Ministry of Economics based on a decision of the German Bundestag. The abbreviation TAMS stands for Total Airport Management Suite and one of the project’s goals is to create a first industrial tool suite solution addressing parts of DLR’s innovative Total Airport Management (TAM) philosophy.

The TAMS Operational Concept Document (OCD) describes principles of TAM, their relationship and the industrial solution that is developed within this R&D project.

Chapter 2 introduces currently existing problems within the Air Traffic Management (ATM) domain and fundamental constraints that frame the research perspective. The current state-of-the-art supplements this view and allows to assess the gap that is still present and that is driving the motivation behind the scientific TAM approach and the TAMS project and its corresponding paradigm shift from an Airport Collaborative Decision Making (A-CDM) philosophy to live Collaborative Airport Planning (CAP).

Chapter 3 describes the approach that is taken within the TAMS project, its vision is explained in detail and additional research and development projects that pick up the underlying notion are briefly mentioned. This chapter concludes with the presentation of TAMS’ goals and the measures that will lead to their achievement.

The subsequent and most important chapter 4 leads to the understanding of the concept of airport operations with TAMS. It starts with the description of the APOC philosophy, offering a new perspective on airport management that poses a paradigm shift towards CAP. After introducing the Why-What-how behind this approach, the difference between either a centralised or a virtual variant of an APOC is covered.

Performance based airport operations as proposed by TAM need corresponding measures to assess performance. So-called Key Performance Indicators (KPIs) will be used within TAMS; these are derived and put into the context of the Airport Operation Plan (AOP) and the APOC, putting an emphasis on the importance of and the quality of underlying data for the central element AOP. Alerts will indicate deviations from expected performance or process behaviour. The descriptions of roles and responsibilities of APOC agents, tasks, decision and negotiation guidelines, working positions and the APOC interaction with the world external to the airport conclude this chapter.

How the tools of the TAMS project industrial partners address the described TAM conceptual elements, how these are combined and how the functionality is enhanced into a first industrial total airport management (TAM) application suite (a TAMS) is explained in chapter 5.

The above-mentioned expectation of a paradigm shift at airports that will employ e.g. a TAMS solution and the necessity of a migration procedure is recommended to be addressed prior implementation at the airport addressed.

The envisaged target processes at the airport with the focus on collaborative airport planning within an airport operation centre (APOC), formalised as Business Use Cases (BUC), will complement this document in Annex B [62]. These consider all partners involved in the management of flights and its supporting processes. The descriptions presented are on an abstract and more logical level, not taking into account specific technical definitions related to software implementation. The BUCs will be associated to one or several Operational Scenarios (OS), picturesque situations the airport is confronted with.
This document is intended to remain on a high and abstract level. Descriptions required for understanding the technical details of TAMS belong to the second-level concept documentation represented in the TAMS System Requirements Description [64] and TAMS System Architecture Description SAD / Interface Definition Documentation IDD [63].
2. Introduction

2.1. Motivation

2.1.1. Global Trends and Forecasts

The aviation industry has developed with strong growth rates in the last decades. In the late 1980s, the total number of IFR\(^1\) flights in Germany increased by 9 to 13 % per year [18]. The total number of international passengers in Germany records an annual mean accretion of 7.4% in the 1990s [60], while the total number of industrial flight movements in the same decade shows an augmentation of over 45% ([9], [10]). The growth rates in other European countries were similar or even stronger [42]. Barely any other industry developed over such a long period so dynamically and is so dependent on the corresponding infrastructure at the same time. The capacities of runways, airspace, communication and navigation systems, as well as landside facilities are limited. Not all infrastructures can be extended. Where it is possible, long periods for preparation and execution have to be considered. For this reason, the development of long-term scenarios and strategies is of great importance for the aviation industry. They allow early to identify trends and to shape future developments.

At the beginning of the new millennium, one of the most important strategic documents on the European level was the Vision 2020 [44] commissioned by the European Commissioner for Research. Therein, a Group of Personalities comprising representatives from airlines, airports, regulators, air traffic managers, and manufacturers looked ahead and framed expectations of the aviation industry and infrastructure. Three of the main and most concise objectives were: (1) an air transport system that can handle a number of flights tripled in comparison to the year 2000, (2) with a punctuality rate of 99 % and (3) a reduction of process times for passengers (Pax) at the airport to no longer than 15 to 30 minutes for short- and long-haul flights, respectively. The Strategic Research Agenda (SRA) of the Advisory Council for Aeronautics Research in Europe (ACARE) is affiliated to the Vision 2020 ([5], [6], [7]). It defines the areas of research essential to achieve the goals of the vision. Furthermore, the SRA identifies approaches of bringing together the relevant stakeholders and of meeting the challenges on the way to the changes aimed at in aviation industry. In 2004, ACARE presented the SRA 2 with a number of scenarios for the future of the European air traffic management (ATM) and with several High Level Target Concepts ([1], [2], [3]). In 2008, an Addendum to the SRA was published, see [4]. On a global level, the International Air Transport Association (IATA) issued a strategic view of the ATM system [46]. In spite of well-defined objectives, the above-mentioned contributions do not entail any binding actions but represent mere advices.

Since the release of the Vision 2020 to this day a fact-based trend in aviation industry can be derived. The conclusion can be drawn that Europe does not have to face a threefold demand in aviation by 2020 since in the total amount of passenger-kilometres increased only by 22.8% between the years of 2000 and 2008 [39]. Nevertheless, the expected growth rate for air transportation in the next decades is remarkably strong. The EU commission for Mobility and Transport anticipates a doubling of air travel by 2020 compared to 2000 [40]. By the year 2017, Eurocontrol forecasts 22% more IFR flights than in 2010 [30]. Airbus is expecting an annual increase in revenue passenger kilometres of 4.1% [8] and Boeing of 4.4% for European airlines until 2029 [16].

\(^1\) IFR—Instrument Flight Rules
Generally, airports are considered as the restricting parameter for the future growth of the aviation industry [29]. However, there are many challenges to the expansion of capacity for instance that the busiest European airports are close to big cities [74] where land use and noise pollution have significant adverse effects. Time-consuming mediations between the airport operator, residents, and environmental associations are often the result. Politically, the development of airports in Germany is also limited and strict approval procedures have to be fulfilled [17]. Such administrative decisions and stakeholder negotiations can last over long times and often retard an infrastructure project by years ([12], [52]). For these reasons, an enhanced utilisation of existing capacities by increasing the efficiency of procedures and systems will be inevitable.

Efficiency, however, is not the only area of interest for the ATM system. In 2004, the European Parliament and the Council laid the foundation for the Single European Sky (SES) initiative with a number of regulations ([69], [70], [71], [72], [68]). These aimed at enhancing particularly safety, efficiency, and punctuality. The emphasis shifted with SES 2 to sustainability, monitoring and regulation of the performance of the ATM system ([65], [38]). The Single European Sky ATM Research (SESAR) program emanated from the initiative as its technical component to perform the necessary tasks in research and development. Two of the main deliverables of the corresponding definition phase were the ATM Target Concept and the ATM Master Plan ([56], [57]). With these documents, SESAR establishes a concept that aims at enabling all airspace users to conduct their operations with minimum restrictions and maximum flexibility while meeting or exceeding a number of key performance targets. The approach is based on the four-dimensional trajectory (position and time) which represents the intention of the user. The ATM system shall ensure the safe and cost efficient execution of the trajectory with minimal alteration. Restrictions to the intention may only be accepted for reasons of separation and safety and for the greater benefit of an optimised ATM network. On the airport level, the key elements of the SESAR concept is an evolution towards a more collaborative, performance based process of airport operations planning. In particular, SESAR calls for the identification and definition of those processes necessary for ensuring common planning, common situation awareness, and a common performance framework for airport operations. These demanding objectives are the directive for the SESAR Joint Undertaking assigned with the currently running development phase of SES. In summary, it can be stated that the expectations on the future airport go far beyond the mere overcoming of shortcomings in runway capacity.

Another core task entailed by the SES regulations is the analysis and assessment of ATM activities ([69], [65], [38]). In 2010, this function of the ‘Performance Review Body’ [66] was finally conferred upon Eurocontrol [67] that handed the task on to the previously founded Performance Review Commission (PRC). The mission of this committee is to identify key performance indicators (KPIs\(^2\)), to set target values for the ATM system, to collect data, and to report the results of the review. Moreover, the PRC shall propose potential improvements to the effectiveness of the network ([31], [66]). These recommendations may be approved by the Commission of the EU and transmitted to national authorities who need to implement binding national objectives [38]. Even in case there are no consequences for member states, the annual Performance Review Report of the PRC makes national ATM systems and their performance comparable and reveals weaknesses [48]. With the ATM Airport Performance (ATMAP) Framework, the PRC identified key performance areas (KPAs\(^3\)) and associated KPIs particularly for airports. It elaborated an approach for assessing operations of the airports’ airside and the nearby airspace and the airports’ integration in the network [51].

\(^2\) The general purpose and the utilisation of KPIs in TAMS will be addressed in chapter 4.3.

\(^3\) The general purpose and the utilisation of KPAs in TAMS will be addressed in chapter 4.3
Therewith the achievements and failures of airports on their way to meet the SESAR expectations become measurable and the necessity of improvements in the KPAs become more pressing.

After the consideration of the historical and current data on air traffic, the political environment and its high-level goals as well as the areas of improvements expected from airports, an approach from the functional point of view seems suitable. Therefore, the following paragraphs will highlight the current operational procedures and challenges at airports.

2.1.2. General Operational Problem

One feature of many airports is that their organisational structure evolved historically over the years. Depending on the airport, these structures are manifold and complex due to a large number of processes, constraints, dependencies, stakeholder4 interests, and responsibilities.

The term “processes” includes all processes related to air transport on the land- and airside. For instance, air traffic control (ATC) is seen as a stakeholder because their controllers are responsible for processes during the several flight phases, taxi phase and so on. In this context, other stakeholders are the airport operator, airlines, ground handlers, authorities, and security service providers (cf. Figure 2-1).

Accordingly, at one airport the interests of all stakeholders are very different in nature. The following figure exemplarily shows the main framework of interests at an airport. As the airport operator has economic interests in addition to quality criteria and performance values, other stakeholders are more interested in complying with the contractual terms (e.g. ground handler) or maintaining the safety and security in air traffic (e.g. ATC, authorities) in addition to their economic interests. Airlines thereby represent the link between the actual end customers - the passengers - and the airport. Besides their economic interests, they are constantly concentrating on their customers’ needs and requirements. Therefore, airlines partly act as a delegate of passengers towards the airport, because at the end the passenger is paying for the whole service (a great amount solely through his own ticket).

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4 In air transport, we define stakeholder as those who are responsible for a specified process

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Figure 2-1: Interests of stakeholders

Depending on the role of the stakeholder at the respective airport, a changing diversity of interests arises. In Figure 2-1, this fact is exemplarily highlighted through the blue connections. For example, the airport operator can take on ground handling tasks whereas airlines due to the ownership of infrastructure, such as terminals, have their own opportunities to design the interior and accomplish tasks and services (e.g. baggage services, passenger services, gate management). The situation is further complicated by a business competition of airlines among themselves or between several companies, such as ground handlers applying for service contracts of the airlines. Depending on the size of an airline at the respective airport, the airline can also establish own services and therefore compete with e.g. the airport operator offering the same services. The airline might provide passenger services, like ticket sales, check-in, special services (unaccompanied minors, PRM\(^5\), VIP services, airline lounges, etc.), boarding, as well as ramp services like baggage make-up, baggage transfer, baggage transport, aircraft loading and off-loading, and cargo handling. Often such services as catering, cleaning, water, toilet, pushback, and towing as well as aircraft maintenance are organised in combined units with grouped actors. Sometimes even the gate management and the entire de-icing process are also provided by an airline with own personnel. Each one of these separate processes has one or multiple dispatchers allocating the necessary resources to get the process done in time.

Based on these interdependencies, it is obvious that a variety of stakeholders can be involved in different ways in the process chain of each flight from approach to takeoff, resp.

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\(^5\) PRM – Persons with Reduced Mobility

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from entering the terminal until leaving (also see Figure 2-2). This poses the problem that due to economical reasons only the own processes of one stakeholder are planned and optimised, partly supported by tools, without the aim to find an airport-wide optimum or goal. Furthermore, the described structures cause more problems since the stakeholders are not aware of possible effects of their own planning on other stakeholders’ plans and therefore do not consider such effects. Observations at airports revealed that stakeholders often do not recognise the need for information exchange and furthermore that a spatial separation of operation centres of different stakeholders exists. That can cause longer reaction times on identified issues and inefficiencies in communication and cooperation of the stakeholders, e.g. due to a limitation to voice communication. In addition, stakeholders do not notice many things of other stakeholders, which are happening while these other stakeholders are managing their own processes.

Thereby, inefficiencies along the process chain may arise, such as waiting queues in the terminal or congestions at the runway, what in turn leads to (rather unnecessary) time buffers incorporated precautionary into the schedule. The principle of first-come first-served may also foster this situation.

Additionally, the heterogeneous system landscape at airports often induces the problem that stakeholders are planning with different and partly divergent information and that a system-supported aggregated comprehensive analysis and prediction of processes is nowadays missing at the airport. Often prediction and expected possible consequences can only be worked out individually based on the operational experiences of local personnel of the different stakeholders.

The complexity and variety of processes is one of the greatest challenges at an airport. The following figure (Figure 2-2) exemplarily highlights the standard process chain related to one flight. For any other flight a similar process flow exists but actors, sequence, and number of processes or other constraints (e.g. terms of contract) could alter each time. In general, at airports three main process flows exist: (1) departing and (2) arriving passengers and (3) air-to-air processes of aircraft (turnaround). Sub-processes like baggage and cargo are regarded as an integral part of this three main process flows. The processes are shown on an abstract level in Figure 2-2 and contain several complex sub-processes with different participating stakeholders. For instance, the process of unloading baggage of an aircraft requires that in addition to the appropriate equipment for unloading of the freight compartment, also baggage cars, drivers, and capacities in the baggage handling system can be provided on time. This sub-process chain requires an interaction between the airport operator and the ground handler who both provide their resources to get the superior process (unloading) done. In the end, the respective composition of stakeholders and the detailed process flows may vary from airport to airport.

The three main process flows shown in Figure 2-2 are largely executed in parallel but some processes depend on one another so that the completion of one process is a precondition for the beginning of the other process. For example, passport control cannot take place until the passengers have checked in or the cleaning of the aircraft cannot take place until all passengers have disembarked. This means that the processes depend on another in a varying level of detail and are accomplished by different stakeholders with their respective interests (cf. Figure 2-1).
In this document, the landside is defined as a set of processes dealing with passengers and baggage within the airport terminal; the airside is defined as a set of processes related to the handling of an aircraft at the apron, taxiways, runways, and in the terminal manoeuvring area (TMA). Therefore, all areas and actions within the terminal belong to the airport landside whereas areas, vehicles, and actions outside the terminal belong to the airside. The ground access, which includes public and private transport to and from the airport, is beyond the scope of airport processes in this sense.

A significant and central interface in the whole process chain is the gate where landside and airside process flows concur. Through this central interface, there is a clear dependency between airside and landside. Deviations on both sides at the day-of-ops\(^6\) such as disruptions or delays during operations influence each other. Therefore, deviations on the one side may easily affect the other side and cause further disruptions or delays. For instance, passengers have to wait for their baggage at the baggage belt within the terminal until it is unloaded from the aircraft and conveyed to the right belt, so that delays or disruptions during the unloading on the airside entail delays at the baggage claim on the landside. Hereby, it is clear that for achieving an optimal and failure-free process flow an integrated handling of airside and landside processes becomes necessary. Nowadays these interdependencies are identified at airports but they are merely limitedly considered in the planning process. The figure also highlights that several stakeholders, like airport operators, have an influence on the process chain of passengers but also on the process chain of aircraft. Thereby, inefficiencies may arise, as every stakeholder is keen to achieve an optimal process flow on its own with limited information about the intermediate process steps.

---

\(^6\) The “day-of-ops” means the day of operations and encompasses the whole 24h time horizon of the current day.
Whereas nowadays it is mostly well known on the airside where and in which process step each aircraft is at a given time, on the landside scheduling of terminal operations is mostly restricted to resource allocation with a medium term planning horizon. It is based on flight schedule and only very rough passenger booking information, as far as it is available to the different process partners. Adaptations of the operation plans to the current situation are complicated primarily due to lacking communication among the process partners and missing knowledge about the momentary whereabouts of passengers. With certain information of the passenger location generally only being available after check-in (in case of airport check-in) and boarding, no automated identification and consequently remediation of resources’ excess or shortage is possible ahead of the actual disruption. So far, no kinds of estimations or simulations are made to gain forecasts for the next two to three hours hence entailing the possibility of long waiting lines, crowding, and passenger delays.

In summary, the following problems at airports arise:
- manifold complex airport structures,
- different interests of stakeholders depending on the respective airport,
- competitive situations between different stakeholders or among themselves,
- usually only optimisation of stakeholders’ own processes,
- scarce integrated consideration of land- and airside processes,
- often no or only limited visibility of effects of own planning on other stakeholders’ plans,
- often spatial separation of operation centres,
- delays in the process chain, in general through the principle first-come first-served,
- heterogeneous system landscape at airports,
- lack of system-supported aggregated comprehensive analysis and prediction of airport processes,
- missing information about whereabouts of passengers on the landside.

### 2.2. State of the Art

There are a number of performance areas where airports need improvement as shown in section 2.1.1 and a number of operational challenges for airports presented in section 2.1.2. Consequently, the following paragraphs will examine the status quo of tools and recently developed procedures to support airports in the respective fields of activity. In this context, the available technology and methods will be presented as well as the progress of their implementation.

The most prevalent solution is a set of tools helping controllers to handle efficiently a larger number of operations per time. These tools are in use to a varying extent at most large and at some mid-sized airports to monitor and to manage the complex processes for runway, surface, and turnaround operations. To a certain level, the time horizon of the planning period can be extended enabling for example a timely reaction on capacity shortfalls and the deviation of processes. The following paragraph presents the tools in brief.

The purpose of an Arrival Manager (AMAN) is to handle approaching flights in a more efficient way. Depending on its design, an AMAN can be used for a simple monitoring of arrivals up to a complex sequencing and an advisory generation for the controller. The specification for a Departure Manager (DMAN) varies from a simple pre-departure
sequencing (PDS) up to an advanced DMAN taking into account constraints for optimal takeoff sequences including pre-departure sequencing. With the introduction of A-SMGCS (Advanced Surface Movement Guidance and Control System) at an airport, assistance tools for the coordination of surface operations become available. These tools allow the flexible and optimal planning of taxi procedures and provide accurate taxi-times for each flight. Today, many airlines schedule their aircraft rotations in their flight plans anticipating and estimating potential handling delays. With the implementations of ground handling support tools, the optimisation of processes, resources, and costs of ground handling becomes feasible. Major airports often work with dispatching systems to plan the utilisation of aircraft parking positions and passenger gates. These tools are very flexible and able to consider different kinds of constraints. In contrast, assistance tools for terminal operations are less developed and mostly restricted to resource allocation. Major airlines have software tools available for the coordination of transfer passengers but otherwise no essential applications exist for supervising, managing, or forecasting passenger flows for process steps throughout the terminal.

While each existing airside tool enhances the effectiveness of some sub-processes of the overall process chain, the outcome is limited due to little information exchange with other assistance tools. Mostly, the input data originates merely from flight plans or estimated times. In this case, the calculated times and proposed sequences cannot be optimal. Hence, the sharing of data between stakeholders and their systems becomes more and more important to achieve progress in relevant performance areas. By now, most midsize and major airports have therefore introduced some kind of airport operational database (AODB), though with a varying stage of completion and consequently with a varying kind and amount of data. Generally, data is available in form of master data of the airport and the airlines (e.g. infrastructure information, aircraft types, airport codes) and in form of data commonly described as “fact data” containing flight schedules, timestamps of airport operations as well as actual information of specific flights (e.g. ATOT\(^7\), number of passengers, cargo information). The quality of the data thereby strongly depends on the acquisition method, i.e. if the entries in the database are set manually or ideally automatically. Due to the sensitivity of the data, however, it is yet not possible to combine all useful or respectively sensible and already available data of all stakeholders at the airport in one single database. Consequently, the major stakeholders usually operate their own databases and only supply fundamental information to the common AODB resulting on the one hand in data redundancy and on the other hand in less information for other stakeholders. Therefore, common awareness of the actual situation or good predictability of upcoming events cannot be ensured. Consequently, one of the main goals of recent changes at airports as well as of several on-going research projects, e.g. SWIM (System Wide Information Management) [59], is to improve the data sharing and hence the situation awareness among the different stakeholders. Some of these changes are introduced in the following paragraph.

One of the key enablers for the SESAR target concept (cf. 2.1.1) is the general principle of Collaborative Decision Making (CDM). “Through CDM, decisions are made, supported by improved processes on the basis of common situational awareness and consequently resulting in a better understanding of the network effects on the decisions. This improves the general quality of the decisions, helping to more accurately achieve the desired results” ([56], p. 17). On the airport level, the Airport CDM (A-CDM) standard has been established comprising specifications of roles, responsibilities, and processes [41]. It is based on the A-CDM Operational Concept Document [32] while the initiative came from the Single European Sky regulations ([69], [72], [68]) and a subsequent mandate of the European Commission to

\(^7\) ATOT – Actual Take Off Time

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develop the standard [21]. A-CDM implements a standard for the sharing of relevant information between airport partners notably related to specific milestones. The network represented by the Central Flow Management Unit (CFMU) and A-CDM equipped airports exchange airborne flight progress information, so called flight update massages (FUM), and departure planning information (DPI). This procedure ensures a timely and more accurate planning of the network and an improved short-term allocation of airport resources. Thus, the A-CDM concept aims to harmonise airport operations of the main involved airport partners: airport operators, aircraft operators, ground handlers, de-icing companies, air navigation service providers, and CFMU. A-CDM has the intention to improve flight operations through the increased involvement of aircraft and airport operators in the entire process of air traffic management (ATM) and through an enhancement of the slot compliance to CFMU slots. One of the main outputs of the A-CDM process will be an accurate Target Take Off Time (TTOT) based on a Target Off Block Time (TOBT) provided by the aircraft operator. Overall, delays shall be reduced and the predictability of the system improved. These benefits may be achieved with relatively low investment by interfacing existing systems [24].

The benefit of A-CDM has been shown by EUROCONTROL in initial studies at selected trial airports. The implementation of A-CDM brought benefits for all involved partners in terms of more efficient operations, better utilisation of resources, and increased punctuality [25]. A number of European airports are currently implementing the concept and some airports amongst others Paris-Charles-de-Gaulle and Frankfurt am Main Airport have already launched a fully operational system [26]. The initiation of A-CDM is optional for airport operators and EUROCONTROL proclaims that the information provided by CFMU to A-CDM airports is a valuable and sufficient incentive. Airport CDM may be implemented in different stages. The level of complexity realised depends on the airport concerned. In 2004, Athens International Airport has shown that even a very basic A-CDM tool already provides a reasonably accurate TOBT and enhances the predictability of operations [15]. In summer 2007, Munich Airport became the most advanced A-CDM airport when it successfully started to exchange DPI messages with the CFMU [20], thus entering the network level of A-CDM. At the same time, Munich Airport has also demonstrated local benefits of A-CDM. Since it was introduced, average taxi times have decreased, airport stakeholders use A-CDM procedures to allocate ground resources optimally, and CFMU slot adherence has improved [20]. These operational benefits were expected. EUROCONTROL predicts also a financial gain with a return on investment achievable for all stakeholders within the second year after the implementation [24]. It is expected that other airports introducing A-CDM will experience the same operational and financial benefits [26].

The previously introduced assistant tools and procedures present the opportunity to improve and optimise airport operations. The implementation and especially the application of those measures mostly fall in the competence of the various operational entities of the respective airport. Today, a wide range of such operation centres can be found and all of them have strict fields of responsibility. Often only limited cooperation and sharing of information exists. Generally, the number and size as well as the function of those centres vary from airport to airport and strongly depend on the airport size and the utilisation of capacities. Most operation centres are typically operated by the airport though they are also common for major airlines (e.g. hub control centres) or security. The fundamental tasks, however, are similar for all centres consisting of information gathering and recording, respectively, and if necessary initiating and coordinating measures to ensure optimal handling of changes during the operation. At midsize and large airports, operation centres are customary for

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8 In this context, operation centre is synonym to operational entity, what is more suitable for stakeholders like ATC, where the tower controllers or supervisors are the responsible persons for ATC resources.
security/safety, terminal services, flight operations, baggage, and IT services. Usually, also a special operation centre for crisis management is available. However, a personnel restriction to one stakeholder is common for practically all operation centres. Only very recently, some airports started to set up superior operation centres with representatives of different stakeholders to improve the communication between them and the understanding of each other, for example Zurich Airport.

2.3. Furthermore Existing Gaps

This section reflects the current operational problems presented in section 2.1.2 and the state of the art of assistance tools and processes presented in 2.2, which shall improve the performance of airports in operational as well as long term goals (cf. 2.1.1).

There are a number of auxiliary tools for the optimisation of arrival and departure sequences, of ground movements, and of turnaround processes (cf. 2.2). The individual systems are generally not linked and plan mostly based on separate data sets. Due to inaccurate input data, the programs often do not exploit their potential. The respective operators can only detect influences of their decisions in their own system while the implications to other tools are not visible. The logical consequence is to interconnect the tools. This will presumably entail an improvement in several areas but is problematic since the necessary system interfaces might not have been pre-designed when implementing each system.

Contrary to the more sophisticated airside auxiliary tools, current solutions for the support of terminal operations are merely restricted to resource allocation programs. With the help of such systems, medium- and short-term planning is supported. However, at the day-of-ops, adaptations to resource allocations are mostly made manually on short notice. Nowadays, the terminal management monitors passenger flows only manually and separately for the different process steps. An automated and comprehensive surveillance does not yet exist. Additionally, the prediction of upcoming demands or events is not yet realised and consequently, the planning of forthcoming passenger flows as well as the utilisation of process stations is not established, either. It is obvious that there is a need for further developments on the landside but even the strategic research perspective on the European level developed by SESAR (cf. 2.1.1) regards the airport landside only to a small extent. Notwithstanding, the gate is one of the most important central interfaces (cf. 2.1.2) where at the right point in time the two so far independent process chains of passengers and aircraft have to connect. Consequently, the integration of the land- and airside is of great importance for the optimisation of the overall system, which is not acknowledged by the relevant community up to now.

In recent years, a distinct progress was achieved in the joint utilisation and mutual provision of selected fundamental data amongst the stakeholders. At some airports, there are even shared and collaboratively applied airport operational databases (cf. 2.2). The application of such an AODB, however, does usually not replace the company-owned data management of each stakeholder and does not include all information needed for the overall optimisation of airport processes. Furthermore, operational decisions are mostly still made in order to maximise only the benefit of the decision maker. This philosophy does not harmonise with the paradigm shift initiated in the SESAR concept (cf. 2.1.1) towards collaborative planning of airport processes fulfilling the objectives in common performance parameters.

The concept of A-CDM (cf. 2.2) is a first step in this direction. However, A-CDM will not lead to an environment where the decisions of one stakeholder are made in full awareness of the implications for the others. Solely the individual constraints are taken into account, consequently resulting in a local but not a global optimum of the airport system. Even if all airports in a network have implemented A-CDM, the advantage is limited to an improved
accuracy in planning and to a superior reactivity of the network concerning single events. Furthermore, the application of A-CDM in adverse conditions is still largely in a conceptual stage.

At few airports, a solution for direct communication of the stakeholders has been implemented, customised to upcoming needs on site. Some of these solutions even include a centralised control room. There are, however, not necessarily all relevant stakeholders involved or the control centre is used exclusively for crisis management. Collaboration on a day-to-day basis to maintain and ameliorate the performance level in a normal operating state is not conventional. Where such cooperation between all airport partners on a daily basis is put into practice, mostly tactical\(^9\) planning is conducted. A pre-tactical planning is the missing link between long-term strategic activities on the one hand and tactical planning as well as ad hoc reactions to pending challenges on the other. The pre-tactical planning will provide the opportunity to handle adverse conditions in an optimised way or even to sustain the normal operations due to an early identification of problems. By means of common situation awareness, countermeasures can be initiated before the unfavourable situation even arises. If the adverse circumstances cannot be predicted and arrive instantaneously the collaborative, pre-tactical decision process can presumably accelerate the return to the normal state in the aftermath of the situation. This is particularly the case if the global optimum is prioritised above the optimum of each stakeholder in these situations. Support tools of the medium-term planning as well as specified procedures for the collaborative optimisation are indispensable but still have to be defined and developed in future.

In summary, the following gaps are still pending:

- no system-supported comprehensive planning along the whole process chain,
- no system-supported comprehensive prediction particularly in adverse conditions,
- insufficient comprehensive situation awareness of the stakeholders about the different airport processes,
- lacking integration of landside and airside processes,
- missing prediction and limited surveillance of landside processes,
- no collaborative airport planning process for operational problems,
- no planning and actions of stakeholders according to harmonised performance parameters,
- A-CDM is only a first step into the direction of collaborative airport planning,
- lack of pre-tactical planning,
- limited communication between different stakeholders.

\(^9\) In chapter 3.1, the terms "tactical", "pre-tactical" and "strategic" will be defined and further explained for the TAMS concept
3. Approach of TAMS

3.1. Background

As introduced in the previous chapter, airports are the central nodes and the bottleneck of the air transportation system and the interfaces to other means of transportation, e.g. train or car. The complex problems airports are facing can only be addressed through a thorough and comprehensive solution that takes management of airside and landside processes into account. This is the goal of the Total Airport Management Suite (TAMS) project, in which DLR (German Aerospace Center) is collaborating with the German aviation industry Siemens AG, Inform GmbH, Barco Orthogon GmbH, Flughafen Stuttgart GmbH (FSG), and ATRiCS Advanced Traffic Solutions GmbH & Co. KG to create an innovative airport management system. TAMS, which provides a platform for this area of research, is funded by the German Federal Ministry for Economics and Technology. TAMS is a landmark project planned from December 2008 to May 2012.

The aim of the TAMS initiative is to build a first industrial solution suite to satisfy the required tasks of TAM, a holistic and performance based management approach of airside and landside airport processes. Therefore, the underlying basis – a solution suite satisfying the specifications of A-CDM is completed first. Based upon this, specific TAM key elements will be included and extended by software based landside management capabilities. As TAMS fully respects all turnaround processes and makes the interdependent landside airport processes manageable, the planned system suite poses a unique value for the TAMS partners. The outcome will be fully SESAR compatible and even extends the SESAR scope in Collaborative Airport Planning (CAP).

However, TAMS is not the first project, which deals with the general idea of TAM. To implicate TAMS into the context of current science activities, the following paragraphs introduce briefly other related projects.

TAM-OCD

The DLR Institute of Flight Guidance in collaboration with EUROCONTROL Experimental Centre has developed an operational concept and logical architecture for a Total Airport Management system in 2006. The new concept builds upon the current A-CDM system for airports to produce a comprehensive airport management system based on an Airport Operation Plan (AOP). Also an Airport Operation Centre (APOC) is envisaged, in which people responsible for stakeholder-individual areas – such as airport, air traffic control, airlines etc. – come together in order to draw up, dynamically update, and implement this plan with a tactical and pre-tactical time horizon\(^{10}\) [22].

FAMOUS

Subsequent to the development of the TAM-OCD, the German Aerospace Center started the internal project FAMOUS (Future Airport Management Operation Utility-System). The project ended in 2010. FAMOUS was addressing first steps in the experimental realisation of the TAM-OCD, including building blocks that TAMS reuses for necessary system developments and the simulation environment [23].

Episode 3 Collaborative Airport Planning

Episode 3 (Collaborative Airport Planning) is a project within the sixth framework programme

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\(^{10}\) For definition of the tactical and pre-tactical time horizon compare chapter 3.3
of the European Commission. EUROCONTROL and European partners including DLR conducted it in 2007 to 2009. The Episode 3 project fully integrates the TAM concept [22]. This project encompassed a number of validation techniques, which were used to refine the SESAR operational concept; and, in particular, the various associated “Use Cases” that describe the roles, responsibilities, and possible actions for various individuals in accomplishing diverse tasks related to collaborative airport management. (cf. [37], [34])

**SESAR**

SESAR (Single European Sky ATM Research) was launched by the European Community. SESAR is the technological dimension of the Single European Sky. It has started with the Definition Phase in 2005 and is planned to end with the Deployment Phase in 2020. SESAR will help to create a ‘paradigm shift’, supported by state-of-the-art and innovative technology. SESAR aims to eliminate the fragmented approach to European ATM, transform the ATM system, synchronise all stakeholders and federal resources. For the first time, all aviation players – except research establishments so far – are involved in the definition, development, and deployment of a pan-European modernisation project (cf. [58]). Different work packages of SESAR deal with elements of TAM, like APOC and AOP, but there are no specification documents available until now.

**TITAN**

Another project within the European Research Framework (Seventh Framework Programme) is called Turnaround Integration in Trajectory And Network (TITAN) and is focussing on the turnaround process. It was launched in 2010. The aim of TITAN is analysing the aircraft turnaround process in view of identifying opportunities for improvements as well as the potential influence of traditionally external processes like passenger flow and baggage handling. In the TITAN project, processes on the land- and airside are considered and their impact on turnaround is analysed. Some of these processes, like passenger flow management, have never been treated before in the A-CDM context. TITAN will improve predictability on local and network level, enabling all stakeholders like airlines, ground handlers, and airport operators to increase the efficiency of their operations leading to cost savings via better utilisation of stakeholders’ resources. (cf. [53])

**ASSET**

Another project also using the principles of A-CDM and TAM is the Aeronautic Study on Seamless Transport (ASSET). ASSET is a project within the Seventh European Framework Programme, whose multinational consortium is coordinated by the German Aerospace Center. Fourteen partners in five countries from industry and research, representing nearly all directly or indirectly involved stakeholders (airports, airlines, aircraft, etc.), work jointly on this project. The project aims to find an integrated approach to improve the various modules of airside and landside airport process chains in order to tackle the lack of punctuality and predictability in these processes. ASSET develops two generic airport models to represent a medium-sized and a hub airport. Various operational scenarios are implemented into the models to simulate and assess process alternatives in terms of their optimisation potential. The optimised solutions are additionally assessed in detail regarding monetary and operational aspects. (cf. [11])

**3.2. Vision**

Motivated by the introduction in chapter 2, Total Airport Management (TAM) shall be a concept, to cope with these challenges in the future. The Vision of TAM is to realise the paradigm change from an event based and individual planning of flight operations at an
airport to a Collaborative Airport Planning (CAP), which is based on a defined service level agreement. Therefore, TAM can be understood as the performance based controlling of an airport by using defined airport performance parameters, based on a commonly agreed Airport Operation Plan (AOP), which is built upon a common database and decision making. On the one hand, TAM shall facilitate to keep up efficient and customer-friendly airport operations respectively. On the other hand, TAM consequently shall continue the concept of trajectory based flight planning related to airports by considering the overall turnaround process.

The concept of A-CDM is an important baseline for TAM. Therefore, the now standardised A-CDM Information Sharing (ACIS), the A-CDM Turnaround Process (CTRP), and other functional concept elements of A-CDM, which improve the planning accuracy of flight events, are an important input for the AOP. As a significant improvement, TAM takes the turnaround process and so the concatenation of arriving and departing flights into account. This includes more than is usually done: Based on regular information for an arriving flight all milestones for the concatenated departure leg will be estimated as soon as possible. With this information, possible delays are known early and applicable actions can be taken. Furthermore, TAM provides a novel framework to handle adverse conditions. The concept provides more information about the situation for a greater time horizon and allows an early prediction of the traffic situation in adverse conditions. This aspect also assures airport planning with respect to a common service level agreement, what is beyond the scope of A-CDM.

The concrete vision of the TAMS project is to implement an operational Total Airport Management with the help of a system suite consisting of industrial tools and prototypes to demonstrate the feasibility of TAM with respect to a possible implementation in the near future. The TAMS concept emanates from the TAM approach and is based on the following five pillars:

1. Bringing together all airside and landside stakeholders at one airport to realise CAP.
2. Calculation and prediction of A-CDM Milestones in a high accuracy, by integrated assistance systems under consideration of landside processes.
3. Assurance of the situation awareness by a pre-tactical prediction and planning of traffic operations over the next 24h and the deployment of TAM specific user interfaces for visualisation.
4. Holistic planning and controlling of flight operations for the next 24h considering landside processes using the AOP and the defined airport performance parameters, to adhere to a common performance goal.
5. Support of stakeholders during the decision-making within the CAP process, using improved functionalities and features of assistance systems.

3.3. Scope

The scope of TAMS is the entire airport with monitoring and guiding of airside and landside operations, taking additional information available through System Wide Information Management (SWIM) into account. TAMS makes use of specialised tactical and pre-tactical management systems that are well defined and capable to handle 4D-movements. TAMS will cover the time horizon of the day-of-ops but also the next 24 hours ahead.

Currently, generally two different descriptions for the differentiation of time phases for the planning process of flight operations can be found. On the one hand, the differentiation in
strategic, pre-tactical, and tactical phase like in [22] and [23], and on the other hand, the definition of the ATM Life Cycle introduced by SESAR shown in Figure 3-1 with Long Term, Medium Term, Short Term, Trajectory Execution, and Post Flight Phase [35]. Important for both variants is, that the differentiations are seamless so that the borderline between the time phases are only roughly defined. The TAMS concept needs these definitions to describe the planning process as well as for the implementation of the concept, where the deployed assistance systems play different roles according to the time phases.

![Figure 3-1: SESAR ATM Life Cycle [35]](image)

The difference of time horizon differentiations is the viewpoint, from which the procedures are defined -- the airport viewpoint or the en-route viewpoint. The strategic/pre-tactical/tactical time phases focus on the air-to-air process chain and are defined to describe the planning process for all actions taking place at an airport and its TMA. In contrast, SESAR looks on the en-route process chain and therefore on the gate-to-gate process. Figure 3-1 shows, that the Trajectory Execution phase encompasses all flight phases of a SESAR flight trajectory from off-block at the departure airport to in-block at the destination airport. For that reason, the definitions of borderlines between the different time phases correspond to the off-block of departures; an arrival is always within the execution phase after its take-off, independent of its flight time. This is not sufficient for TAM. For TAM, it is important to differentiate the planning of arrival processes in the same way as for departure processes. This gap will be filled by the additional application of the strategic/pre-tactical/tactical variant of the time horizon description, because the definitions of pre-tactical and tactical time phases do not focus on one specific single time event (the off-block time in SESAR), they may also be applied on arrival time events.

Nevertheless, the time phase differentiation of SESAR is for TAMS as important as the strategic/pre-tactical/tactical time phases. The SESAR ATM Life Cycle gives the stakeholders indications for constraints or possible changes in the planning of airport flight operations - a flight within the execution phase is always difficult or even impossible to re-schedule. The following paragraphs introduce the definition of both types of differentiations and describe how they are used in TAMS.

- **Definition of strategic phase**
  - Today, the strategic phase typically starts after the slot conference and ends seven days before the event [22]. Therefore, this time phase is definitely out of scope of TAMS.
Definition of pre-tactical phase

Today, the pre-tactical phase typically encompasses the time from seven days before the event until the start of the tactical phase [22]. Within TAMS, the pre-tactical phase encompasses the time between 24 hours before event execution and the start of tactical time phase (between 30 minutes and 3 hours before the execution of the event). This is an important aspect of TAMS as well as to comply with the requirements of performance based airport planning and handling of adverse conditions and to fill the gaps introduced in chapter 2.3.

The quality of the planning process within the pre-tactical phase can be described as rough planning. The rough plan contains process times for flight events that are calculated predominantly based on scheduled times and standard process durations. Therefore, a rough plan may be inexact, incomplete and instable, but it shall be a good basis to estimate the further development of the traffic situation ahead of the tactical phase.

Definition of tactical phase

TAMS defines the tactical phase as a phase between pre-tactical phase and ad-hoc level. Therefore, the tactical phase starts between 30 minutes and 3 hours before the execution of the event. The ad hoc level itself is the execution of the event, e.g. the actual off-block or take-off.

Because the quality of planning within the tactical phase can be described as detailed planning, the range of this phase depends strongly on the applied planning method or assistance tool. The detailed plan contains process times for each flight event that are calculated based on accurate and reliable estimated times and also not on standard process durations. A detailed plan intends to be complete and reliable.

SESAR ATM Life Cycle\(^\text{11}\)

Long Term Phase

This phase encompasses the time horizon of several years until approximately 6 month before the day-of-ops. However, this phase is not scope of TAMS.

Medium Term Phase

The Medium Term phase starts around 6 months prior the flight event and ends at EOBT\(^\text{12}\) -24 hrs. Therefore, the Medium Term Phase overlaps in small parts with the pre-tactical phase in TAMS.

Short Term Phase

The Short Term Phase begins with EOBT -24hrs and ends with OBT\(^\text{13}\) -15min. This SESAR time phase overlaps largely with the pre-tactical phase as well as with the tactical phase for the planning of short-haul arrivals and departures in TAMS.

Trajectory Execution Phase

This phase starts at the end of the Short Term Phase (OBT -15min) and ends if

\(^{11}\) The following definitions refer to [35], Annex B, where the whole definitions of actions within the time phases can be found.

\(^{12}\) EOBT – Estimated Off-Block Time

\(^{13}\) OBT – Off-Block Time
the flight finished his flight trajectory with the in-block at the destination airport. For TAMS, this time phase encompasses the departures if the Short Term Phase ends, and all arrivals, after take-off at their departure airport. Therefore, this time phase covers the tactical and ad-hoc time phase as well as the pre-tactical time phase if an arrival is e.g. a long-haul flight.

### Post Flight
- The post flight phase starts at the day after the day-of-ops and shall contain analysis of the processed flight. These analyses are generally important to optimise operational procedures continuously. Nevertheless, the TAMS operational concept document lays its focus on the collaborative airport planning process before event execution.

## 3.4. Goals

As shown in section 2.2 and section 2.3 present developments only consider parts of the air transport system. Currently no suitable systems having the possibility to integrate airside and landside aspects are available, although the need for the development of a comprehensive airport management has been proven. Thereby, a significant cause is probably the historically evolved structure of airports (cf. section 2.1.2) and the paradigm of individual planning instead of collaborative airport planning (cf. section 3.2).

The TAMS vision is to resolve the operational problems mentioned above (cf. section 3.2). Therefore, TAMS represents a comprehensive approach whereas airport processes shall be coordinated, controlled, and regulated among all stakeholders in an appropriate manner. Based on this TAMS vision, the following goals can be derived, which shall contribute to the achievement of the described vision.

### Better Cooperation of Airport Stakeholders

Nowadays, stakeholders at an airport like ATC, airport operator, ground handler, and airlines are solely responsible for their own processes at the airport. They plan and organise these processes on their own and in separate operation centres. Due to this usually spatial separation information sharing, communication, and mutual decisions are very rough which finally results in suboptimal cooperation and process coordination. Therefore, the processes are not harmonised optimally with each other and reasons for actions are not discussed and sometimes even not known, what in turn can result in misunderstandings and conflicts. At the end both factors induce that supervision and regulation of airport processes do not proceed in an optimal manner. With the TAMS concept, a better coordination of all airport stakeholders shall be achieved. Thereby, it is expected that suboptimal processes caused by lacking coordination can be avoided in the future.

### Collaborative and Coordinated Planning

To enable supervision and regulation of an airport in respect of central airport performance parameters (cf. section 3.2), required actions and steps have to be developed, coordinated, and defined collaboratively in advance. Thereby, the adherence to agreed performance parameters shall be achieved. In the TAMS concept a supervision and regulation of airport processes on a superior level is assumed whereby a coordination of the planning processes of each stakeholder becomes necessary. Hereby, the timely provision of relevant data for the stakeholders own planning process shall be guaranteed and the planning results shall lead to

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14 In this context, operation centre is synonym to operational entity, what is more suitable for stakeholders like ATC, where the tower controllers or supervisors are the responsible persons for ATC resources.
the achievement of the stakeholders’ interests.

In case that a coordinated planning can be obtained, positive effects regarding the target goals can be expected. The coordinated planning between different stakeholders will presumably have an effect on better predictions regarding the estimated overall process flows and the available resources. The coordinated planning process provides a comprehensive image of the estimated development of airport operations. According to this image, the development of the agreed performance parameters can be deduced and the compliance with defined targets can be determined. Thus, conclusions can be drawn about required controlling or also about regulating actions in certain process flows.

Effective and Efficient Resource Management

At an airport, an effective and efficient utilisation of available resources poses a central challenge for all operating stakeholders. Thereby,

- **effective utilisation** represents the use of resources for the fundamental fulfilment of assumed tasks, in which an appropriate service delivery with respect to quantity, quality, and on-time performance is necessary.
- **efficient utilisation** represents the ratio of used resources to achieved results with respect to cost effectiveness.

Even though effectiveness (the fulfilment of contracts) has to be guaranteed in the first instance, efficiency is of fundamental interest for each stakeholder in respect to the management of his affairs. Concerning economic aspects, the efficient utilisation of available resources becomes mandatory so that positive company earnings can be achieved. This is especially significant for airport operations due to often high costs like personnel or infrastructure investments. Therefore, the company’s economic success is ensured. The objective of a maximal utilisation of resources often corresponds to single process steps or only parts of process chains. Thereby, the stakeholders attempt to provide as many services as possible by using the available resources.

Because of constantly changing constraints (e.g. arrival and departure times or weather events) a continued adjustment of planned resources becomes mandatory. With the TAMS concept, an increase in effective utilisation of resources shall be achieved by providing stakeholders the possibility to coordinate their resource planning and use. Hereby, an unnecessary allocation of resources shall be avoided and capacities for utilisation of resources shall be created, which otherwise without TAMS, would be bound. Further, the TAMS concept shall enable all stakeholders to efficiently plan and utilise their available resources with respect to the expected traffic development.

Reduction of Avoidable Delays

Generally, stakeholders involved in airport operations are interested in complying punctually\(^\text{15}\) with the pre-planned schedule that is influenced by frequently emerging changes or deviations. In air traffic, delays arise always at the time when primary planned times of events (e.g. off-block time of an aircraft) cannot be kept during operations. That means the planned time deviates from the actual time for a certain event. A great variety of causes can lead to these unpunctualities, but it can be assumed that parts of them are avoidable. Overall, avoidable delays can be defined as delays caused by an imbalance of capacity and demand or inefficiencies along the process chain as a result of deviations, whose occurrence can be avoided if they are recognised in time and appropriate actions are taken.

\(^{15}\) In this context punctual means without any delays (on time).
As delays induce costs, a natural interest in avoiding these obsolete delays exists. A study published by the Performance Review Commission reveals that delays greater than 15 minutes induce average costs of 77 Euro per minute for an airline (cf. [49], p.42). Further, airport operators and airlines are interested in being punctual due to the high priority punctuality and implicitly delays have for passengers. Periodical surveys, such as skytrax World Airport Awards, highlight the punctuality at different airports and enable comparisons.

The TAMS concept shall contribute to the reduction of avoidable delays caused by e.g. inefficiencies between different actors. A decrease in costs and a greater operational stability plus further positive effects, such as a reduction of operational bottlenecks can be expected.

**Prediction of Events and Response on Predicted Events at an Early Stage**

Nowadays, only a limited perception of evolving events exists at airports. Regulative reactions on events are carried out ad-hoc or only on short notice due to divergent information or non-existing predictions. This results in insufficient coordination among all stakeholders and consequently lacking information and inefficient utilisation of resources.

The possibility to detect events influencing airport operations in time provides an essential basis for early counteractions. Depending on the event, the early detection is already possible nowadays. However, depending on the effect of the event, the detection and handling time can be insufficient to respond appropriately and to counteract the anticipated effects.

With the TAMS concept, a longer detection and handling time for the response on events shall be achieved: on one hand to detect evolving events at an early stage and on the other hand to make events recognisable, which cannot be detected in time, yet. A benefit for all stakeholders is even the information that such an event can occur with a certain probability and a lasting influence on airport operations.

### 3.5. Instruments for Achievement of Goals

**Transparency of Processes**

The distribution of responsibilities and the associated process ownerships results in a complex mix of issues: First, there is only limited information exchange about processes and even less about the process development of other stakeholders. Second, stakeholders quite often seem to be only interested in some direct links to other stakeholders’ processes that exert influence on their own. It is mostly out of a stakeholder’s scope to understand the way another stakeholder carries out processes and his possible causes for acting in a certain way, e.g. the reason for delays induced by other stakeholders. Still, all stakeholders’ processes somehow depend on each other’s such that each change in the process chain can influence a stakeholder’s own processes.

Enhancing process transparency aims to give stakeholders the opportunity to understand the influence of other stakeholders’ acting and to understand how their own acting may influence others.

It is envisioned that improved process transparency will result in a better cooperation between stakeholders, in recognizing upcoming events earlier, and, consequently, in a reduction of avoidable delays. The latter is the case due to a better understanding of the reasons behind these delays.
Enhanced Situation Awareness
As mentioned before, there is a lack of information exchange and transparency. Enhancing information exchange and transparency does, however, not automatically result in a better understanding of the processes of other stakeholders and their influences on own processes. In addition, central airport parameters need to be interpreted correctly by the stakeholders and actions have to be derived accordingly.

Enhancing situation awareness means to provide stakeholders with necessary information so that they can easily recognise upcoming events, identify relationships between processes, and evaluate situations and influences on their own actions. A high level of situation awareness is one prerequisite for a foresighted management of own processes.

To sustain such a high level of situation awareness the introduction of alerting mechanisms appears important. As mentioned before, stakeholders shall be able to recognise upcoming events in time. To achieve this, notifications and alarms seem to be an appropriate instrument, cf. chapter 4.4. This helps stakeholders to evaluate the relevance of situations and anticipated effects on the traffic flow, airport parameters, stakeholders’ own processes, etc. This can be visualised and thus interpreted by the stakeholders. Therefore, an appropriate coding, system support, or other mechanism needs to be developed.

Central Airport Performance Indicators
Today, a set of indicators that show the performance of the whole system “airport” does not exist sufficiently. Of those parts of the set that exist, only singular indicators such as the overall punctuality are considered. In addition, these indicators are calculated post-hoc and, thus, cannot be used to steer and control current daily airport operations. Additionally, deviations from scheduled data take only place at the process level and cannot be predicted. The result is a lack of awareness as the deviations indicate potential issues.

Defining a limited set of central airport performance indicators that summarise and evaluate airport data, which are obtained in the past and predicted for the future, can offer a solution, cf. chapter 4.3. Individual values of these indicators can then be used to set constraints for future airport operations. Hence, the constraints may affect stakeholders’ processes and serve as a kind of guideline, to which stakeholders agree upon. Another advantage of these central airport performance indicators is that deviations from these indicators show upcoming issues, which raises the stakeholders’ awareness and enable a better cooperation. Last, these central airport indicators can also be used for benchmarking with other airports.

Improved Prediction of Traffic Situations
Today stakeholders often do not recognise upcoming events, e.g. affecting the future traffic flow and resulting in a mismatch between demand and capacity, or they become aware of the effects just a short time before the event takes place. One reason is e.g. insufficient system support that can disclose effects of upcoming events on the traffic prediction. Often staff of the stakeholders has only a limited imagination of the effects to be expected and has just own processes in view. Another reason can be insufficient or deviating data – provided by different stakeholders – which itself is used for the prediction.

The improved prediction of traffic situations aims to raise the quality of the estimation for a larger time horizon compared to today, cf. chapter 4.2. This allows stakeholders to discuss possible impacts on the traffic flow and their own processes. Furthermore, they can work out strategies to solve problems they are now aware of. One of the examples is that better weather forecasts allow the calculation of the influence on traffic flow more precisely and at an earlier stage. This gives the stakeholders the opportunity to react on the situation, e.g. by adapting their demand or resource capacities, cf. chapter 4.5.3.
Decision Support

Nearly every airport stakeholder is equipped with decision support tools for optimising his own operations, e.g. for equipment utilisation or personnel deployment planning. However, stakeholders often only concentrate on their own processes. Finding an overall optimum of the airport operations seems to be out of the consideration so far.

The aim of proper decision support is to provide stakeholders with a kind of a system that supports them to find an overall optimum, inter alia to consider all the processes of the process chain or the central airport parameters. The stakeholders shall understand consequences of their actions, recognise upcoming events, get opportunities to discuss different proposals and solutions – concerning e.g. feasibility or economical issues of their own company – and then make decisions relevant to their own processes, cf. chapter 4.5.3.

However, decision support also means to provide the executing staff with adequate information, so that they can work as it has been constituted between the stakeholders.

Common set of data

Today, the distribution and processing of data takes place in different stakeholder systems. This can induce differing predictions of the same process times due to variable precision of the calculations that lead to potential inaccuracies. Consequently, e.g., the usable capacity might not be utilised to its maximum, buffers need to be implemented, and stakeholders might not work as efficient as possible.

Therefore, it seems to be sensible to use one common set of data at the airport. Such a data set shall contain all relevant data needed for collaborative airport planning and managing and shall incorporate only the most precise data available, cf. chapter 4.2.

Working on a Commonly Agreed Plan

To fulfil the requirements listed in previous chapters, it is necessary that all stakeholders not only use the same set of data, they also need to work and agree on a common plan to jointly manage the airport in the near future, cf. chapter 4.2 [4.2]. This plan describes necessary process flows and incorporates the capacity of all available resources. Furthermore, the basis for decisions will be developed through the planning process, e.g. by setting measurable goals. In addition, stakeholders get the opportunity to monitor the entire process and intervene to make adjustments where necessary. If agreed goals seem to be missed, a new planning process needs to be initiated.

This commonly agreed plan represents the basis for detailed planning of every stakeholder and it appears necessary, that the stakeholders’ own planning has to be coordinated and merged with this common plan.

Post-analysis and Statistics

Today at airports, stakeholders are capable of performing analysis and statistics on recorded data. Results can manifest deviations from scheduled data, performance values etc.

The goal of the new approach is an active management of the airport by e.g. setting central airport parameters, making commonly agreed decisions based on predictions and forecasts, and implementing a commonly agreed plan on the execution level. Consequently, in post-analyses and statistics the execution of agreed plans needs to be evaluated. Furthermore, questions can be answered: Were the decisions made the right ones? What was the effect of these decisions? Did predicted events indeed appear accordingly? Did forecasted weather have the expected influence on the traffic? Did the stakeholders perform as good as possible? What problems have not been solved?

Finally, all analysis and statistics help stakeholders to improve their actions on upcoming
events and may help in revising system predictions of events and their effects, forecasting weather etc.

TAMS focuses on the development of prototypes and does not intend to bring them into service, so that stakeholders on a particularly airport can use them operational. In this sense, TAMS is a first step that demonstrates the capabilities of described enhancements. Post-analysis, as done today (e.g. slot adherence, number of flights, responsibilities for induced delays) is a later step that can be carried out after test implementations in real environments and thus is beyond the scope of TAMS. Therefore, fine-tuning based on these analyses will not take place in TAMS.
4. Concept of Airport Operations with TAMS

Within the introduction in chapter 2.1.1 and the vision in chapter 3.2 this document speaks of a paradigm change in the European air traffic management; a paradigm change from an event based and individual planning of flight operations at airports towards a Collaborative Airport Planning (CAP), which bases on a defined service level agreement.

To follow this paradigm change, airports are forced to measure and publish their achieved service level not only retrospectively, but rather to handle proactively and continuously during each day-of-ops to ensure the achievement of the service level agreement. Therefore, the stakeholders of an airport have to consider a number of factors and constraints in their process planning. The Total Airport Management (TAM) is seen as a concept how the future requirements for airport service quality can be fulfilled.

The most important criterion to sustain an agreed service level by TAM is to assure that all participating stakeholders are aware of the current and predicted situation at an airport and act with the intention to reach the common goals. Another fact of TAM is, that an airport can only achieve the ambitious aims of service quality, which are desired by the air traffic network (cf. chapter 2.1.1, if the stakeholders react in a forward-looking and proactive way to predicted situations of capacity bottlenecks to avoid the decrease of service quality as good as possible.

To fulfil these tasks a rethinking, new processes and roles, and an according environment are needed. With an APOC, the necessary infrastructure as well as the framework for practicing new tasks can be established.

4.1. Principle of the Airport Operation Centre (APOC)

As stated in 2.1.2 there is a need for a direct communication due to spatial separation of operation centres causing possibly longer reaction times and inefficiencies in communication and cooperation of the stakeholder.

The principle of an APOC is that the stakeholders at an airport, who participate in the airside and landside planning and execution of flight related processes, come together to implement the collaborative airport plan. Within the TAMS project, the APOC covers a period of 24h (cf. chapter 3.3). The following aspects are part of CAP within TAMS:

- The stakeholders evaluate the current and predicted situation at the airport by planning on a common base of information. This information contains the best available data of the airside and landside traffic situation, turnaround processes, weather conditions, and other constraints, which influence airport operations and quality of service level. The information will be collected, analysed, and visualised.

- Through the collaborative way of working and planning, the stakeholders learn to assess the interests, possibilities, and constraints of other stakeholders and to regard them for their own planning. Furthermore, the stakeholders shall exchange their different expertises and experiences to optimise global airport planning and accelerate the process of solution finding and decision making.

- Based on the two previous aspects, the stakeholders define common performance goals, orient their process planning and plan execution towards these goals.

Therefore, the APOC builds the framework for all activities and instruments, which are necessary for CAP. In TAMS the important instruments are the Airport Operation Plan (AOP), the application of Key Performance Indicators (KPIs) and an appropriate alert management, cf. chapter 4.2, 4.3, and 4.4.
The final users of an APOC are the APOC agents, who are nominated by the different airport stakeholders to represent the stakeholders’ interests in CAP. The agents shall have the responsibility to evaluate the situation, to find suitable solutions for unwanted deviations in traffic operations and to negotiate with other agents within the framework of CAP. An essential task of the APOC agents is the definition of a common service level agreement, which is based on the Quality of Service Contract (QoSC) which is defined on a management level, cf. [22]. This QoSC shall be in focus of every stakeholders’ planning and execution of airside and landside processes.

An agent shall in principle act uncoupled from the tasks of his operation centre16, but not independent from it. In addition, an agent shall maintain continuous contact to his operation centre, because the responsibility for final planning and plan execution still lies by the operation centre. Therefore, many decisions cannot be taken outside an operation centre or have at least to be validated by it. Furthermore, the CAP of TAMS will not change the existing structure of responsibilities for resources at an airport, what is considered important to ensure the acceptance of an APOC. A more detailed description of the roles of the APOC agents follows in chapter 4.5 of this document.

To execute their tasks, the APOC agents need applicable assistance, which shall be ensured by using a so-called APOC Video Wall and suitable APOC working positions. Thereby, the APOC Video Wall is a display, which shows the current and predicted airport situation at every time to ensure a minimum of situation awareness. Furthermore, the Video Wall shall support the CAP process visually.

However, the APOC working positions shall provide all required functions for the APOC agents to analyse problem situations individually and find adequate solutions. Thereby, the specific agent’s requirements and areas of responsibility have to be respected. A more concrete description of the tools APOC Video Wall and APOC working positions follows in chapter 4.6 of this document.

A set of possible operational scenarios and business use cases, which describe the operation method of an APOC can be found in the TAMS document [62].

4.1.1. Possible APOC Implementations

The TAMS project intends to define the APOC in such a way, that the concept allows airports to implement the APOC in near future, according to their specific needs and economical constraints. Therefore, this concept concentrates on the description of instruments and tasks, which are part of the APOC, independent of the way of its implementation.

The way of APOC implementation, centralised as physical room or virtual as network between the different APOC agents, depends strongly on the needs and the organisation structure of an airport. In principle, also a combination of centralised and virtual APOC is thinkable, so that a number of agents work together in one room and the rest of agents are connected via the virtual APOC network. However, the previously described principle of an APOC is identical and is therewith independent from the way of APOC implementation.

According to each airports needs and interests, both variants of an APOC have advantages and disadvantages. For example, the amount of investment for a centralised APOC may be lower, if bigger operation centres with different stakeholders already exist and only the expansion of APOC instruments and tasks is needed. Here, the aspect of investment may be

16 In this context, operation centre is synonym to operational entity, what is more suitable for stakeholders like ATC, where the tower controllers or supervisors are the responsible persons for ATC resources.
more an advantage than a disadvantage.

However, not only the implementation of an APOC can differ, also the establishment of APOC agents may differ from airport to airport. On the one hand, an APOC agent can execute exclusively the APOC agent tasks, on the other hand it might be possible that a nowadays existing position, e.g. in an operation centre, will be extended by the role of an agent. The last option may have the advantage that decisions would be taken faster, but a disadvantage may be the amount of additional time needed to execute both roles. The way of establishment of APOC agents does not necessarily depend on the way of the APOC implementation, even if the combination of roles might be more suitable for a virtual APOC. However, it is also thinkable, that the environment of a centralised APOC is also used for other activities. For the whole TAM implementation process, it might be easier for the stakeholders to nominate APOC agents, if there is the possibility of role combination.

It is obvious, that the stakeholder of an airport, who intends to implement the TAM concept, has to execute a requirement engineering process to find the best way of implementation, which ensures the most convenient and economical solution. Therefore, this document does not intend to make this decision. Nevertheless, the following text mentions characteristics, potential advantages and disadvantage of both APOC variants.

**Centralised APOC**

**Characteristics**

In this case, the APOC is understood as a physical room with space for different working positions for APOC agents and a centralised Video Wall everybody has in sight. Therefore, the characteristics of this kind of APOC implementation are:

- one large-scale Video Wall, centralised in the APOC, where everybody has it in sight,
- possibility for the APOC agents to communicate face-to-face,
- connection to the operation centres of the agents via computerised technology or telecommunication,
- stakeholder specific support tools and functions at the working places of an agent, additional to the APOC working position features.

**Advantages**

- Direct communication face-to-face, which can support
  - the development of a comprehension of interests, possibilities, and limitations of other stakeholders’ scope of action,
  - the spontaneous and fast exchange about the current situation and of proposed solutions of predicted bottlenecks in traffic operations,
  - the centralised Video Wall enables the discussion and negotiation at the same place about the same topics and avoids the impression that everyone speaks about different things,
  - the non-verbal speech of the human behaviour is an important criterion of the communication and offers e.g. the possibility to check directly if an information was understood by other agents.
- The centrality of an APOC can support the long-term establishment of the TAM ideas, not least by the mutual observation of the agents, so that they are forced to participate in the CAP processes.
Disadvantages

○ To install and equip a centralised APOC, not only an adequate room in size and location, but also significant monetary investment into new infrastructure may be needed.

○ If the APOC agents are not nearby in their operation centre, it may be required to change or establish organisational structures, processes, and communication practice.

○ A change of decision making processes and responsibilities within the organisation of the stakeholders may be necessary.

○ The feedback process between an APOC agent and his operation centre to take decisions within the CAP process may be time-consuming because of complex responsibilities and communication procedures.

Virtual APOC

Characteristics

The virtual APOC is defined as a network between the APOC agents. Therefore, the agents stay in their usual stakeholder-specific environment, for example inside today existing operation centres. The characteristics of this kind of APOC are as follows:

○ The APOC Video Wall is implemented as additional screen at the working place of the APOC agent, not as large-scale display.

○ The communication between the APOC agents takes place via IT or telephone channels and/or video/telephone conferences.

○ The APOC agent works inside his operation centre and therefore, a face-to-face communication with the responsible persons of the operation centre is possible.

○ An APOC specific interface next to the agents operation centre working position is installed.

Advantages

○ The agents may use the existing system infrastructure to communicate inside the stakeholder’s environment. Therefore, the investment in implementation of an APOC environment may be less than in a centralised one.

○ Less or no changes in organisational structure, communication, and responsibilities inside a stakeholders´ organisation to enforce the CAP are necessary.

○ Direct communication face-to-face between the APOC agent and responsible persons inside his operation centre can support faster determination of solutions for situations of predicted bottlenecks in traffic operations.

Disadvantages

○ The non-direct communication between APOC agents may decelerate the negotiation process along the CAP.

○ The development of common situation awareness and a teamwork culture between the APOC agents may be hindered. Therefore, the long-term establishment of the TAM ideas may be endangered.

○ Situations of misunderstanding may be longer undiscovered, because the discussions and negotiations base possibly not on the same information.
4.2. Airport Operation Plan (AOP)

TAMS requires the implementation of an AOP [22], the means to share, monitor, and modify commonly agreed performance goals as well as stakeholder-individual constraints (cf. section 3.5) for Execution and Short/Medium Term Phase. The AOP covers, as the name already says, the airport operations: from arrival over turnaround and terminal operations up to departure. This includes also the linkages of aircraft that come in as arrival and leave as departure (“air-to-air”). It covers the gap in between “gate-to-gate”, which opens a brighter planning horizon and increases the predictability also for the advantage of the network.

The AOP is the plan, the agents in the APOC discuss, negotiate, and agree upon. That all stakeholders operate on the same plan enhances the transparency of processes, cf. chapter 3.5. The AOP is dynamic; it is influenced e.g. by impacts arising out of the ATM Network or changes out of the aggregated stakeholders resource plans. A specific support tool 17 does the generation/re-planning of the AOP automatically, taking into account the high level targets and deviations resulting out of changed stakeholder plans. The agents in the APOC discuss the new, pending AOP generated by the tool and negotiate/modify the AOP up to an agreement. One example for modifying the AOP is to update the commonly agreed performance goals, the Quality of Service Level (QoSL), in accordance to a capacity shortfall situation.

The AOP shall be as well the commonly agreed plan as the data structure for information sharing. The AOP serves as a common database to which each stakeholder in the APOC has access. Although, the AOP changes over time, it has to be ensured that subsequent changes, esp. initiated by tools, will not lead to an instable AOP.

The AOP will contain operational data available nowadays at the airport enriched by data, which will be provided by novel planning systems, which cover the whole pre-tactical time horizon and are ideally able to optimise the airport operation plan fulfilling commonly agreed service agreements and state-of-the-art assistance systems e.g. AMAN. As A-CDM is a basis for TAMS, the A-CDM concept element “Information Sharing” encourages the implementation of the AOP, containing also the shared data. The data the AOP contains encompasses the Execution and the Short Term Phase as well as the Medium Term Phase and therefore, the complete pre-tactical and tactical timeframe, too (cf. section 3.3).

Additionally an AOP includes constraints like capacity data for airport resources, which influence the airport planning. As it is currently not seen that all data the airport stakeholders use, are exchanged between all stakeholders, the AOP may contain optional data fields, e.g. for further passenger data.

The AOP is a hierarchically organised, layered plan (i.e. a higher level is a planning soft constraint to all lower levels in the plan), with the following planning levels:

- **Performance Level:** The dynamically agreed set of performance goals is the highest level of the AOP. The key task for defining an AOP is to define and agree on the KPIs, which represent the main parameters of the airport performance. Later the AOP will contain the set of values for those KPIs the stakeholders at the airport have agreed upon to achieve the QoSL.

- **Traffic Flow Level:** An airport can be operated making use of different strategies, e.g. on the airside, the selection of a runway configuration is a certain operation strategy and directly related to traffic flows: airport runway capacity is directly dependent on the selected runway configuration. Traffic flows depend on the traffic

17 Instead of one single tool, also a suite of several coupled tools may be suitable.
demand and on the available capacity figures. Queues are not yet processed demand remaining due to a lack of capacity. This AOP level deals with amounts of aircraft, passengers, and baggage instead of individual aircraft or passengers. The AOP will contain the operation strategy, the capacities, and the planned flow.

- **Event and Resource Level:** The event and resource level is dealing with individual objects – e.g. flights, aircraft, crews, passengers, stands, baggage belts. The event plan shows e.g. the target flight milestones – landing, in-block, off-block, and take-off – or the target passenger milestones – check-in, security, boarding – thus the usage of different resources by one object. The resource plan is a dualism to that, showing the usage of a certain resource by the events of different objects – e.g. the stand occupation by different flights. Any Traffic Flow Level intentions will find their limitations in situational resource availabilities. This means the AOP will at least contain flight data e.g. scheduled times, estimated times, target times, planned times\(^\text{18}\) and actual times, runway (RWY), parking position etc. The Event and Resource Level may cover the complete planning horizon.

With each layer down, not only the depth of details increases but also the update rates. On Event Level, spotting a single flight, estimates will come in, actuals will be added, and other times will be confirmed. Several updates in the Event Level may change the Traffic Flow Level and big changes on the Traffic Flow Level may force to agree on new performance goals for the Performance Level, so that this may change also.

### 4.2.1. Required Static Data

The AOP requires static data, which are not components of the AOP itself. Those data are e.g. the topological data of runways, runway length, topological data of parking positions and taxiways, or data about terminal infrastructure like number and location of check-in counters. In contrast, the information e.g. “the parking position xy is closed” is an operational information and therefore component of the AOP.

### 4.2.2. Data for Incorporation in an AOP

The AOP shall contain airside and landside data to represent the airport operational plan. To enhance the overview, the following two sections are introduced.

#### Airside Data

The AOP usually contains:

- an agreed set of performance goals as values for KPIs, e.g. punctuality,
- taxiway-system capacity over time,
- operational strategy of using runways over time,
- runway capacities over time (depending on the operational strategy over time),
- taxiway closures (current and planned),
- parking positions closures (current and planned),
- runway closures (current and planned),

\(^{18}\) A “planned time” is a kind recommendation and/or forecast. The word „target” cannot be used as the TOBT and TTOT, which are both called „target” have different meanings: The TTOT is a really planned time, the TOBT a time confirmed by an operator.
flight plans (airport and ATC), with estimated, “planned”, and confirmed times (e.g. TOBT).

Landside Data
The AOP usually contains:

- long term planned closures/inhibitions of resources, e.g. due to construction work,
- capacities of resources over time, including short and medium term capacity bottlenecks (e.g. due to malfunction),
- agreed level of performance goals,
- flight-related passenger information including estimated, planned and confirmed times.

### 4.3. Key Performance Indicators

In the TAMS context, Key Performance Indicators (KPI) are measures that enable the evaluation of the quality of an AOP and the management of airside and landside operations according to the quality goals continuously. Therefore, KPIs are parameters that allow a performance based controlling of an airport. In the TAMS environment of an APOC selected and permanently updated indicators are displayed. Measures suited to interpret timeframes ranging from a few minutes to 24 hours in advance are necessary to evaluate the actual and estimated future situation at an airport. KPIs showing the estimated situation enhance the actual awareness of all stakeholders.

Before we go into more detail how KPIs suited for TAMS can be defined, a brief overview on KPIs and their use in ATM is given.

Key performance indicators (KPI) are defined to measure performance in key performance areas (KPA). The International Civil Aviation Organisation (ICAO) [47] as well as the European Operational Concept Validation Methodology (E-OCVM) [33] define both terms related to ATM:

- **KPA (ICAO):** Key Performance Areas are a way of categorising performance subjects related to high-level ambitions and expectations.
- **KPA (E-OCVM):** Key performance areas are broad categories that describe different areas of performance of an ATM system.
- **KPI (ICAO):** Indicators are a mean of deriving past, current, expected performance levels, which are quantitatively expressed.
- **KPI (E-OCVM):** Key performance indicators measure performance in key performance areas. A key performance indicator is a measure of some aspect of a concept or concept element, for example, ‘the total number of runway incursions per year’, ‘mean arrival delay per week at airport X’.

SESAR D1 and D2, ICAO 9883, and IATA One Sky – Global ATM Vol. 2 ([47], [45], [54], and [55]) define 11 key performance areas (KPA) to categorise performance subjects of the airport system. SESAR [55] assigns these KPAs to three groups: 1. Societal Outcome, 2. Operational Performance, and 3. Performance Enablers. The 11 KPAs are:

- **Group 1 – Societal Outcome**
  - Environment (& Sustainability)
  - Safety
Within the Episode 3 project, a performance framework based on the SESAR KPAs has been defined [36]. This document defines KPIs for the six KPAs Capacity, Environment, Safety, Efficiency, Predictability, and Flexibility with the focus at an ECAC (European Civil Aviation Conference) level, e.g. number of movements in Europe in a given time period. On a local level, performance indicators for Airports, TMA, and En-route are defined. However, most indicators are set with the scope to enable a later definition of European-wide performance targets that shall be met by all airports of a certain category. Therefore, most are not defined in an ideal manner for the TAMS concept.

The Airport Performance Framework (ATMAP Framework, [51]) prepared by PRC reviews the performance of the airport system without accusing specific actors. ATMAP defines a number of KPIs for seven KPAs. SESAR [54], [55], and IATA [45] cover the assessment of technical or organisational changes of the ATM-System. Where SESAR and IATA cover more generally the way to set up a performance framework and can be seen as a guideline, ATMAP has set up a specific performance framework to allow the Performance Review Commission (PRC) of Eurocontrol an evaluation of airport performance. Common for all so far introduced KPIs is their restriction to airside performance parameters even though the KPAs definitions show a wide scope thus allowing the possibility for their employment for the landside, as well.

In general, KPIs for TAMS shall be specific, measurable, include the airside and the landside, drive the desired behaviour of actors, be easy to share and understand, and compatible to ICAO guidelines [47]. Problems related to the definition of KPIs can be of mathematical nature as well as acceptance problems from the side of the actors.

**ATM Airport Performance Project**

KPAs of the group “Operational Performance” are of particular interest for TAMS. KPIs defined for these areas evaluate the performance of an airport’s operations. The PRC has introduced the “ATM Airport Performance Project”, to develop KPIs and define a performance framework consistent to “European Council Regulation 549/2004” [69]. A number of partners from airports (e.g. Frankfurt, Munich, London, Manchester, and Zurich), airlines (e.g. Air France, Brussels Airlines), ATC (e.g. Belgocontrol) and coordinators (e.g. Brussels) have been involved in this project. First results have been published December 2009 in “ATM Airport Performance (ATMAP) Framework – Measuring Airport Airside and Nearby Airspace Performance” [51]. The European Council Regulation 691/2010 [73] defines a performance scheme for air navigation services and network functions as part of the performance scheme introduced by the Single European Sky II package. This regulation
focuses on the work of the ATMAP group. So far, KPIs for five KPAs have been developed within this project, see Figure 4-1.

Figure 4-1: KPAs and KPIs defined in the ATMAP Framework

Basically, the selected KPAs match those of the group “Operational Performance” defined in SESAR and described above. In addition, the relation between “Capacity” and “Traffic Volume & Demand” has been taken into account, to get meaningful characteristics. “Punctuality” and “Predictability” are examined separately. The more elaborated KPIs for the areas “Traffic Volume & Demand”, “Capacity”, and “Punctuality” are defined as denoted in Table 4-1.

The ATMAP framework is still under development and further KPIs related to additional KPAs will be developed in coming project phases. KPIs related to “Efficiency” and “Predictability” are still evaluated and may be adapted.

A first ATMAP review report evaluating the IATA seasons Summer 2009 and Winter 2009 – 2010 for about 20 major European airports is published in 2011 [50].

Focus of the ATMAP group is post-analysis of airport operational performance on the airside. Some of the defined KPIs as e.g. punctuality measures are suited to be used as high granularity KPIs in the TAMS environment of an APOC. Other measures as e.g. service rate do not consider special airport processes; they evaluate the process chain as a whole. Similar measures based on a process level would be more helpful in a TAMS context. Therefore, we will give a brief overview on KPIs defined in the A-CDM Implementation Manual by Eurocontrol [27].
<table>
<thead>
<tr>
<th><strong>KPI</strong></th>
<th><strong>Metric</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Handled traffic</td>
<td>Number of flights arrived and departed to and from an airport in a given time period</td>
</tr>
<tr>
<td>Coordinated demand</td>
<td>Number of flights with assigned airport slot</td>
</tr>
<tr>
<td>Coordinated cancelled demand</td>
<td>Number of cancellations, out of the coordinated demand, per 1,000 flight operations in a given time period</td>
</tr>
<tr>
<td>Airport Declared Capacity</td>
<td>Average number of airport slots per hour</td>
</tr>
<tr>
<td>Service Rate</td>
<td>1% percentile of the numbers of movements per 10-min rolling hours in busy periods</td>
</tr>
<tr>
<td>Arrival Punctuality</td>
<td>Percentage of flights arriving no more than 15 minutes (alternatively 3 min) late compared to scheduled arrival times</td>
</tr>
<tr>
<td>Departure Punctuality</td>
<td>Percentage of flights departing no more than 15 minutes (alternatively 3 min) late compared to scheduled departure times</td>
</tr>
<tr>
<td>Early arrivals</td>
<td>Percentage of flights arriving 15 minutes or more ahead of schedule</td>
</tr>
<tr>
<td>Departure delay causes</td>
<td>Percentage of contributory cause to departure delays based on airline reported IATA delay codes</td>
</tr>
</tbody>
</table>

**Key Performance Indicators for A-CDM**

The definition of key performance indicators is also necessary to measure and manage A-CDM processes. KPIs are developed to visualise benefits of A-CDM as well as to allow an early identification of positive and negative changes within the process flow making use of data collection. Therefore, it is necessary to implement KPIs additionally to the other KPIs defined in this chapter.

Basis for this concept shall be KPIs presented in the A-CDM implementation manual [27]. This manual proposes performance drivers, indicators, and measurements for four main areas: Efficiency, Environment, Capacity, and Safety. In line with the general characteristics desired for KPIs as stated above, the A-CDM guideline recommends to take a limited but representative set of KPIs into account that cover the operations of all involved partners. The manual provides a long list of KPIs suited for A-CDM purposes. In case, A-CDM is established at an airport, KPIs can be selected from this list or defined as agreed by the involved partners.
Proposed Key Performance Indicators for the Landside

Previously the focus for the definition of performance parameters was clearly on the airside. Within the framework of TAMS, however, the desired integration of airside and landside entails the need for landside KPIs. Based on the KPAs defined by ATMAP, Figure 4-2 shows an interpretation of possible landside KPIs.

![Figure 4-2: KPAs defined in the ATMAP Framework and possible interpretation of landside KPIs](image)

Furthermore, following the KPAs defined by SESAR, the KPAs “Environment”, “Safety” and “Security” shall be added to those already employed by ATMAP. Possible KPIs for these KPAs can be the energy efficiency of the terminal buildings, number of severe injuries in the terminal, or the number of security incidents at the control stations.

Sample of Key Performance Indicators for TAMS

Especially for TAMS, the granularity of measurements has to be considered. Where some of the ATMAP KPIs above are of too high granularity, some of the following KPIs are only suited for an APOC in an aggregated form for TAMS – i.e. no comparison of times for single flights unless a specific problem is identified and shall be analysed in more detail. Reasonable sources are current measurements performed at airports on a regular basis. In addition, controlling procedures implemented by Deutsche Flugsicherung GmbH (DFS) with influence on TAMS have to be considered. Similar as for A-CDM, KPIs can vary from airport to airport. As a starting point, Table 4-2 below presents possible KPIs for TAMS. These have been selected from the ATMAP list above, the A-CDM implementation manual [27], the list of landside indicators proposed above, and measurements of TAMS partners that have already proven benefit. These parameters are suited to be used as central airport parameters as denoted in section 3.5 of this document.

Additionally, other parameters might be helpful for a post-analysis of some airport processes or for some stakeholders, e.g. stakeholder specific definitions of punctuality, number of ghostflightplans (more than one ATC-flightplan for one event), comparison EOBT to SOBT\(^1\), comparison TSAT\(^2\) to TOBT, or DFS Take-Off quality.

\(1\) SOBT – Scheduled Off-Block Time
\(2\) TSAT – Target Start Up Approval Time
<table>
<thead>
<tr>
<th><strong>KPA</strong></th>
<th><strong>KPI</strong></th>
<th><strong>Metric</strong></th>
<th><strong>Source</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>Handled traffic</td>
<td>Number of flights arrived and departed to and from an airport in a given</td>
<td>ATMAP</td>
</tr>
<tr>
<td>Volume &amp;</td>
<td></td>
<td>time period.</td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>Handled Pax</td>
<td>Number of arriving and departing passengers processed in a given time period</td>
<td>Defined for TAMS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>Airport Declared</td>
<td>Average number of airport slots per hour</td>
<td>ATMAP</td>
</tr>
<tr>
<td></td>
<td>Capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slot compliance</td>
<td>Number of TOBT not compliant with CTOT(^{21})</td>
<td>A-CDM Manual</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of flights departing outside assigned CTOT</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of flights departing outside airport slot</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aggregated Comparison CTOT to ATOT for regulated flights (-5min/+10min)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Terminal Capacity</td>
<td>Average number of available process stations in a given time</td>
<td>Defined for TAMS</td>
</tr>
<tr>
<td>Punctuality</td>
<td>Arrival Punctuality</td>
<td>Comparison AIBT(^{22}) to SIBT(^{23}), Percentage of flights arriving</td>
<td>A-CDM Manual, ATMAP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>no more than 15 minutes (alternatively 3 min) late compared to scheduled</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Departure Punctuality</td>
<td>Percentage of flights departing no more than 15 minutes (alternatively 3 min) late compared to scheduled departure times</td>
<td>A-CDM Manual, ATMAP</td>
</tr>
<tr>
<td></td>
<td>Early arrivals</td>
<td>Percentage of flights arriving 15 minutes or more ahead of schedule</td>
<td>ATMAP</td>
</tr>
<tr>
<td></td>
<td>Departure delay causes</td>
<td>Percentage of contributory cause to departure delays (based on airline</td>
<td>ATMAP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reported IATA delay codes)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waiting time at</td>
<td>Aggregated Comparison ATOT to [AOBT+Taxi time]</td>
<td>Defined for TAMS</td>
</tr>
<tr>
<td></td>
<td>runway</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{21}\) CTOT – Calculated Take Off Time  
\(^{22}\) AIBT – Actual In-Block Time  
\(^{23}\) SIBT – Scheduled In-Block Time  
\(^{24}\) AOBT – Actual Off-Block Time  

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<table>
<thead>
<tr>
<th>KPA</th>
<th>KPI</th>
<th>Metric</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boarding</td>
<td>Aggregated Comparison of ASBT&lt;sup&gt;25&lt;/sup&gt; to ESBT&lt;sup&gt;26&lt;/sup&gt; for different times of</td>
<td>Defined for TAMS</td>
</tr>
<tr>
<td></td>
<td>Punctuality</td>
<td>measurement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Passenger</td>
<td>Percentage of passengers catching their connection flight (out of all transfer passengers)</td>
<td>Defined for TAMS</td>
</tr>
<tr>
<td></td>
<td>Connectivity</td>
<td>in a given time</td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td>READY reaction time</td>
<td>Aggregated Comparison Push-Back/Taxi Given and AOBT (resp. AOBT – ARDT&lt;sup&gt;27&lt;/sup&gt;)</td>
<td>A-CDM Manual</td>
</tr>
<tr>
<td></td>
<td>Aircraft stand &amp; Pax gate freezing time</td>
<td>Number of short-term position changes (e.g. after [ALDT&lt;sup&gt;28&lt;/sup&gt;-30min])</td>
<td>A-CDM Manual</td>
</tr>
<tr>
<td></td>
<td>Level of Service (LoS)</td>
<td>Actual LoS compared to planned LoS over a given time (LoS criteria could be waiting times,</td>
<td>Defined for TAMS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>length of queues or service times)</td>
<td></td>
</tr>
<tr>
<td>Predictability</td>
<td>Stand allocation accuracy (EIBT&lt;sup&gt;29&lt;/sup&gt; Predictability)</td>
<td>Aggregated Comparison EIBT to AIBT</td>
<td>A-CDM Manual</td>
</tr>
<tr>
<td></td>
<td>Stand allocation accuracy (EOBT Predictability)</td>
<td>Aggregated Comparison EOBT to AOB T</td>
<td>Defined for TAMS</td>
</tr>
<tr>
<td></td>
<td>TOBT/TSAT Predictability</td>
<td>Aggregated Comparison TOBT/TSAT to AOBT/ASAT&lt;sup&gt;30&lt;/sup&gt;</td>
<td>A-CDM Manual</td>
</tr>
<tr>
<td></td>
<td>TTOT Predictability</td>
<td>Precision of TOBT for different times of measurement, Aggregated Comparison TOBT to best estimate (EOBT)</td>
<td>Defined for TAMS</td>
</tr>
<tr>
<td></td>
<td>ELDT&lt;sup&gt;31&lt;/sup&gt; Predictability</td>
<td>Aggregated Comparison ALDT to ELDT for different times of measurement</td>
<td>Defined for TAMS</td>
</tr>
</tbody>
</table>

<sup>25</sup> ASBT – Actual Start Boarding Time  
<sup>26</sup> ESBT – Estimated Start of Boarding Time  
<sup>27</sup> ARDT – Actual Ready Time (for movement)  
<sup>28</sup> ALDT – Actual Landing Time  
<sup>29</sup> EIBT – Estimated In-Block Time  
<sup>30</sup> ASAT – Actual Start Up Approval Time  
<sup>31</sup> ELDT – Estimated Landing Time
### 4.4. Alert Management

Alert Management comes into play, when operational critical problems or deviations from AOP occur. In the context of TAMS, an alerting mechanism is important, to represent contemporary problems in operations or deviations from AOP. If agents shall react timely on those problems or deviations, an alert management is necessary. The aim of alert management is to monitor predefined processes and the adherence to predefined parameters. Another aim is early notification about the problem by the appropriate agent within the APOC. Using alert management, delaying flights in response to critical situations can be reduced or even prevented, because the time span between occurrence and appropriate reaction of the agent can be significantly reduced. The management and the handling of alerts, is described in section 4.4.2.3.

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31 ELDT – Estimated Landing Time  
32 EPGT – Estimated Passengers at Gate Time  
33 APGT – Actual Passengers at Gate Time  
34 ARR & DEP – Arrival & Departure
4.4.1. Types of Alerts

In order to perform their duties properly it is necessary that the agents be informed about incidents and deviations. In TAMS, it is distinguished between A-CDM alerts and TAM alerts. A-CDM alerts are exclusively related to milestones of specific flight events. They are defined in A-CDM documents, cf. [27]. TAM alerts are not only related to specific flight events but rather to operational events, like a bottleneck of resources. These operational events affect airport operations and airport performance. This also includes deviations from predefined KPI targets – the Service Level Agreement (SLA).

In TAMS, the alerting mechanism can be divided in three categories:

- **Video Wall notification:** These are more notices than alerts. These messages inform the agents about operational events, which affect the APOC agents' field of duty. Notifications can be done via a message box at the Video Wall. Notices about various events can be presented, e.g. “14:00 – 14:15 inhibition of RWY 33 snow removal”. This type of alert can trigger processes to update capacity values. That means defined Operational Scenarios and Business Use Cases ([62]) are carried out.

- **Agent notification:** These are stakeholder specific messages, which are displayed directly on the Agent working position. The agent notification can be realised with an alert-inbox-tool: This tool may show subjects in a pop-up window and collect all alerts, e.g. as text message, until they are processed. The agent notification includes A-CDM alerts (cf. [27], Annex 2.2) and messages from the operation centre, e.g. about bottlenecks of resources. After receiving such an agent notification, the agent consults its operation centre and/or passes the information to all other APOC agents. Furthermore, it is possible, that the agent does a separate what-if probing with the information from the agent notification to see further impacts of the alert's cause. (cf. section 4.5.3).

- **Performance alert:** This alert is raised if there is a violation of performance objectives and/or deviations from the AOP and may be visualised by a coloured marker. Here, the alert criterion may be a preference and possibility window (cf. section 4.4.2.1). Performance alerts will be shown on the Video Wall and the agent working positions. All values from the Service Level Agreement and all timestamps (actual, estimated, and scheduled) of individual flights shall be taken into account to create a performance alert. This type of alert shall trigger the agents to search the reason of this alert. In a next step, the agents handle the cause of the problem.

What type of alert and which alert can be important for which agent is partially described in the operational scenarios and business use cases in [62]. This is not part of the Operational Concept Document.

4.4.2. Management of Performance Alerts

The management of alerts encompasses the definition, monitoring, diagnosis, and handling of alerts. Thereby, the Video Wall and agent notifications have only an informative function to support the agents in diagnosis and handling, so that these categories of alerts will not be discussed further.
4.4.2.1. Alert Definition

For the definition of alerts, the agents define thresholds for KPIs to differentiate normal operations from deviations. This is necessary in order to determine which extent of deviation has to trigger an alert. For this, definitions for preference and possibility windows may be a useful instrument. The idea of preference and possibility windows is coined by [22] and describes plan deviations with a kind of colour coding. The benefit of these windows is the fast detection of deviations from the AOP. Thereby the range of acceptable deviations is defined by the user itself.

Preference and possibility windows can be set manually by the agents or calculated automatically by an assistance system. Not every agent can define each preference and possibility window. The agent is allowed to set/modify only windows, which are within his area of responsibility. The possibility window is useful for the management of alerts on all levels. Especially, where unchangeable constraints define an earliest and a latest time for an event or where a manual alert definition for a great number of single events may be not feasible. The subchapter 4.4.2.4 gives an example for these earliest and latest borderlines, based on the A-CDM milestones.

The preference and possibility windows on performance and flow level are currently intended to be defined manually by the APOC agents within a CAP process, because the thresholds for an alert may be very variable, and may depend strongly on the current traffic situation.

The following paragraphs describe the difference between and the handling of preference and possibility windows.

Preference Window Definition

The preference window shown in Figure 4-3 (Event-Level) is determined by stakeholder constraints. This window can be interpreted as the stakeholder's wish. Target times within this window are acceptable and can be displayed green on the Video Wall and on the agent working position HMIIs\(^35\). That means no intervention or change of the AOP is necessary as long as target times (or KPIs on performance and flow level) are within the preference window.

On performance level, specifications are made about deviations of the agreed stakeholder objectives depending on time. The specifications of preference windows on flow level consider the time-related utilisation of airport resources, like runway and taxiway without consideration of individual objects, like airplanes. Display criteria can be queue lengths, e.g. a queue on the taxiway of no more than 2 aircraft can be displayed in green, 3 up to 5 can be displayed in yellow and more than 5 can be shown in red. On the event level, there are temporal specifications, which can be planned object based (airplanes, stand & gate) [23].

\(^{35}\) HMI – Human Machine Interface
Possibility Window Definition

Possibility windows represent areas within which the operation is still possible, but not preferred. Operations outside the possibility window may be not possible, e.g. the remaining fuel on board of the arriving aircraft determines the right threshold of its possibility window for the landing time. The preference window is always within the possibility window. KPI targets and target times within the possibility but outside the preference window can be displayed yellow on the Video Wall and on the agent working position HMIs. Targets out of the possibility window can be displayed red.

On performance level, possibility windows can be defined due to legal specifications, e.g. regulation of noise protection. On flow level, the capacity of a resource defines the possibility window, e.g., a ground handler’s staff planning or the utilisation of runways. On event level, the possibility window may be defined by technical conditions, e.g. the available amount of fuel of an airplane.

For Example, the following Figure 4-4 shows the relationship between delay and demand, cf. [23]. The dependencies between throughput and punctuality plus preference and possibility window can be derived from this figure.
4.4.2.2. Alert Monitoring

Deviations occur driven by current and predicted traffic data and weather information. In most cases, alerts of all three alert categories are carried out simultaneously. If the performance alert shows the predicted impact of an incident, then the Video Wall notification indicates the cause of the performance alert. The agent notification can contain information about the cause as well as information about the expected consequences. For example, [27] defines the alert CDM01 as “No Airport Slot available, or Slot already correlated – immediate update of ATC flight Plan EOBT or request new Airport Slot – The A-CDM process may be suspended until reception of your rectification”. Generally, the following three stages of performance alerts can be distinguished:

- The first stage describes a condition where defined alert parameters are within the preference window (green area). In this case, intervention of agents is not necessary.
- The second stage describes a condition where defined alert parameters are within the possibility window but out of the preference window (yellow area). In this case,
even an intervention in planning can be useful. The kind of intervention depends on the cause. The alert diagnosis identifies the cause. There is no need for intervention if the deviation is small and no constraints are violated by the cause. Nevertheless, is the reason the beginning of a larger problem, an agent’s intervention in the AOP is highly recommended.

- In the third stage, the defined alert parameters are out of the possibility window (red area). In this case, an intervention and adaptation of the AOP is mandatory.

### 4.4.2.3. Alert Diagnosis and Handling

The diagnosis is needed to identify causes of deviations within the active AOP. Negotiations will be necessary if excessive interventions in the AOP are essential, cf. chapter 4.5.3. If only a small intervention in AOP re-planning is required, e.g. re-planning of a small number of events, the decision is mostly taken by operation centres. In this case, it is an adjustment by the operation centres, and a negotiation between APOC agents is not required urgently. Figure 4-5 shows the handling of performance alerts. Due to the automatic changes of the AOP by the re-planning of pre-tactical systems, situation awareness of APOC agents will be retained. The required amount of communication for re-planning the AOP will be explained with help of operational scenarios and in business use cases [62].

After the reason for the alert has been solved, the alert shall be deleted automatically.

![Figure 4-5: Handling of performance alerts](image-url)
4.4.2.4. Alert Management on Event Level

Basis for the preference and possibility windows on event level may be the A-CDM milestones and deviations thereof. If a system identifies a deviation, an alert is raised and shown to the agents. Therefore, the agents have the ability to notice a problem and react on it.

In the context of European harmonisation and standardisation, a uniform coding for A-CDM alert messages is defined [19]. The APOC agent shall receive these messages as an agent notification on his APOC working position HMI. Another possibility is to show these A-CDM alerts in a separate tool, like the Central Flow Management Human Machine Interface (CHMI) tool of the CFMU at Munich Airport, as described in [19].

Example for Preference and Possibility Window on Event Level

The definition for preference and possibility windows may be implemented in different ways. One way is to use the Off-Block and On-Block event. The borders of possibility windows determine the period in which the next planned target time should be. Table 4-3 gives an example for these definitions based on A-CDM milestones.

Table 4-3: A-CDM milestones and borders of possibility window

<table>
<thead>
<tr>
<th>Milestones</th>
<th>Planned (reference) Time</th>
<th>Start Time</th>
<th>End Time</th>
<th>remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before A-CDM</td>
<td>SOBT</td>
<td>SOBT-30 min</td>
<td>SOBT+20 min</td>
<td>airport slot tolerance / agreed locally</td>
</tr>
<tr>
<td>M 1</td>
<td>EOBT</td>
<td>EOBT-15 min</td>
<td>EOBT+15 min</td>
<td></td>
</tr>
<tr>
<td>M 2</td>
<td>EOBT</td>
<td>EIBT+MTTT</td>
<td>EOBT+15 min</td>
<td></td>
</tr>
<tr>
<td>M 9</td>
<td>TOBT</td>
<td>TOBT+0 min</td>
<td>Next EIBT at same stand</td>
<td></td>
</tr>
<tr>
<td>M 2 – M 14</td>
<td>CTOT-EXOT</td>
<td>(CTOT-5 min)-EXOT</td>
<td>(CTOT+10 min) -EXOT</td>
<td>If flight is regulated</td>
</tr>
<tr>
<td>M 10</td>
<td>TSAT</td>
<td>TSAT-5 min</td>
<td>TSAT+5 min</td>
<td></td>
</tr>
<tr>
<td>M 13–M14</td>
<td>ASAT</td>
<td>ASAT-0 min</td>
<td>ASAT+2 min</td>
<td></td>
</tr>
<tr>
<td>M 15</td>
<td>AOBT</td>
<td>0 min</td>
<td>0 min</td>
<td></td>
</tr>
</tbody>
</table>
Another way is the application of defined performance criterions like the punctuality criterions for departures or KPIs, cf. chapter 4.3. For an example regarding scheduled flights, see Figure 4-6. The SOBT is not changeable. Therefore, the block behind the letters is coloured in grey. The TOBT is measured against the SOBT. The constraint for colouring the block behind the letters is here defined by the general punctuality definition from IATA but also every other airline specific definition of punctuality is thinkable. That IATA-definition says, a flight within 15 min after the SOBT is considered punctual. As in the example, the block will be coloured in yellow if the TOBT is close to the limit of 15min – the preference window is violated. If the delay is more than 15min, the colour will change to red and a flashing border may additionally highlight the block – the possibility window is violated.

Figure 4-6: Exemplary preference and possibility window on event level
4.5. Roles of Agents

This chapter illustrates the tasks of the stakeholder agents in the APOC. The description of the functional roles in section 4.5.1 is derived from potential stakeholder objectives and responsibilities. These depend on the particular airport and situation (cf. 2.1.2) and may differ in some cases from those described in this document. Since the TAMS concept intends to be generic, some level of abstraction is needed. Thus, the description of goals and interests of the stakeholders may be incomplete or may differ from the situation at existing airports. Nevertheless, the deduction of the fundamental roles of the agents in this section can be assumed relevant for most airports.

This approach assumes that the roles of agents are independent of the configuration of the APOC, cf. 4.1.1. Therefore, an agent has the same responsibilities, whether he sits in a physical room or participates in a virtual implementation of TAMS.

As outlined in section 2.1.2, there are a number of independent organisational units and companies involved in the overall process at an airport. Moreover, the distribution of tasks and the way they are performed evolved over time. This results in complex process chains, which cannot be generalised. Therefore, this and the following chapter 4.6 are limited to the major players at the airport, each represented by an agent. This level of abstraction helps to keep the argumentation straightforward and to improve the applicability to real airport conditions. In the implementation of the concept, the users have creative freedom to adapt permanently or even occasionally the composition of the workforce in the APOC in accordance with local requirements.

The identified major players (cf. 2.1.2) and therefore the selected agents are Airline Agent, Airport Agent, Ground Handling Agent, ATC Agent and Moderator. The Moderator plays a special role and becomes particularly important during a negotiation. The other four agents represent the main stakeholders at the airport. On this abstraction level, it is neglected that there will presumably be several Airline Agents representing different airlines. In addition, the Ground Handling Agent acts for a number of companies and entities in charge of different tasks in the turnaround process. It is also possible that airlines are represented by their ground handler and that more than one Ground Handling Agent is part of the APOC staff. The ATC Agent is the representative of the air traffic control units responsible for ground control, takeoff and landing and terminal control. Moreover, the special task of the Airport Agent has to be mentioned. He has not only to co-ordinate and represent the mostly independent operational units for air- and landside of the airport but also a large number of service providers and authorities. Especially for large and complex airport structures, a division in one airside and one landside Airport Agent may be reasonable.

To realise effectively a Collaborative Airport Planning (CAP) (cf. 2.1.1), each agent shall act independently within the meaning of the stakeholders represented by him. However, he cannot take all decisions on his own and must closely coordinate with the decision makers in the corresponding operational centres outside the APOC, cf. 4.1. This communication is presented in section 4.5.2. The performance based approach (cf. 3, 4.3) of this concept requires the agents to examine the impact of their actions on the KPAs before the actual implementation. The resulting importance of what-if probing in the context of CAP will be discussed in section 4.5.3.1. The negotiation process and the special role of the Moderator are described in section 4.5.3.2.

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36 In this context, operational centre is synonym to operational entity, what is more suitable for stakeholders like ATC, where the tower controllers or supervisors are the responsible persons for ATC resources.
4.5.1. Functional Roles

Chapter 4.1 already referred to the principles of the work agents fulfil in the APOC. The agents shall represent the goals of their stakeholders, while ensuring the compliance with the QoSC and SLA. The QoSC has been negotiated between the stakeholders on management level and is a basis for the agents work. The SLA represents the shared objectives, developed in a collaborative process within the APOC. Therefore, first the objectives of each interest group and afterwards the jointly arranged agreement will be briefly described in the following.

The interests of the actors and the dependencies between them depend largely on the organisation of the particular airport as described in section 2.1.2. At this point, the considerations will therefore be limited to the overall objectives. It can be assumed that minimising costs and increasing revenues is the decisive goal of any economically independent organisational unit. Other intentions such as long-term customer loyalty or safe operating procedures can ultimately be attributed to the necessity for economic success. Exceptions are legal requirements. Amongst others, these aim at safety and security and have to be met by each interest group independent of the related costs. For some stakeholders the primary objectives are set by regulations, such as the air navigation service provider. In addition, there are also actors such as police and customs that are solely state-owned and thus do not follow the objective of profit maximisation. In the following, the interests of the four key actors as defined above are presented.

The goal of an airline aligned with the overall purpose of profit maximisation is firstly the steady functioning of operational processes. On the tactical level, deviations from the ideal plan and related changes to the plan shall be minimised and made as far in advance as possible since changes propagate in the network, e.g. by the loss of slots or the lack of aircrafts elsewhere. Thus, the potential damage increases further. Secondly, the airline wants to achieve long-term customer loyalty by the highest possible level of service. This includes the reliable and orderly provision of transport and additional services. On the one hand, this requires the exact adherence to time sequences of processes. On the other hand, the service objective can make rescheduling of e.g. resources necessary to ensure the passenger transport for example the non cost-efficient and spontaneous deployment of a larger aircraft than necessary when the scheduled aircraft cannot be used. The two main goals of an airline consequently are interdependent and partly exclude each other.

The ground handler is interested in providing his service to the customer, usually the airline, in a low cost way with as little idle capacity of its resources as possible. At the same time, flight delays induced by the ground handler shall be reduced to a minimum in order to avoid fines and to strengthen long-term customer loyalty.

The airport operator has the goal to increase the airport’s attractiveness to airlines and to passengers under optimal use of resources. This objective can be achieved by reliable and sufficient supply of various infrastructure facilities of the air- and landside. Furthermore, the airport is interested in a high throughput, which strengthens the revenue side, both with landing fees as well as with retail sales. In addition, the acceptance by the local population may constitute a target, to gain public attention as a business centre or as an employer or to fulfil obligations and promises of a mediation process. This goal can be achieved in particular by minimising noise and pollutant emissions, which shall be controlled by the KPA environment. Hence, public acceptance may be competitive to the throughput.

At the airport, one group of stakeholders follows different objectives than the above-mentioned. Authorities have e.g. responsibility for the compliance with laws or for the protection of airport and state in general. These authorities are usually not subject to the goal
of profit maximisation, but still have to meet their legally established tasks even with limited resources. An efficient use of human resources is accordingly of great interest for them, too. Private Security Service Providers likewise have objectives clearly regulated by rules. They must however reach the highest possible level of service with minimal costs. On the defined level of abstraction that includes only the four main stakeholders, the airport operator represents the goals of this group within the TAMS concept.

The objective of air traffic control at an airport is the safe, orderly, and smooth flow of air traffic in the TMA, on runways, and taxiways. In the case of deregulated air navigation services also the efficient use of human resources and technical equipment plays an important role.

In section 4.3 eight KPAs were presented. In these areas, the overall system capacity of the airport shall be assessed. For the derivation of the role of agents on an abstract level, KPIs are not suitable since there is a great number and variety of them. However, to perform well in all KPAs can be seen as the common goal of the interest groups represented in the APOC even though the companies’ own goals do not necessarily conform to these KPAs in each case. An airline, for example, does not favour a large traffic volume of other airlines at the airport because thereby the probability of capacity shortfalls and restrictions to the airline’s own operation increases.

Because of such conflicts, one of the most important tasks of the management is to determine the Quality of Service Contract (QoSC) as a basis for the work of the APOC agents, cf. 4.1. Therein, the common objectives and thus the desired level of performance are set by agreeing on target values for the KPIs defined in the contract related to the KPAs. In general, KPAs resp. KPIs influence and partly exclude each other. A weighting of the performance areas and associated indicators shall be carried out either in the QoSC on a management level or in the SLA by the APOC agents. The QoSC and SLA shall be set in such a way that they can be accomplished. Therefore, the SLA is revocable and shall be adjusted in case of relevant changes in the parameters of influence, if no measures can be taken in order to meet the original SLA. The adaptation of the agreement is also a task of the agents. With the approval of the SLA, the agent recognises the APOC objectives as his own targets and thus regards the fulfilment of the SLA and QoSC in the CAP process if necessary as more crucial than the specific interests of the represented stakeholders. Certain responsibilities, however, particularly if they are related to safety and security can never be overruled by a QoSC or SLA. The agent represents the objectives of the stakeholders on the performance level already in the definition of the SLA and on flow and event-level by the joint effort in the APOC for a system-wide optimum, which shall provide advantages over the previously targeted individual optima in the long term for all stakeholders. The QoSC defined on management level is therefore of central importance and the associated KPAs are the starting point for further defining the SLA. The SLA is in turn the starting point for further defining the role of agents.

For this purpose, the responsibilities of the four stakeholder agents in the eight KPAs shall be examined. It shall hereby be clarified who can influence which key performance area in what way and with what kind of resources. This information is presented in the following table where the KPAs safety and security are combined for the reason of simplification.
<table>
<thead>
<tr>
<th></th>
<th><strong>Airline</strong></th>
<th><strong>Airport</strong></th>
<th><strong>Ground handler</strong></th>
<th><strong>Air traffic control</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traffic Volume &amp; Demand</strong></td>
<td>- Number of flights that take place and/or are cancelled</td>
<td>- Reliable provision of available land- and airside resources</td>
<td>- Reliable provision of available ground handler resources</td>
<td>- Best possible use of available airspace, runways, and taxiways</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>- Timely information about unused slots</td>
<td>- Successful coordination of organisational entities on the landside</td>
<td>- Close collaboration with airport to reschedule stand allocations on request and adjust to deviations in the turnaround process</td>
<td>- Best possible use of available airspace, runways, and taxiways</td>
</tr>
<tr>
<td></td>
<td>- Close collaboration with ATC and ground handler</td>
<td>- Close collaboration with ground handler to reschedule stand allocations on request and adjust to deviations in the turnaround process</td>
<td>- Close collaboration with the airline</td>
<td>- Close collaboration with the airline in the allocation of and adherence to slots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Sufficient number of open process stations</td>
<td>- Sufficient amount of available resources</td>
<td></td>
</tr>
<tr>
<td><strong>Punctuality</strong></td>
<td>- Timely information of rescheduled or cancelled flights</td>
<td>- Reasonable, long-sighted and adjustable stand and gate allocation</td>
<td>- Use of additional manpower</td>
<td>- Change in operating procedures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Opening of additional landside process stations</td>
<td>- Use of additional physical resources</td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>- Use of aircraft type adapted to situation</td>
<td>- Avoidance of long routes for passengers in close collaboration with airline and its information about transfer passengers</td>
<td>- Close collaboration with ground handler to efficiently use airport and ground handler resources</td>
<td>- Avoidance of unnecessary elongation of flight paths and routes on the ground</td>
</tr>
<tr>
<td></td>
<td>- Close collaboration with ground handler to efficiently use airport and ground handler resources</td>
<td>- Scheduling maintenance or constructions in times of low traffic</td>
<td></td>
<td>- Close collaboration with airline respecting schedule changes in choice of operating procedure</td>
</tr>
<tr>
<td></td>
<td>- Timely information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airline</td>
<td>Airport</td>
<td>Ground handler</td>
<td>Air traffic control</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>----------------</td>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td>about schedule changes</td>
<td>- Timely information about slots and scheduled times</td>
<td>- Compliance with agreed schedule for time and duration of services</td>
<td>- Timely coordination with airline about slots and slot variations</td>
<td></td>
</tr>
</tbody>
</table>

**Predictability**

- Timely information about slots and scheduled times
- Timely information about construction works and associated inhibition of resources on the airside and landside

**Environment**

- Collaboration with ATC about environmentally compatible flight paths
- Provision of routes on the ground comprising less distance and/or less time of movement
- Use of electric vehicles
- Avoidance of unnecessary drives
- Provision of specific operating procedures to avoid noise pollution
- Collaboration with airline about environmentally compatible flight paths

**Safety/Security**

- Unloading of baggage of No-Shows
- Maintenance of aircraft
- Compliance with other regulations and documentation of irregularities
- Snow clearance and de-icing
- Marking of construction sites
- Fire service
- Compliance with other regulations and documentation of irregularities
- Close collaboration with ATC at the handover between apron, taxiways, and runways (in case airport is responsible for apron)
- Compliance with regulations and documentation of irregularities
- Snow clearance and de-icing
- Adherence to minimum separation requirements to guarantee the safety of air and ground traffic
- Compliance with other regulations and documentation of irregularities
- Close collaboration with airport at the handover between apron, taxiways, and runways (in case airport is responsible for apron)

The Table 4-4 illustrates that in principle all agents have influence on all performance areas. No stakeholder can abdicate from his responsibility for a joint decision by arguing that he could not affect the situation. A further important finding shown in the table is that the influence is often guaranteed only through cooperation and coordination between two agents. This shows the importance of the collaboration of agents in the APOC. Therewith measures can be used, which are not available to their full extent in the optimisation of sub-
processes or individual troubleshooting for the lack of jointly set targets.

In general, it is the objective of the APOC agents to develop a common plan: the AOP (cf. 3.2, 4.2), to enable compliance with the common goals. In this sense, it is for example the role of agents on the flow level to consider at an early stage whether the planned operational procedure is the best solution for the predicted traffic situation or a change of the procedure is advantageous. In this context, using alternative resources, changing schedules, or switching to alternative processes may also be a feasible action. The responsibility for the resource to be planned or the process to be modified remains with the agent who represents the associated stakeholders. In most cases, the agents cannot make their decisions independently; they first have to consult with the represented stakeholders outside the APOC to get their approval. This role is described in more detail in section 4.5.2. The following Table 4-5 presents a generic view identifying which agent in the APOC is generally responsible for which resource. The table distinguishes between the operational and physical responsibility and the responsibility for resources in use. Usually, resources are managed in operational processes by a person in charge of the physical owner. However, in some cases the responsibility depends on the situation. E.g., the runways are operationally managed by ATC as long as the airport as the physical owner does not close the runway for maintenance reasons. Likewise, the airport allocates the stand but once the stand is in use, the airline is responsible for the operating time. How the agents manage and control the resources and use them in the CAP process is described exemplarily in the document [62] that contains the operational scenarios and business use cases corresponding to this concept.

### Table 4-5: Responsibility of stakeholder agents for CAP related resources

<table>
<thead>
<tr>
<th></th>
<th>responsibility for resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“operational”</td>
</tr>
<tr>
<td></td>
<td>“physical” if different than operational</td>
</tr>
<tr>
<td></td>
<td>“in use” if different than operational</td>
</tr>
<tr>
<td><strong>Airline</strong></td>
<td>aircraft, crews, maintenance</td>
</tr>
<tr>
<td></td>
<td>stands, gates, terminal, check-in</td>
</tr>
<tr>
<td><strong>Airport</strong></td>
<td>stands, gates, apron, terminal, security, baggage claim, check-in</td>
</tr>
<tr>
<td></td>
<td>runways, taxiways, baggage system</td>
</tr>
<tr>
<td><strong>Ground handler</strong></td>
<td>cleaning, fuelling, baggage handling (cars, belts), catering, potable water/waste water, cargo handling, ground power and air starter unit, passenger stairs, aerobridges, towing/pushback tractors</td>
</tr>
<tr>
<td></td>
<td>aircraft</td>
</tr>
<tr>
<td><strong>Air traffic control</strong></td>
<td>runways, taxiways, TMA</td>
</tr>
</tbody>
</table>

37 The responsibilities for resources refer to the general appearance at airports in Germany and might differ in individual cases inside and particularly outside of Germany.
Another task of the agents is to discuss measures on short notice to restore the normal state as quick as possible after any problems. In case an agent is definitely not involved in solving a particular problem because his resources are not decisive, he shall support the other actors by a steady flow of information and thus by strengthening the situation awareness. Developing situation awareness through collaborative behaviour and timely disclosure of relevant information to the other members of the APOC shall be the role of all agents in any situation and on every level.

On the event level, the agents are responsible for pursuing the planning from the performance and flow levels consistently in the process and resource planning of their own events. The agents shall thus ensure that the joint goals can ultimately be implemented operationally. It may occur that the agent cannot execute the associated actions by himself due to lack of accountability. In this case, the agent shall delegate the action to the responsible person in the represented organisational unit.

The functional role of stakeholder agents in the APOC can be summarised as follows:

○ They shall represent the objectives and interests of one or several stakeholders at the airport.

○ They shall aspire to a system wide optimum of the airport by collaboration and exchange of information.

○ On the performance level, they shall determine common goals and frame them in the SLA by the weighting of KPIs.

○ They shall accept the binding status of the QoS C and SLA and adapt the agreement if applicable.

○ On the flow level, they shall participate in attaining every single KPA target since they can influence directly or indirectly all KPAs.

○ They shall closely collaborate in order to facilitate all potential factors of influence.

○ On the flow level, they shall establish a joint plan, which shall lead to the best possible realisation of the QoS C and SLA. In addition, they shall adapt the plan to suit the particular situation.

○ During the generation and implementation of the plan, they shall maintain the responsibility over the resources, which belong to the field of activity of the represented stakeholders. The agents shall consult with the stakeholders in respect of the utilisation of resources and get the approval for decisions.

Finally, the role of the Moderator will be considered. He shall be primarily responsible for the preservation and maintenance of the SLA, i.e. the defined targets, and shall initiate an adjustment of the agreement if necessary. He shall ensure the cooperation of the agents towards a common goal so that the collaborative approach shall not be lost between the stakeholder objectives. The Moderator has an impartial position. During a negotiation, he has the task to moderate it. The process of negotiation and the corresponding specific roles of the agents are discussed in section 4.5.3.2. The Moderator is an independent person as far as his role is considered useful in the particular implementation of the APOC. Otherwise, his tasks shall be transmitted to one or more stakeholder agents. However, this approach may entail in some cases the problem that a moderating agent may not act entirely neutral. As illustrated in the introduction to this chapter, the agents usually represent a range of stakeholders and organisational units. The interaction between these units and the agent is described in the following section.
4.5.2. Interaction between APOC and “the Outer World”

Even if an agent is in charge in a particular situation, in general the agent cannot take decisions independently. The agent probably was granted with limited authorisation by the represented stakeholders and has to consult them before certain decisions can be made. The agent possibly represents a number of independent organisational units. These are located outside the APOC, but they have the right to take the final decision. Therefore, two different processes of decision making shall be distinguished: The first is the joint decision making between the different agents in the APOC, which is part of the CAP process and is described in detail in section 4.5.3. The second process is the consultation of the responsible operation centre (OC) outside the APOC by the agent and will be subject of this section. Thereby, the role of the agent shall be the coordination and communication with the OCs. The infrastructure and related utilities required for this task are described in chapter 4.6.

During the CAP process, initially the role of the agent shall be to enable the necessary information exchange between APOC and OC needed for the decision-making process within the APOC. The agent shall communicate and justify the necessity of a decision and propose measures to the OC that were considered appropriate in the APOC. The OC shall in turn conduct an in-house investigation of potential steps. If the measures considered possible by the OC differ from the recommendation of the agent, the impact of these deviations in terms of the overall airport system shall be re-evaluated. This shall be done within the APOC, cf. 4.5.3. Overall, a consultation process can consist of multiple exchanges between the agent and the OC. An example of such a consultation may be the request of the Airline Agent to the OC to delay, reschedule, or eventually cancel a certain amount of flights. Now the OC may test in its own systems whether this request can be met, what kind of disadvantage it entails for the airline, and which flights can be considered. The suggestion or request for a CAP process may also come from an OC and shall be communicated to the corresponding agent who shall initiate the process within the APOC.

When the coordination with the OC is completed, the agent shall communicate the measures that can be taken within the APOC. Furthermore, it is necessary that the actions, which were decided and approved in the APOC and accepted by the OC, are implemented by the executive entities. For this reason, these entities shall get instructions sent by the OC or directly by the APOC agents to ensure that the reality matches the plan. This process chain is shown in Figure 4-7. Since the implementation of the decisions shall be conducted by each stakeholder and will be different at each airport, the exact procedures are outside the scope of this concept.

The exchange with organisations that are not direct stakeholders at the airport in question is also part of the interaction between the APOC agents and the outer world. Some examples are:

- neighboring airports, which shall be informed of particular decisions (e.g. in anticipation of additional traffic) or from which information shall be obtained about their traffic situation,
- DEP airports that have to take the ARR capacity of the APOC airport for their DEP slots into account,
- CFMU, which shall be informed not only about the capacity of the airport, but also about DEP / ARR prioritisation and the SLA, and which shall timely inform the APOC agents about the slot allocation at DEP airports,
- meteorological services, which are an important external source of information,
- authorities working at the airport, if they are not already represented by the Airport
Agent,

- transportation companies, which shall ensure the accessibility of the airport landside and shall communicate current or potential restrictions on their services.

Which external partners of the APOC agents are relevant for the outside communication depends on the organisation of the individual airport and on the particular situation. For an APOC implementation, the distribution of tasks regarding the contact with external entities has to be arranged. One possibility is that the agent closest to the subject of the external organisation takes charge of the communication, for example, the ATC agent with the CFMU and the airport agent with transport companies. Another solution may be that the external communication is handed over to the Moderator.

Finally, it shall be noted that the limited number of representatives in the APOC may result in internal conflicts for an agent, if the agent acts for competing stakeholders. This problem must be considered when dealing with the issue of fairness within the CAP process, cf. 4.5.4. In summary, the role of agents in the interaction between APOC and the outer world consists of the following points:

- They shall coordinate all represented organisational units and their potentially competing goals with the plan developed in the APOC.
- They shall collect information from the represented stakeholders as well as from supporting organisations.
- They shall communicate the content, the context, and the necessity of measures to OCs.
They shall adopt suggestions and requests for CAP processes from OCs and initiate the processes in the APOC.

They shall support the OCs in the evaluation of measures regarding the impact on the overall system.

They shall communicate the approval of measures by the OCs in the APOC.

They shall transmit decisions taken within the APOC to the OCs or directly to the executive entities.

They shall inform related organisations about relevant APOC information and decisions.

4.5.3. TAMS Collaborative Airport Planning

In this section, two basic components of collaborative airport planning are described: what-if probing and the negotiation process.

4.5.3.1. What-if Probing

In case that unwished deviations are detected in the AOP (cf. section 4.2), the APOC agents shall elaborate suitable measures to counteract respective deviations. Thereby, all those parameters in the AOP that can also generally be manipulated in the various systems under normal operating conditions shall be adjustable.

The functionality of what-if probing shall enable the agents to elaborate possible solutions on all planning levels, cf. section 4.2. It shall also allow an assessment of feasibility, resulting effects, and costs of the solutions without already executing any changes in the active AOP. Therefore, the functionality of the what-if probing is an essential instrument for decision support and consequently conduces to target-based, pro-active traffic management with regard to the QoSC and SLA, cf. section 3.5. Further, what-if probing is needed by the agent to convince their stakeholder (OC) from the necessity and the benefit of a decision.

In combination with the negotiations among the APOC agents during the CAP process, the solutions and measures obtained from the what-if probing provide a basis for discussion and are supposed to support a quick agreement. The parameter changes, on which the what-if probing is based on, shall thereby always be traceable. The CAP process is exemplified in the following section.

On performance and traffic flow level, each agent shall also have the possibility to elaborate solutions for resources outside his area of responsibility. The agent may introduce those results as a proposal for a solution in a future negotiation process or may use them to initiate a new negotiation process. However, also with TAMS the responsibility for the implementation of such a solution shall lie with the owner of the resources (decision maker).

With respect to the actuality of the results of a what-if probing, the data basis on which the what-if probing is based on shall be updated according to the necessity defined by the object of investigation. Ideally this means, that the data basis is kept as up-to-date as possible.

Assuming the AOP is maintained by more than one planning application in the sense of the hierarchical planning as described in section 4.2, two versions of what-if probing can be distinguished: on one hand the single what-if and on the other the joint what-if probing.
Single What-if Probing

Single what-if probing is solely used at the level of single planning applications. The agent uses the available application isolated in order to evaluate the effects of possible changes solely on this system level. Therefore, single what-if only affects the related hierarchical planning level or those parts of the level, which are covered by the respective system. Effects due to changes of the what-if probing on other planning levels or other planning systems are not considered.

The advantage of a single what-if probing lies in the possibility of pre-selecting potential solutions before activating the complete planning cycle for all solution scenarios. For instance, a single what-if probing might already detect, that a measure has contrary effects. This measure could then be abandoned without any further evaluation. However, it can thus not be ensured that all possible effects on other systems or hierarchical planning levels will be detected.

A single what-if probing on event level can cover only one process step, such as turnaround. With regard to achieving the actual goals, potentially a great variety of measures has to be evaluated and their feasibilities have to be clarified by the agent in consultation with the respective operation centre. Only after this first step, effects of the single what-if probing shall become relevant for following CAP process steps.

Joint What-if Probing

Contrary to a single what-if, the joint what-if probing shall comprise all systems and thereby all hierarchical planning and process levels. The original planning hierarchy shall thereby stay unchanged.

It ultimately depends on the aim of the what-if probing which systems or planning levels, respectively, are involved in a joint what-if. In its full extent, joint what-if probing comprises the complete planning process starting from the performance level to the traffic flow level up to the event level containing every single process step. Alternatively, the what-if probing can start from the opposite direction, e.g. from the event level up to the performance level, thus enabling an evaluation of the effects the possible solutions may have on the performance level. The latter approach is mainly of interest if problems occur ad-hoc on a tactical level whilst potentially entailing medium to long-term effects. In certain circumstances, it can merely be of interest to evaluate possible measures solely on the event or resource level, too. In this case, not all systems have to be involved in the joint what-if probing though there must be a minimum of more than one.

The advantage of joint what-if probing lies in the possibility to evaluate the effects a possible solution can provoke on all hierarchical planning levels. Thus, the information basis for a negotiation can be consolidated. For instance, by using a joint what-if probing for changes in the planning during the turnaround process, the effects in the departure sequence can be analysed.

Every APOC agent shall have the possibility to initiate a joint what-if using the systems available to him. This will enable the agents to assess the feasibility, costs, and possible effects of their own solutions, also at other planning levels.

4.5.3.2. Negotiation Process

The objective of collaborative airport planning is the optimisation of the whole airport system for the time horizon of the next 24 hours. Thereby, all hierarchical planning levels of the AOP shall be considered: the performance, traffic flow, and event level. To foster the CAP process, all agents shall share their interests with each other and during a negotiation they
shall come to a mutual decision with respect to the QoSC and SLA. Therefore, a common awareness shall be established for the situation, the possibilities, and the limits of other stakeholders as well as for the effects own actions have on other stakeholders’ plans.

The solutions and measures deduced by a what-if probing, as described above, shall provide an essential basis for the improvement of the situation awareness and consequently the negotiation process.

**Actors**

- **Initiator** – each agent within the APOC can initiate a negotiation.

- **Decision maker** – agent responsible for the implementation of a respective measure, cf. section 4.5.1, Table 4-5. The decision maker shall generally respond to negotiation requests. However, he also has the authorisation to refuse a negotiation request, to interrupt an on-going negotiation, or to implement a solution arbitrarily.

- **Agents (support)** – all APOC agents participating in the negotiation.

- **Moderator** – structuring and moderating the negotiation process. Furthermore, the Moderator shall regard the adherence of the SLA and in case the SLA is the subject of negotiation the adherence of the QoSC; if it is foreseeable, that the adherence of the SLA is at risk, the moderator shall initiate a CAP process, too.

**Preconditions**

All agents have access to the necessary assistance systems within the APOC and, if required, to their operation centre (OC). The connection to the OCs assures that the agents can discuss possible inquiries and allows for the agents’ decision making ability also in cases where the responsibility lies not with the agent himself but with the operation centre.

Furthermore, a deadline for ending the period of negotiations shall be defined before starting a negotiation process. The responsibility for the adherence to this deadline falls to the moderator. Thereby, it shall be guaranteed that enough time is left for successful implementation of a selected measure.

**Postconditions**

- **Successful final state**: a solution has been found and changes are implemented in the AOP.

- **Failed final state**: no solution has been found and consequently no changes are implemented in the AOP.

**Trigger**

A collaborative airport planning process shall be initiated in case of following situations:

- A situation is forecasted which will affect airport operations in such a manner that deviations from the current AOP and the SLA have to be expected. In this case, solutions shall be jointly discussed to counteract the deviations. If no measure is successful or feasible, the agents shall consider the possibility to adjust the SLA to the situation and to inform the network about the bottleneck situation. A possible example for such a scenario can be for instance a severe weather event.

- An agent can counteract unwished deviations in the AOP or the performance objectives by measures within his responsibility, which however would influence other stakeholders. In this case, common situation awareness shall be generated before the AOP is altered in any form. This kind of approach shall ensure that
possible alternatives can be suggested and the final decision is made with respect to the system wide optimum.

○ An agent found a solution for unwished deviations in the AOP or the SLA whose implementation is outside his responsibility. In this case, every agent shall have the possibility to suggest wishes and possible solutions. The decision maker in turn shall analyse their feasibility with respect to the system wide optimum before refusing a solution, if applicable.

The CAP process comprises two steps: first the identification of a possible solution via what-if probing and secondly the negotiation of possible solutions. In the first step, the agents thereby need to identify possible solutions for the specific problem and evaluate the feasibility, costs, and effects with the help of a what-if probing. In a negotiation process, the agents shall derive as a second step the best possible out of all available solutions.

Based on the operational concept of the FAMOUS project (cf. [23]), the following paragraph presents a generic flow of a CAP process in the sense of TAMS.

**Main Flow**

1. The initiator identifies an unwished deviation in the AOP or the performance objectives and places a request for a CAP process to the decision maker. The initiator may already suggest a first possible solution.

2. The decision maker decides that the requested CAP process will be carried out.

3. The decision maker develops own solutions for counteracting the presented deviation, by completing the necessary what-if probing (single or joint what-if) and through identification of one or more solutions. The decision maker should thereby also consider the solution suggested by the initiator.

4. The decision maker sets a deadline defining the maximum time period possible for the CAP process. Furthermore, he informs all agents and the moderator about his solution(s) and the respective deadline.

5. Based on the solution(s) proposed by the decision maker, all participating agents may analyse feasibility, effects, and costs of the respective solutions within their resources via what-if probing (single or joint what-if) and inquiries with their operation centres if necessary.

6. The moderator gathers all information related to the available solutions, visualises it for all participating agents, and invites all agents to a negotiation process for decision making.

7. The negotiation ends with a mutual decision for one of the identified solutions within the deadline.

8. The decision maker implements the identified solution.

9. The changes made in the what-if probing used for the selected solution are incorporated into the database, all systems, and consequently the AOP.

**Alternative Flows**

[3] – The decision maker has the need to implement a solution immediately.

The decision maker interrupts the CAP process.

[Alternative flow continues with step 8 of the main flow.]
[4] – The decision maker prefers one of his own solutions and does not want to discuss solutions of other stakeholders (not recommended).

The decision maker interrupts the CAP process.

[Alternative flow continues with step 8 of the main flow.]

[5] – One (or more) agents present an alternative solution.

Every agent has the possibility to present alternative solutions.

The decision maker collects all alternative solutions and decides which aspects of these he wants to consider further.

The decision maker conducts, if necessary, additional what-if probing and inquiries with the operation centre if necessary.

[Alternative flow continues with step 6 of the main flow.]

[7] – The defined deadline set by the decision maker expires without identification of an alternative solution.

The decision maker finishes the CAP process and implements the solution, which is most useful in his opinion.

[Alternative flow continues with step 9 of the main flow.]

[7] – The defined deadline set by the decision maker expires without identification of an alternative solution.

The decision maker prolongs the deadline and informs all agents.

[Alternative flow continues with step 5 of the main flow.]

Failure Flows


The decision maker rejects the request for the CAP process made by the initiator.

[3] – The decision maker cannot derive an acceptable solution for the deviation identified by the initiator.

With the remark that no solution could be found, the decision maker rejects the request for the CAP process made by the initiator.

4.5.4. Fairness within the CAP Process

Fairness is a central requirement for a TAM system. Situations occur regularly during the decision making process where one agent accepts certain restrictions for the stakeholder(s) represented by him in order to avoid greater disturbances of the overall system. One example is the cancellation or postponement of selected flights in order to enable an in-time handling of other flights. Due to a limited number of agents in the APOC these situations may also provoke internal conflicts for an agent, if he represents competing stakeholders, cf.
4.5.2. In this sense, the principle of fairness ensures that the agent or stakeholder agreeing to additional constraints gains benefits of some kind. An example for a simple solution is that when an Airline Agent cancels or postpones flights, he is allowed to prioritise some of his other flights. Through the APOC such coordinated priorities can be visualised, managed, and distributed to all assistance systems and stakeholders. Especially sequences of departures and arrivals have to reflect the prioritisation. Once all agents are aware of this process that shall enhance the fairness, coordinated priorities can be taken into account before eventually other priority rankings (“wish-lists”) are considered.

A fundamental question is how to assure an equal division of the inevitable constraints or required additional resources among all stakeholders over a long period of time. The answer to this question is outside the scope of the TAMS project, since the requirements for a usable practise to assure the fairness within the CAP process have to be defined in close collaboration with later users of TAM, who are aware of the requirements and implications of CAP at their specific airport. Because the TAM concept is currently furthermore an object of research and development and no implementation of the concept at an airport exists yet, which would allow any live human in the loop trials, this step of concept specification cannot be taken although, the TAMS project may contribute essentially.

A visionary idea is to establish a point rationing scheme where weighting functions evaluate the actions of each agent in respect of their benefit to the common goal: obtaining the agreed service level. Such a bonus malus system can extend the fairness-horizon to a well-balanced situation after a number of decision making processes. The point system also needs to define how and for what earned points can be used by the agents to attain an advantage in a later situation. The reasoning behind the earning and using of points in a bonus malus system has to be transparent to all agents to guarantee the fairness in the long run.

4.6. APOC Working Positions

This chapter describes the requirements for working positions within an APOC. These requirements result from the roles and responsibilities of agents, identified in chapter 4.5. First, a draft of the APOC Video Wall and its information is shown. After that, chapter 4.6.2 explains requirements of agent working positions.

4.6.1. APOC Video Wall

The APOC Video Wall is the main tool to ensure the overall situation awareness for all APOC agents, independent from their specific interests. Furthermore, the APOC Video Wall shall ensure that agents can monitor the current state of the airport and that the assessment of the airport condition is based on the same information. This APOC Video Wall concept can be seen as a draft. Figure 4-8 shows a schematic representation of an APOC Video Wall. It is divided into four columns with 12 differently sized areas.
The two columns on the left are foreseen to show the predicted information like queue monitoring for the next 24 hours. The two right columns represent the actual state of the airport. Areas 9 – 12 of the right column are task-specific and allow the provision of variable information.

The structure, the concrete content and its graphical visualisation have to be understood as a proposal and depend on the airport and its stakeholders at which TAM is intended to be implemented. However, to be in line with the principles of the TAM Video Wall, it is important, that the elements, which show the predicted and current situation, are determined in their position and their general kind of information and visualisation. This aspect ensures that every APOC Agent is able to get the minimal needed situation awareness at every time as fast as possible to participate at the Collaborative Airport Planning process.

Figure 4-9 represents an example, how all Video Wall areas can be used together in an implementation. The following sub-chapters describe the functions of each area in more detail.
4.6.1.1. Section with Predicted Information

Areas 1 to 5 belong to this section.

**Area 1 – Agent Messages**

This area presents important information about the airport. This could be e.g.

- information and reasons about inhibitions of airport parts (e.g. runway, terminal),
- information about expected adverse weather conditions,
- information about inhibition of closure of airports.

Furthermore, this field shows the temporal occurrence of events and their estimated duration. For this area, only the moderator shall have writing permissions to enter the events.

**Area 2 – Quality of Service**

Area 2 presents the common performance objectives of all actors, the Quality of Service Contract (QoSC) and Service Level Agreement (SLA), predefined and parameterised Key Performance Indicators from the QoSC, and target values for the KPIs adaptable by APOC agents from the SLA. The objective of the TAM approach is to give reliable information on the airport status to the network, cf. [22]. Therefore, the agents shall aim to respect this agreement and to adjust their operations accordingly. For this area, the moderator shall have writing permissions to enter the objectives for each performance parameter.

**Area 3 – Weather Radar**

This area shows a map with weather radar. In addition, there can be a scalable display of the weather radar for a closer look.

**Area 4 – Key Performance Indicators, Weather, Strategy**

Area 4 is used to monitor planned and expected KPIs, weather conditions, the strategy of runway utilisation, and the arrival/departure ratio over time. For this area, the moderator shall have writing permissions to enter the runway utilisation strategy.

**Area 5 – Queue Monitoring**

Area 5 is used to monitor resources and queues. The Video Wall can show a rough description for each resource. The agents’ desktop clients can show in addition a more detailed display with further information.

4.6.1.2. Section with Information of Current Situation

This section consists of areas 6 and 7.

**Area 6 – Airport Situation**

Area 6 shows an airport map. The resources, like runway or aprons, are colour-coded. The colour indicates the status of the respective resource. For example, green means, everything is as planned, yellow means the resource is located within the possibility window (cf. [22]) and red means the resource is outside the possibility window. Furthermore, the airport map can show A-SMGCS data and wind data.

**Area 7 – Airspace Situation**

Area 7 shows the airspace situation near the airport. In this display, the agents can see the airside arrival queue and the airside departures.
Areas 8, 9, 10, 11, and 12 are within this section.

**Area 8 – Date and Time**
Area 8 shows the current date and time in local time (LT) and UTC (Universal Time Coordinated).

**Area 9 – Airport Performance Monitoring**
Area 9 is used as a task-specific area that allows presenting other variable information. In this example, area 9 shows airport performance monitoring data.

**Area 10 – Tasks**
Area 10 is a task-specific area that allows the presentation of task-specific information. In this implementation, area 10 shows tasks which have actually to be handled by the agents within the APOC. These tasks depend on the selected information in area 1. For this area, only the moderator shall have writing access to enter the events.

**Area 11 – Workflow**
Area 11 is a task-specific area, too. It allows the presentation of detailed task-specific information. For this area, the moderator shall have writing access to enter the events.

**Area 12 – Variable Displays**
Area 12 is a task-specific area. In this area, different airport information may be displayed, e.g.:
- arrival/departure time tables,
- video live streams of airport resources (apron, terminal, etc.),
- other recent news.

### 4.6.2. Agent Working Positions

Besides general requirements for agent working positions, requirements of the stakeholders regarding their working position in a TAMS environment are described in this section.

#### 4.6.2.1. General Requirements for Agent Working Position

This section describes requirements for working positions that are not specific for a certain stakeholder. This means, all working positions, except the moderator working position that will be explained in chapter 4.6.2.6., must meet these requirements. These requirements result from the roles and responsibilities of agents, identified in chapter 4.5. Generally, it has to be ensured that each agent only has access to data from his area of responsibility. It has to be ensured that company confidentialities remain protected. For all working positions, an automatic interaction is needed, e.g. with the Airport Operational Database (AODB) to guarantee the availability of information necessary for a common situation awareness. To comply with the needs of the APOC agents to discuss decisions with operation centres, all working positions shall provide communication devices connected to the stakeholders’ operation centres. Furthermore, all working positions shall offer the possibility to display information from stakeholder-specific support tools, if these are not installed at the workplace of the agent. A further feature is the display of alerts, as described in chapter 4.4. Following the performance-based approach of TAM, all working positions shall display a number of...
KPIs. These KPIs were identified in chapter 4.3. Furthermore, all working positions shall support the APOC agents to define reasonable settings for the weighting of performance parameters through visualisation of their impact on the flow planning of stakeholder resources, e.g. increasing the importance of emissions compared to throughput will affect the queue at the runway. The working position shall support the APOC agents in defining and negotiating reasonable settings for the service level agreement. For this task, all agents need suitable abilities to forecast flow and performance developments.

Most predictions are based on historical data/experience for a certain situation and the forecasted weather as well as demand. This makes functions for on-time and post analysis important. Thus, the agent working positions provide functionalities to analyse data and display the results in a practical way. The agent working position shall also allow the aggregation of information on events.

The working position HMI consists of configurable views. These views enable the APOC-agent to monitor and influence the development of the airport processes on performance, flow, and event level. The working position allows the monitoring of different topological areas in dedicated views depending on the stakeholder. These views shall be configurable in an extent that reaches from showing details to abstract schematic views depending on stakeholders’ requirements. The focus lies on the visualisation of flows through critical resources like runways, taxiway, terminals, aprons, and arrival and departure fixes.

Furthermore, the working position displays the active AOP for the next 24 h. The granularity of this plan shall depend on stakeholders’ interests.

In addition, the working position shall provide possibilities for what-if probing, execution of tasks, and negotiation of parameter settings between stakeholder agents.

What-if probing is necessary to allow the agent an analysis and evaluation of several alternatives regarding their benefit. Further, the working position shall provide a function to show results of what-if probing on the Video Wall. Finally, but not less important, the working position shall provide a function to send the results of what-if probing to the operation centres of the stakeholder.

Another task of an APOC agent is the negotiation of what-if probing results, cf. chapter 4.5. For this reason, the working position shall provide an infrastructure, which makes a participation in negotiation possible. That means the working position shall provide facilities to communicate with each agents’ operation centre and between the agents within the APOC, especially if it is implemented as a virtual environment. Furthermore, the working position shall allow the agreement or disagreement to results. Further, the working position shall provide a comparison between flight plan data by an AOP and flight plan data from a what-if probing. Additionally, the working position shall enable the agent to draw conclusions about advantages and disadvantages between these data sets.

Section 4.6.2.2 and the following address the specific needs of stakeholders. These specific stakeholder requirements depend on the APOC agents interests. Nowadays, the TAM concept in general is an object of research and development. Consequently, also the roles and tasks of APOC agents have to be defined. A full validation with possible APOC users has not yet been carried out. Therefore, the following interests of APOC agents and their corresponding requirements for APOC working positions are assumptions based on the current state of knowledge.

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4.6.2.2. Airline Working Position

The Airline Agent is interested in a stable flow of operation processes of the airline(s) he represents. It is assumed that in case of process deviations the Airline Agent tries to re-adjust these deviations to meet the current AOP. Therefore, the Airline Agent shall have a detailed view of the operating processes of each flight within his scope. The Airline Agent only needs a rough overview about flights from airlines, which the Airline Agent does not represent.

Thus, the working position shall provide a tool, which presents a detailed view of all flights, in the scope of the Airline Agent. That means, it shall display all scheduled, estimated and actual times and the character (scheduled flight, charter flight, feeder, etc.) of a flight. This tool shall give a detailed overview of all turnaround processes like check-in, boarding, fuelling, etc. Furthermore, this tool shall show deviations in turnaround processes. In addition, the working position shall provide input facilities to prioritise flights, which are defined during negotiation, e.g. between two airlines.

Moreover, the working position shall only permit parameter and prioritisation changes for flights from airlines, which the agent is representing. For this, the working position shall provide input options, if the existing systems do not yet provide these functions. The working position shall prevent the change of flights from airlines not represented by that agent.

In addition, the working position shall provide the feasibility to enter cancellations and delays of flights into the system. According to our current knowledge, the decision about a cancellation or delay of a flight will be made in the airlines operation centre and not by the APOC Airline Agent. The Airline Agent however enters the information about cancellations or delays of flights. With this information, a new AOP will be created. The working position shall provide opportunities to distribute flight information particularly to the Airport and Ground Handling Agents to enhance situation awareness.

Besides that, the working position shall display airline-specific KPIs, for example average punctuality and average throughput of the airline during the day of operation. Further, the working position shall provide a comparison specifically between average airline punctuality and average airport punctuality. Furthermore, the working position shall provide a comparison between airline throughput and airport throughput. These comparisons are necessary to give the airline the opportunity to compare and re-adjust its own performance values with regard to airport values.

4.6.2.3. Airport Working Position

This chapter describes the operational requirements for an Airport Agent working position derived from roles and responsibilities that are determined in chapter 4.5. The main responsibility of an Airport Agent is to ensure the compliance with agreed Key Performance Indicators for airside and landside, like airport punctuality. A further responsibility is the efficient use of land- and airside airport resources, like terminal areas. Due to these responsibilities, the airport working position shall give information about the agreed key performance indicators, specifically indicators like overall airport punctuality, overall airport delay, and throughput of sub-areas of the airport like runways, apron, and terminals. Furthermore, with this working position it shall be possible to perform and compare capacity forecasts considering different operating procedures of the airport and the correlated procedure costs. Thus, it is necessary that the working position provides options to enter operational strategies (e.g. increasing punctuality, increasing throughput, etc.) in the area of an airport’s responsibility in order to achieve planning objectives. If necessary, the working position shall additionally provide options to input blocked and open airport areas like apron,
taxiway, runway, and terminal areas. Furthermore, it should be possible to send information to other tools e.g. S/GMAN about closing gates or advising A/DMAN about changes in runway utilisation. A further responsibility of an Airport Agent is monitoring the current situation at the airport. Thus, the working position shall provide a tool, which presents a detailed view of all flights regardless of the airline. The working position shall display all scheduled, estimated, and actual times and the character (scheduled flight, charter flight, feeder, etc.) of a flight. This tool shall give a detailed overview of all turnaround processes like check-in, boarding, fuelling, etc. Furthermore, this tool shall show deviations in processes to the Airport Agent. To arrange these matters and to get information, it is necessary that airport working positions provide equipment for communication with affected operation centres like apron control, traffic centre, stand and gate management, terminal management, security, federal police department, baggage management, and ground handler.

4.6.2.4. ATC Working Position

This chapter describes the operational requirements for an ATC Agent working position derived from roles and responsibilities that were determined in chapter 4.5. The main responsibility of the ATC is to guarantee safety of air traffic within the arrival and departure areas and to guarantee safety of ground movements. Thus, a responsibility of the ATC Agent is adherence to the handling of a planned and agreed number of departures and arrivals through the taxi- and runway system. The tasks and responsibilities of ATC Agents lead to the following additional functions of the ATC-working position.

The working position shall provide features to achieve awareness about the predicted traffic load of airspace resources of the airport and within its TMA. Furthermore, the working position shall provide the actual regional traffic situation to enhance the situation awareness of the ATC Agent. Furthermore, the ATC working position shall provide a view for pre-departure sequencing to enable collaborative airport planning. For further information about pre-departure sequencing compare the Airport-CDM Implementation Manual [27].

Furthermore, the working position shall provide input options to enter capacity strategies and ATC operating procedures. In order to discuss operational procedures, the working position shall provide possibilities to communicate to operation centres like Approach Control, Tower Control, Ground Control, Clearance Delivery, and CFMU/ATFCM\textsuperscript{38}.

Furthermore, it is conceivable that inputs of ATC-operating procedures are directly displayed on the Video Wall to improve the situation awareness of all agents and to discuss these operating procedures among the other agents.

4.6.2.5. Ground Handler Working Position

Chapter 4.5 describes that the main task of a ground handling operations centre is to schedule and control the use of ground handling resources (employees and vehicle fleet). Thus, the ground handling working position shall provide a tool, which enables the display of a flight's status during the turnaround process. This tool shall give a detailed overview of all turnaround processes like boarding, fuelling, etc. Furthermore, this tool shall show deviations in turnaround processes. In addition, the working position shall provide input facilities to prioritise flights, which are defined during negotiation, e.g. between two airlines. Another responsibility of the Ground Handling Agent is the adjustment between available ground

\textsuperscript{38} ATFCM – Air Traffic Flow and Capacity Management
handling resources and required ground handling resources. For this reason, the HMI of the working position shall display a comparison between available ground handling resources and required ground handling resources. If available, the working position could trigger an alert on the HMI in case the ground handling resources fall below required resources. Usually, the Ground Handling Agent needs equipment for communication to operation centres of all airlines and to the Airport Agent or directly to the airport stand and gate management. This communication is necessary to share information e.g. about deviations in handling processes.

4.6.2.6. APOC Moderator Working Position

The Moderator should have no stakeholder specific tasks, like execution of a what-if probing or participation in negotiations. The tasks of the moderator, determined in chapter 4.5, are preservation and maintenance of the SLA, initiation of adjustments to the agreement, organisation and moderation of negotiations during the Collaborative Airport Planning process and controlling of contents at the Video Wall, cf. chapter 4.5. Thus, the working position shall provide an access to input airport information (e.g. terminal inhibition) and performance objectives to the Video Wall. Furthermore, the moderator working position shall provide functions and input options to preserve and maintain the SLA. Another function should be an input option to initiate the adjustment of the SLA if necessary. Furthermore, the working position should provide possibilities to control the different elements of the Video Wall.
5. Implementation of TAMS Concept

The previous chapters described the operational procedures that enable Total Airport Management in general. This chapter contains a breakdown of this conceptual approach onto the components needed for fulfilling the deriving requirements. It has been directly created by the TAMS industrial partners Siemens, Barco, ATRICS and Inform with only supplemental information given by DLR on the landside management application PaxMan (cf. 5.3.2.6) and Stand- and Gate Management (cf. 5.3.2.3).

The first subchapter presents the definitions of Time Phases in TAMS. While these definitions themselves are not critical as they have no direct influence on the operations, these definitions will nevertheless be used throughout the whole TAMS project, in internal and in external communication, and are therefore important for TAMS.

An overview of A-CDM requirements, the way the information provided contributes to collaborative decision making and the implementation in TAMS from a high level point of view are described in chapter 5.2.

The applications applied in TAMS to provide the information for enabling a good common situational awareness are described in chapter 5.3. Specifically, the way the TAMS applications support strategy capability and joint what-if analysis are described in 5.3.4 and 5.3.5.

The Video Wall display in the APOC is described in chapter 5.4 and chapter 5.5 deals with the stakeholder-specific workplaces in the APOC.

5.1. Time Phases in TAMS

The APOC shall seamlessly plan on performance, flow and event level - Planning results derived from the performance- and flow-level shall constantly be considered in the planning process on event level. Nevertheless, distinctive transitions in flight status (e.g. filing of ATC flight plan) are constraining the planning process to a degree, that a distinguishing in different time phases is necessary.

Depending on the operational constrains derived from the status of a flight, TAMS shall distinguish between a planning, a reaction and on event level a trajectory execution phase.

Within the planning phase most processes on event level are still in a status that allow a re-planning and additionally there is enough time for tasks like a joint what-if. Within the reaction phase there are already constrains on event level that hinder a free re-planning and there is only limited time for tasks like a joint what-if. As soon as a flight enters its trajectory execution phase it is solely under control of the operation centres.

To enable an easy adaptation of TAMS to different airports, the definition of Time Phases shall orientate on standardized operational processes and thus be independent from tools in use. The definition of Time Phase is based on the definitions that are given by the TAM-OCD and in SESAR. While the TAM-OCD defines these phases more from a flow- and performance orientated view, SESAR defines them more from an event oriented view (Business Trajectory). TAMS shall use following definition of Time Phase:

Time Phases not in scope of TAMS:

- Long Term Phase
  - This phase encompasses the time horizon of several years until approximately 6 month before the day-of-ops. However, this phase is not scope of TAMS.
Medium Term Phase

- The Medium Term phase starts around 6 months prior the flight event and ends at \([\text{now} - 24 \text{ hrs}]\).
- The time boundaries on performance and flow level for the Strategic Phase for TAMS extend from \([\text{now} + 24 \text{hrs}]\) (floating time interval) up to 6 months into the future and largely overlaps with the Medium Term Phase on event (flight) level.

Planning Phases in TAMS:

- Pre-tactical Short Term Phase
  - The Pre-tactical Short Term Phase begins with \([\text{now} - 24 \text{hrs}]\) and ends with filing of the ATC flight plan (around \([\text{now} - 3 \text{h}]\)) for each particular flight. Based on the 4D-trajectory given by the ATC flight plan further planning like CFMU slot allocation can be executed.
  - The time boundaries on performance and flow level for the Pre-Tactical Phase for TAMS extend from \([\text{now} + 3 \text{hrs}]\) up to \([\text{now} + 24 \text{hrs}]\) (floating time interval) and largely overlap with the Pre-Tactical Short Term Phase on event (flight) level.

- Tactical Short Term Phase
  - The Tactical Short Term Phase for a particular flight begins with filing of its ATC flight plan (around \([\text{now} - 3 \text{hrs}]\)) and ends with issuing of TSAT for this flight (A-CDM milestone 10, at \([\text{EOBT/ TOBT} - 45 \text{min}]\)).
  - The time boundaries on performance and flow level for the Tactical Phase for TAMS extend from now up to the pre-tactical phase \([\text{now} + 3 \text{hrs}],\) floating time interval) and largely overlap with the Tactical Short Term Phase and Trajectory Execution Phase on event (flight) level.

Reaction Phase in TAMS:

- Trajectory Execution Phase
  - This phase starts at the end of the Tactical Short Term Phase \([\text{EOBT/ TOBT} - 45 \text{min}]\)) and ends if the flight finished his flight trajectory with the in-block at the destination airport
  - There is no trajectory execution phase on performance and flow level.

Analyse Phase in TAMS:

- Post Flight
  - The post flight phase starts at the day after the day-of-ops and shall contain analysis of the processed flight. These analyses are generally important to optimise operational procedures continuously. Nevertheless, the TAMS operational concept document lays its focus on the collaborative airport planning process before event execution.

Note: The Trajectory Execution Phase for an arriving flight might be defined through its ATOT (Actual Take-Off Time) at outstation. Afterwards procedures like “delay on ground” are no longer applicable and thus the influence of the APOC on this flight is limited.
5.2. A-CDM Implementation

Without timely sharing of accurate information, no common situation awareness can be created for all stakeholders in the Airport Operation Centre (APOC) needed for making collaborative decisions. The enablers for an APOC as outlined in the TAM-OCD are an Airport – System Wide Information Management (A-SWIM) and an operational Airport – Collaborative Decision Making (A-CDM). While A-SWIM is a technical enabler for information sharing, A-CDM describes two different aspects: First how stakeholders can be brought together to agree on sharing information and second how this information has to be shared to effectively control the processes of flights with special regard to their CFMU-slot compliance.

With the implementation of A-CDM comes the necessary functionality to accurately predict the performance of flights on event level (milestone adherence) and to coordinate with other stakeholders, especially with the CFMU. This is the basis for breaking down the performance and flow based planning, done by the agents within the APOC, into instructions on event level, e.g. an early request for a new CFMU-slot, if an aircraft cannot meet its schedule. Further, earlier and more precise forecast on event level can be aggregated to more reliable predictions of the demand for critical resources. This is necessary for creating the common situation awareness needed for making collaborative decisions on basis of the best available information.

5.2.1. Implementation

Scope of TAMS is amongst others to implement a system suite, which is conform to the A-CDM Standard [41].

Starting point for TAMS have been the A-CDM Functional Groups FG0 to FG3 of [28]. Further on, FG4 to FG6 are considered and implemented. The six Functional Groups describe requirements of the different stages during the implementation of A-CDM, see also Figure 5-1.

![Figure 5-1: Airport CDM Functional Groups [28]](image)

### Functional Group 0 – User Interfaces (UI)

The purpose of Functional Group 0 in A-CDM is to describe requirements for User Interfaces, which should provide a situation awareness for all stakeholder representatives.

TAMS Functional Group 0 is realised in the Airport Operation Centre (APOC) with the APOC Clients within the agent working position and the APOC Video Wall (see also chapter 4.6).
The APOC Clients will give the different agents all necessary information an agent need to get an overall situation awareness and to decide on his resources. Otherwise, as one element of an APOC-Client the connection from APOC to the agent’s operational centre may be realised. Furthermore, the APOC Client will give every user the possibility for a personal what-if-probing.

The APOC Video Wall or APOC Power Wall is an interface, visible for every agent within APOC. The purpose of this Power Wall is to offer the same common situation awareness to all APOC agents at every time. For example, airport performance is displayed as well for the current situation as predicted for the next hours.

Functional Group 1 – Airport CDM Information Sharing (ACIS)

The Airport CDM Information Sharing Functional Group supports local decision making for each Airport CDM partner and facilitates the implementation of Airport CDM procedures by creating the necessary information-sharing environment. As such, it also forms the basis for the information sharing and communications requirements of all other Functional Groups.

In TAMS an integration platform is employed, which provides a connecting node and central warehouse for the tactical tools used by the different stakeholders (airport, airlines, ATC, ground handler). The main function of such an Airport CDM Information Sharing Platform (ACISP) is to make all provided data from one tool available to every other tool associated.

Functional Group 2 – A-CDM Turnaround Process (CTRP)

The main objective of this Functional Group is to improve the situation awareness for all Airport CDM partners in and around an Airport through the definition of milestones enabling the close monitoring of activities as flights progress. CTRP comprises important events in the progress of the entire flight, which affect subsequent events and activities. By identifying such important events and defining them as milestones, it is possible to estimate their effects on future events related to the flight.

“Milestone: A significant event during the planning or progress of a flight. A successfully completed milestone will trigger the decision making processes for downstream events and influence both the further progress of the flight and the accuracy with which the progress can be predicted.” [32]

Therefore, the defined milestones enable Airport CDM partners to assess the impact of events across several flights and hence make more efficient and timely decisions. All 16 A-CDM Milestones are shown in Figure 5-2; a detailed description of every milestone can be taken from Airport CDM Implementation Manual [27].

![Figure 5-2: A-CDM Milestone Approach](image)
TAMS implements CTRP by the use of several assistance tools. Each of these tools optimises the use of its assigned resources like runways, taxiways and aprons, aircraft parking positions and turnaround process. By connecting the tools TAMS is able to track all A-CDM milestones, execute applicable checks and furthermore calculate consecutively or predict accurately the estimated or target times for the airport related milestones MST 4 to MST 16.

One of these assistance tools in TAMS is a Turnaround Manager (TMAN). The TMAN may be regard as the core of the TAMS CTRP, because the turnaround process of a flight acting as the lynchpin between the arrival and the departure related processes of the ATC and surface management worlds. Reliable predictability of Target Off-Block Times (TOBT) becomes the starting point for any pre- or flight departure sequencing at an airport. The earlier a reliable TOBT can be given, the higher the probability for a guaranteed adherence to a departure sequence – thus enhancing overall throughput at an airport. This is best achieved by monitoring each of the process steps of a ground-handling turnaround in real time and providing early warnings to the A-CDM partners in case of irrevocable irregular operations in order to free up unneeded slots at an airport early enough that they can be used by other flights. The TMAN enables any ground handling entity at an airport to

- predict impending flight delays up to several hours in advance,
- monitor the on-going ground handling progress of any flight in real-time,
- issue automatic warnings to the responsible ground handling process owner who will cause a delay if no corrective action is taken,
- enable actors on both the execution phase, as well as the Short Term Phase to visualise and to jointly remedy an impeding ground handling delay by agreed corrective action (e.g. quick turnaround).

The TMAN does this by re-calculating the TOBT after each update to the ground handling data model either from the flight information system side for “external” time changes or “internally” by comparing the real time process progress to its critical path effect for the overall handling process of a flight. This on-going TOBT re-calculation is first used internally to trigger and benchmark any operational corrective action to recover the scheduled end of handling time. Only when it becomes apparent, that this recovery will not be possible, it will be communicated to the other A-CDM partner systems as a new and qualified TOBT for their further planning.

A detailed description of CTRP in TAMS and of interaction of assistance tools employed can be found in chapter 5.3.

**Functional Group 3 – Variable Taxi Time Calculation (VTTC)**

The period an aircraft spends taxiing after landing or before takeoff is an important parameter affecting estimated times associated with the flight concerned. Especially at large and complex Airports, accurate taxi times are not easy to calculate.

Inaccurate calculations or the use of default values that do not take into account the prevailing circumstances can adversely affect estimated times and consequently the efficient use of available airport and en-route capacity.

The use of VTTC ensures accurate taxi time calculations. There exist several methods of calculating taxi times, suitable to meet the needs of Airports with different complexities and physical characteristics.

The VTTC of TAMS is realised by a Surface Manager (SMAN), which provides a reliable
forecast of expected inbound and outbound taxi times for an accurate prediction of on-block and earliest take-off times.

**Functional Group 4 – Collaborative Management of Flight Updates (COFU)**

COFU will improve the coordination between Air Traffic Flow Management (ATFM) activities of the Central Flow Management Unit (CFMU) and Airport Operations. This results in timely updating of flight data, more consistent CTOT calculation and improved CTOT adherence. A-CDM Airports and the CFMU exchange Departure Planning Information (DPI) and Flight Update Messages (FUM), with the purpose of ensuring the use of identical data in both, the ATFM and Airport operations process.

TAMS considers both FUM and DPI. The first step is the implementation of functionalities, which allow receiving and parsing of FUM followed by functions for generating and sending of DPI.

A FUM by CFMU includes an Estimated Landing Time (ELDT). This time is an important information to all airport stakeholders to plan their resources. With the Arrival Manager (AMAN) and Departure Manager (DMAN), which are employed in TAMS, this information will be furthermore enhanced if the flight is inside the A-CDM airports FIR (Flight Information Region). In this region the AMAN receives radar data and flight plan data of arriving flights and calculates an optimal arrival sequences in respect to the departure slots created by DMAN. This way, a much more accurate calculation of ELDTs is possible.

**Functional Group 5 – Collaborative Pre-Departure Sequence (CPDS)**

This Functional Group describes requirements for the Collaborative Pre-departure Sequence, which adds on functions to the ACIS core module.

TAMS realises the Pre-departure Sequencing through functionalities of SMAN and DMAN. Thereby the SMAN provides an accurate estimated time a flight can be earliest at the runway for take-off (ETOT) by using the TOBT and the calculated variable taxi time (VTT). The DMAN uses this ETOT to create an optimal departure sequence and calculates a TTOT for each flight under consideration of constrains like WTC of each flight, the applicable operation mode, etc. Based on the optimised runway take-off sequence by the DMAN, the SMAN calculates the Target Start-up Approval Times (TSAT) by taken the VTT into account.

This way TAMS provides an accurate Pre-departure Sequencing with the ability to fully exploit runway departure capacity and to react flexible on changes in processes and airport configuration constraints.

**Functional Group 6 – A-CDM in adverse conditions (CDAC)**

The Functional Group 6 provides the means for Airport CDM Partners to anticipate and collaboratively manage periods of reduced overall Airport capacity caused by adverse conditions. The aim of A-CDM in Adverse Conditions application is collaborative capacity management during periods of reduced capacity, e.g. due to fog, strong winds, snow, etc. A-CDM in Adverse Conditions intends to disseminate relevant information to all partners in anticipations of disruptions. Nowadays disruptions are usually solved ad hoc.

CDAC proposes different means to manage adverse conditions and to support a faster recovery to normal operations afterwards. The A-CDM Coordinator may be appointed and an A-CDM Cell may be implemented to manage the actions in adverse conditions efficiently. Both two elements will be part of the TAMS APOC concept.

The tactical assistance tools employed in TAMS like SMAN, TMAN and DMAN will consider the de-icing process, which belongs to the adverse conditions. The Airside Tactical Working Position (ATWP), the working position of the ATC-agent within the APOC, is able to provide
the required warnings if processes are not provided within the specified time frame. The integration platform, which represents the ACISP in TAMS, supports the ACIS of de-icing information too.

5.2.2. Enhancements

TAMS supports the fully use of available capacities by interconnecting not only the process partners, but also the processes itself by connecting the assistant systems and their optimisation capabilities. Now each tactical tool knows the best predicted times of events or processes and can use them for further calculations. This way it is possible, that time buffers applied in air-to-air processes may be reduced by TAMS significantly.

Furthermore, TAMS takes the turnaround process and so the concatenation of arriving and departing flights into account, more than usually done. On the basis of regular information for an arriving flight all milestones for the concatenated departure leg will be estimated immediately. For example, if an updated ELDT for an arriving flight is available the Estimated Ready Time (ERDT) or even an Estimated Start-up Approval Time (ESAT) is calculated for the linked departure leg. With this information possible delays are early known and applicable actions might be taken.

Additionally TAMS provides a novel framework to handle adverse conditions. The APOC concept itself, the Video Wall and the Airport Performance Manager (APM) provide more information about the situation for a greater time horizon and allow a medium term forecast of traffic situation in adverse conditions.

5.2.3. Future Prospects

A first step is to provide a common situation awareness of the 16 A-CDM milestones. Currently there are milestones for monitoring airside processes in A-CDM concept only. Further on, when the holistic integration and monitoring of airside and landside processes will be implemented, it might be necessary to develop and implement new milestones for landside processes. Without being exhaustive, the following table lists exemplary possible milestones:
Table 5-1: Possible new landside milestones

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Time Reference</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check-In completed</td>
<td>ACICT</td>
<td>Actual Check-In completed time</td>
<td>All passengers for a flight are checked in.</td>
</tr>
<tr>
<td>Security control completed</td>
<td>ASCCT</td>
<td>Actual Security control completed time</td>
<td>All passengers for a flight passed security control</td>
</tr>
<tr>
<td>Borderpolice control completed</td>
<td>ABPCT</td>
<td>Actual Borderpolice control completed</td>
<td>All passengers for a flight passed border police control</td>
</tr>
<tr>
<td>Positive baggage match completed</td>
<td>ABMCT</td>
<td>Actual Baggage Match completed time</td>
<td>All pieces of loaded baggage have been matched with the boarded passengers</td>
</tr>
</tbody>
</table>

These additional milestones show whether there are delays in landside or turnaround processes affecting other milestones, e.g. boarding starts (MST 11) or ARDT (MST 12). Otherwise, the impact of airside delays on landside processes can be monitored, for example the late arrival of transfer passengers or transfer baggage (due to delays until MST 7/8) could affect the off-block time of departing aircrafts.

### 5.3. Operational Requirements and correlated Systems

The key to A-CDM and TAM is information sharing. Without sufficient or inconsistent information a collaborative decision making process (CDM-process) is jeopardized or even leads to results that worsen the situation. Thus, TAMS shall assure that sufficient and consistent information in the best available quality is provided to all agents within the APOC.

Each stakeholder possesses information about its own business processes in a quality that allows him to make substantiated decisions within his own area of responsibility. This kind of information shall be accessible to the stakeholder’s agent enabling him to take part in the CDM-process. Therefore and due to the large magnitude of data that has to be processed, planning devices or assistance tools shall be applied in TAMS that provide the aforementioned information. These planning devices / assistance tools shall calculate the whole air-to-air process for each flight. Further they shall provide advice to the agents based on automated optimization.

Following the Total Airport Management approach of performance based airport operations, prognostic functionalities shall be implemented that calculate performance-related KPIs and flows through the runways as the most critical resources at the airport, with a long look ahead horizon (short term phase). Based on this information a (departure side) demand capacity balancing (DCB) shall be executed that smoothens the flow through the runways so that event level planning can be compatible with agreed QoSLS.

To fulfill the requirements for A-CDM as described in the previous chapter, a more detailed monitoring and planning is needed within the tactical short-term phase. The traffic shall be continuously monitored on the event level to provide the agents within the APOC with the latest information available. For example, the closing of a resource like a taxiway, a runway or part of a terminal will significantly affect the demand that can be handled. Further the planning on the event level shall be optimised and assisted by appropriate tools to handle the
complexity without increasing controller workload, to provide a longer look ahead horizon and to enable what-if probing.

This chapter is subdivided into four parts:

Subchapter one describes the requirements posed on the collection, preparation, storage and distribution of data as this is crucial for creating a common situational awareness in the APOC.

The requirements for real world monitoring, which provides estimated and actual times combined with the calculation / planning of target times for the air-to-air process of each flight, are the subject of subchapter two.

Subchapter three deals with the aggregation of data to a flow- and performance-based monitoring and planning of airport processes that allows to accomplish the management of performance-based airport operations within the pre-tactical short-term phase.

The last subchapter presents the requirements that shall be fulfilled to enable a CDM-process backed by joint what-if probing functionality.

5.3.1. Data Management

- Integration Platform for data distribution and AODB as a centralized data source,
- Flight Planning and Resource Management applications for displaying and editing the current Airport Operation Plan (AOP),
- Optionally: Flight Information Display (FIDS) providing relevant information to the passengers within a terminal.

In order to provide A-CDM and TAMS functionality, several subsystems like tactical tools (AMAN, DMAN, SMAN, TMAN, PaxMan), resource management tools (SGMAN, FP, RMS), and prediction tools for the pre-tactical phase (APM) shall be interconnected. Instead of connecting each of the specific systems to all other systems directly (resulting in a set of direct n:m connections and interfaces), all subsystems shall be connected to a central Integration Platform, which shall receive and distribute the AOP and all operational data to the subsystems.

The Integration Platform should fulfil the requirements put on an "Airport CDM Information Sharing Platform" (ACISP). Further, the Integration Platform shall be complemented by a central database making the operational data persistent for a certain period of time. This part of the Integration Platform functionality is often referred to as Airport Operational Database (AODB).

5.3.1.1. Integration Platform and AODB

Integration Platform and AODB functionality are not unique to an A-CDM or TAMS airport; most airports already run an AODB and in some cases information broker systems similar to an Integration Platform. However, implementing an A-CDM or TAMS system without an Integration Platform and AODB would lead to a complexity where most efforts will be spent on solving technical and interface problems instead of improving processes.

Integration Platform and AODB shall provide the following functions:

- A central system, collecting and correlating all information regarding a flight (especially the correlation of the airport schedule (IATA) and the ATC flight plan...
Regardless of the source of the information, the information is correlated with the appropriate flight and distributed in the format and context that are required by the different target systems.

- A central system, providing a set of consistent, agreed data. Instead of holding and updating times (e.g. the ELDT) in each subsystem separately, possibly originating from different sources, all times are consolidated in a central system according to a well-defined data hierarchy. Updates of times are triggered by a central system, so all subsystems know exactly which data is the most current one. As a side effect of a central data repository, the meaning of the times distributed has been agreed by all subsystems connected. The same data field for a certain time (e.g. ELDT) is used for first estimates during pre-tactical phase and all refinements calculated and provided during the tactical and execution phase.

- A central system providing a data repository for all operational data not directly related to individual flights. These are especially the parameters defining a certain “mode of operation” of an airport (e.g. the runway configuration). Since these parameters may be set by different stakeholders (ATC Agent, Airline Agents, Ground Handling Agents, Airport Agent) it is important to provide a central platform, where the negotiated and agreed parameters are stored and distributed to all connected systems. This is an extension to the A-CDM approach providing a common “situation awareness”. By distributing the agreed parameters, a common “Operating Mode Awareness” is ensured by all stakeholders involved.

- A communication hub providing n:m connections without the need for direct bilateral interfaces between the applications, based on an Enterprise Service Bus (ESB). This is crucial for a transparent, manageable architecture, flexibility in configuring message flows and high system performance.

In TAMS, the main function of such an integration platform is to store, check and disseminate information contained in the Airport Operation Plan (AOP). In terms of A-CDM the functionality described above is often denoted as Airport CDM Information Sharing Platform (ACISP).

The present document has a process and functional focus. Therefore, we will not go any further into the description of the role of AODB/APIP in the realisation of the functional requirements in chapter 4. AODB/APIP is an infrastructure tool whose usage will be described in the technical documents (SYRD, SAD, IDD), because it is related entirely to the way the functionality is technically realised and not to the functionality itself.

**Table 5-2: ACISP capabilities**

<table>
<thead>
<tr>
<th>Time frame</th>
<th>processes</th>
<th>operator</th>
<th>Visualisation</th>
<th>Influences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-tactical Short Term Phase</td>
<td>Collection and distribution of elements of the AOP defining the available resource capacities and the strategy parameters for the operation day; distribution of</td>
<td>No operator intervention (except IT administrator)</td>
<td>No visualisation by ACISP</td>
<td>Influence on the strategy for the operation day</td>
</tr>
</tbody>
</table>
5.3.1.2. Flight Planning and Resource Management

Flight planning and resource management are the most important components of an Airport Management System (AMS). Because both have tightly correlated functionalities, we often use the common term AMS.

5.3.1.2.1. Flight Planning

Within TAMS, the flight plan is the core element of the Airport Operation Plan (AOP). It contains flight IDs and schedule information (times, rotation, planned aircraft type).

a) Seasonal Flight Planning

The Seasonal Flight Planning (SFP) is initiated months before a flight event happens. The primary actors are the airlines, airports and national flight coordinators.

SFP shall gather the flight plans from the flight coordinator and airlines. These flight plans are supplemented with additional input from various agents, for instance the planned aircraft type or a rotation information. SFP shall offer the airport operator the possibility to manage flight series and individual flights. The user interface shall present flight series, individual flights and flight details in a table.

SFP shall be integrated with the Resource Management System (RMS) in order to enable the allocation of resources to the flight series. Resource allocation conflicts should be detected automatically within the RMS and indicated in the SFP user interface.

Seasonal flight planning is a necessary preparatory step for operational flight planning, even though in TAMS only the operational flight plan is used.

b) Operational Flight Planning

Typically the operational flight plan is activated a few days in advance of the day of operation (day-of-ops). The operational flight plan is derived from the seasonal flight schedule. Additional flights, not included in the seasonal flight plan can later be inserted manually when necessary.

During the day of operation, numerous flight plan changes, operational data such as aircraft registration and events are entered into the operational flight plan. Operational Flight Planning (OFP) shall offer data entry either automatically or manually through the Operational Flight Planning GUI. A data hierarchy in AODB and integration platform shall solve possible data conflicts in multiple source environments.
After the day of operations all flight data is handed over for post-analysis tasks like billing, reporting and statistics. OFP shall permanently check data completeness and consistency. OFP should give a preview on the post-operational data, so the operator can deal with incorrect or missing data.

5.3.1.2.2. Resource Management System

The Resource Management System (RMS) shall offer the facility to allocate various resources to flights like check-in counters, gates, aircraft stands\(^{39}\), baggage belts and chutes. It shall be possible to allocate any resource to flight series as well as to individual flights. RMS shall be integrated both with SFP and OFP.

The flight-resource allocations shall be continuously checked against a set of operational rules. Warnings shall be given to the operator if he assigns a large aircraft to a small stand for example. The consistency of resource allocations shall be checked over time, taking into account predicted operational data like estimated block times. Detected conflicts shall be indicated on the relevant user interfaces.

Resource assignments have a strong influence on achievable flows and process times at the airport. In TAMS the stand allocation is used within the computation of taxi durations. In future extensions, it is conceivable to also take into account other resource assignments.

5.3.1.2.3. AMS in TAMS

Contribution to AOP management (Chapter 4.2)

OFP and RMS shall provide GUIs for the flight plan and resource data in the AODB. OFP shall provide the possibility to create new flight plans and update or modify existing flight plans. Regular flight plans with recurring schedules are stored in the seasonal flight schedule. From this, the daily flight schedules for the day of operation are derived; OFP shall support this process. OFP shall offer the manual insertion of ad hoc flights through the OFP GUI or automatic import of external data. In any case an authorized user shall be able to supplement these flight plan with additional data which is not received through data interfaces (we list only data relevant for TAMS):

- Flight definition (airline code, trip number)
- Sort of flight
- Scheduled times
- Linkage between arrival- and departure flight (rotation)
- Origin, destination, via
- Aircraft type and registration
- Allocated parking position (aircraft stand)

Throughout the operation of a flight, all of its flight data is supplemented and updated.

AMS shall provide GUIs which present the AOP to users. User-specific filters shall ensure that any agent only has access to AOP data for which he is authorized. For example, an airline agent must not gain access to internal flight data of another airline.

On the event level AMS shall provide an overview of all flight states and times.

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\(^{39}\) The application SGMAN will accept the planning made by the resource management system. It will, in case it detects a conflict, try to re-allocate arriving flights to unoccupied stands and this information is played back to the resource management system.
**Contribution to Airport Operation Centre APOC (Chapter 4.1, 4.6)**

AMS shall support the APOC on two levels: APOC Video Wall display and APOC workplaces.

**APOC Video Wall display (chapter 4.6.1)**

AMS shall be able to send messages to the Video Wall display, which is a central element of the system support for the APOC. The display of individual flight data is currently not planned for the Video Wall, and in any case would rather be taken care of by APM.

**APOC Workplaces (chapter 4.6.2)**

For agent working positions (airport, airline) AMS shall provide user-specific filtered flight information.

- The working position HMI shall contain configurable views.
- The AOP shall be displayed for the next 24 hours.
- Flight data and allocated resource data from the AOP shall be available for presentation, including flight times (schedules, TOBT) and flight character (that is the sort of flight).
- Cancellations and reschedulings shall be supported.
- Edit functions shall be limited according to privileges of agent.

**Alert management (chapter 4.4)**

AMS shall provide notifications, which can be displayed on the Video Wall and/or agent workplaces (see above), the source is manual entry. In future, notifications could be generated automatically by a system, e.g. if performance constraints are violated.

**What-if probing (chapter 4.5.3)**

AMS flight planning and resource management is currently not planned to support what-if probing. In a future extension, it is conceivable to use the stand assignment and the flight schedule times (changes, cancellations, inserts) for what-if variations.

### 5.3.2. Operational Management

- Arrival Management (AMAN) for calculating the arrival process,
- Surface Management (SMAN) for predict, plan and monitor the taxiing process,
- Stand Allocation Management (SGMAN) for assigning suitable stands,
- Turnaround Management (TMAN) for calculating the turn-around,
- Departure Management (DMAN) for calculating the departure process,
- Passenger Management (PaxMan) for calculating both passenger flows and the utilisation of airport terminal resources (e.g. queues of passengers).
5.3.2.1. Arrival Management

The quality of the implementation of A-CDM as a baseline for TAMS significantly depends on a reliable and timely given TOBT from the airlines or ground handlers. The calculation of the TOBT largely depends on qualified input data, where one critical input is the EIBT, which marks the earliest possible begin of the ground handling process and is the result of the ELDT plus taxi-in time.

While it is possible to enter the best available ELDT by hand into the system or to derive a best guess from the aircraft via ACARS, this is either not feasible because of higher controller workload or not qualified enough due to missing information on advisories like duration of holdings etc. Additionally both possibilities would not allow extensive testing in TAMS. A third possibility would be to derive the ELDT from the FUM for this flight. This shall be done for monitoring of A-CDM milestone M3, but is not sufficient for M4 to M6. Thus an assistance tool is needed that automatically provides accurate and timely predictions of the ELDT for further processing. This kind of assistance tool is called Arrival Manager (AMAN).

The deriving requirements are:

- The ELDT for each flight with radar monitoring shall be automatically calculated by an assistance system, the AMAN.
- For calculating the ELDT, the AMAN shall take into account all restrictions applicable for a safe conduction of all flights, like wake turbulence categories, landing speed, runway separations and runway dependencies for example.
- The AMAN shall send the calculated ELDT for each flight with radar monitoring to the integration platform (ACISP).
- The AMAN should provide advisories for each flight with radar monitoring. (Note: This is not in scope of TAMS as it will not be supported by the simulation.)

The current traffic situation shall be continuously reported to AMAN by radar and flight plan data. The AMAN shall monitor the traffic situation and (re)calculate trajectory predictions in cases of a mismatch between actual and predicted positions. An arrival traffic sequence shall be planned based on this input and the current spacing requirements. The plan should result in a set of advisories that are presented to the ATC Agent. The ATC Agent shall be able to modify the sequence (e.g. by a manual change in the arrival sequence) or introduce additional constraints into the calculations, e.g. for what-if probing. Note: Real world changes are up to the controller and the ATC Agent has to find an agreement with them (final decision is up to the controller).

Depending on how arrival traffic evolves, AMAN shall monitor the situation and adapt the planning results and advice generation accordingly. The generated advisories should be optimised according to different selectable goals (for example minimum average delay or minimum deviation from preferred profile).

The AMAN shall allow the setting of the operation mode, especially the Arrival-Departure-Ratio. Further, the AMAN shall enable the insertion of departure slots into the sequence. A flight shall be sequenced as soon as radar data becomes available, which shall coincide in TAMS with the FIR. A particular flight should be pre-sequenced as soon as the AMAN receives the ATC flight plan that contains time over information of some waypoints of the route within the FIR.
5.3.2.2. **Surface Management**

Besides the ELDT, the Taxi-In Time is the other important parameter for calculating the EIBT which marks the earliest possible begin of ground handling. Although important is the Taxi-Out Time, which is needed for monitoring the slot compliancy of a flight as well as for maintaining a stable runway sequence. Both, Taxi-In and Taxi-Out Time shall be calculated in TAMS as stated in A-CDM Functional Group 3.

Assistance shall be provided that increases the situational awareness, prediction quality and give planning support in the area of moving aircraft on the airport surface. This means, that all relevant information of aircraft referring on ground movement between runway and parking position shall be provided. This kind of assistance tool is called Surface Manager (SMAN).

The SMAN shall work at flight event level for the local airport and consider flights from the Tactical Short Term Phase over the Trajectory Execution Phase up to the Post Flight Phase. As information input the SMAN shall use:

1. The Airport Operation Plan (AOP) from the AODB,
2. Ground surveillance data.

Because surface management is ATC functionality, the SMAN-HMI shall be a part of the ATC Working Position. The SMAN shall provide information and functionalities, to support optimal and safe ground movement processes to all aircraft at the airport.

The SMAN shall enrich the AOP by operational data, which is related to moving aircraft on the surface:

1. estimated times (EXIT, EXOT, EIBT, ETOT),
2. actual event times (ALDT, AIBT, AOBT, ATOT),
3. target times (TSAT).

The SMAN should enrich the AOP by the following other data (4.2.2):

1. available taxiway-system capacity over time,
2. taxiway closures (current and planned),
3. operational strategy of using taxiway-system over time.

In order to obtain a stable AOP for all data provided by the SMAN, a minimum change value shall be defined and recalculations shall only performed if a change exceeds the minimum change value.

The SMAN shall provide the five functional groups prediction, planning, monitoring, what-if probing and analysing.

5.3.2.3. **Stand Management**

A critical airport resource are the gates/stands. These resources are planned far in advance during the mid-term phase even before scheduled times for flights are available. The result are airport slots for the slot conference. While the slot conference itself is out of scope in TAMS, a tool shall assist in the planning of stand/gate usage. This tool is called Stand and Gate Manager (SGMAN) and shall use an initial plan for stand/gate occupancy to detect and resolve position conflicts that might occur due to operational flight plan changes (shifting of EIBT for example).

Each change of arrival or departure times or a closure of a parking position shall lead to an
actualised position allocation plan, where parking positions are determined with respect to operational constraints. These constraints shall include but should not be limited to the type of aircraft, standard turnaround times, assignment strategy, closed or occupied parking positions, and stability of positions in case of a new planning.

The SGMAN shall provide a graphical user interface for easing the awareness of resource allocation. In addition to the automatic assignment, this graphical user interface shall allow manual shifting of parking positions. Gates are not part of SGMAN and have to be assigned in a step following the allocation of parking positions. For analysis purposes, it shall be possible to display usage rates of certain position areas.

<table>
<thead>
<tr>
<th>Time frame</th>
<th>processes</th>
<th>operator</th>
<th>visualisation</th>
<th>Influences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day of ops</td>
<td>Position allocation and updates</td>
<td>[optional Airport]</td>
<td>occupation and resource utilisation of positions</td>
<td>turnaround processes, taxiing</td>
</tr>
</tbody>
</table>

For more details on SGMAN, see [43].

5.3.2.4. Turnaround Management

The Ground Handling Turnaround activities of a flight are commonly executed by various different ground handling organizations at an airport. These cooperate according to the available ground time and the space available around an aircraft during its turnaround. Whereas the turnaround activity sequence can be fulfilled by the actors without a central progress monitoring or steering component as is the case at most airports today, a detailed real-time progress overview of all handling processes and progress events on their critical path of a flight is needed in order to give reliable information and TOBT predictions to all other stakeholders in an A-CDM chain. Typically there are between 40 to 70 different events and processes per flight in the ground handling sequence which need to be recognized, monitored and their timeliness consistently re-calculated for the prediction of the flights TOBT. Whereas some systems track fixed timestamps within this process chain and thus attempt to pre-calculate an end of handling, the daily operational situation is far more dynamic than that.

- The flight times of arriving aircraft will vary from the scheduled times.
- Task durations in aircraft ground handling turnaround depend on aircraft type and configuration.
- The loadfactor of a flight determines the task durations.
- Turnaround tasks are started late and will impact others negatively leading to delays.
- Transfer processes depend on the nature of the transfer conditions (Schengen, non-Schengen).
- Transfers will have different durations dependent on the distances between the stands of where they are parked at an airport.
- With different resource availability levels for conducting a process (i.e. 2 stairs
instead of one, 2 fueltrucks instead of one, 2 boarding agents instead of one, etc.) the handling tasks durations will vary.

- At times, handling service levels will consciously not be fulfilled in order to regain delay times.
- The Airlines will give different flights different priorities in handling the aircraft. These priorities will be set according to varying different reasons, i.e. curfew at the destination airport, avoidance of misconnected passengers, monetary value of the flight, aircraft positioning needs within the airlines network, etc.

The ground handling turnaround process shall be assisted by a planning and monitoring device, the Turnaround Manager TMAN, that interacts with the A/DMAN, SMAN, PAXMAN and other applicable tools.

- The TMAN shall automatically calculate a TOBT after any change in either the flight time updates or handling process progress. It shall only pass on qualified TOBTs to the other TAMS systems.
- The TMAN shall consider dynamic task durations for each turnaround task, i.e. consider the loadfactor of a flight, etc.
- The TMAN shall calculate the turnaround processes on a critical path and issue alerts when one or more of the processes generate a delay.
- The TMAN shall support feasible quick turnaround calculations, which can lead to turnarounds below the general minimum connection time.
- The TMAN shall support a costmodel based on airline preference decisions for the departure sequence.
- The TMAN shall be able to conduct what-if calculations on a tactical level – jointly with the A/D- and SMAN
- The TMAN shall be configurable/ filterable in a manner, that it can be used separately at an airline-, airport- or ground handler working position and/ or can show their combined process progress chain on an APOC level for joint decision making.

Its first objective is to recognize and visualize upcoming delays for flights at a time when corrective action by a ground handling controller can still be taken. In order to support such corrective action the TAMS TMAN has been provided with the means to generate alerts.

The following benefits should be achieved by introducing a TMAN

- realistic and reliable Target Offblock Times for better planning of the TSATs and Pre-Departure Sequence,
- Reduction of ground handling delays due to earlier and pro-active planning possibilities,
- improved planning basis for the various resource allocation systems.

### 5.3.2.5. Departure Management

While a simple collaborative pre-departure sequencing (CPDS) is sufficient to fulfil the requirements that the implementation of A-CDM poses, a more detailed planning of the departure process is needed as soon as the pre-departure sequencing has to interact with an assistance system like an AMAN. A conflict free planning of the TTOT is needed that takes all applicable constraints into account. While this can be done by a controller through
The needed assistance tool is called a Departure Manager (DMAN), which shall be a tool that automatically calculates a runway and off-block (pre-departure) sequence and provides optimised take-off and off-block times for all departures within its focus. It should assist the controller to achieve maximum runway throughput without adding to controller workload and whilst maintaining or improving current safety levels. The deriving requirements are:

- The departure process shall be assisted by a planning device, the DMAN, that interacts with the AMAN and other applicable tools (e.g. SMAN).
- The DMAN shall establish automatically a conflict free runway sequence, which results in a TTOT for each departure.
- The DMAN shall calculate automatically a conflict free off-block sequence taking an external provided EXOT into account. This results in a TSAT for all departures.
- The DMAN shall send its planning result, the TTOT and the TSAT, to the integration platform (ACISP) to make it available to all other planning devices.
- For enabling a what-if probing, the DMAN shall allow a manually altering of its planning results by the ATC Agent.

Note: In the “real world” the manually altering of the sequence has to be agreed by the controllers and would therefore not implemented by the ATC Agent.

The following benefits should be achieved by introducing a DMAN:

- Reduction of fuel consumption and environmental impact
- Enhanced runway throughput with reduced average delay of individual aircraft
- Guaranteed fair treatment of different airlines
- Collaborative pre-departure sequencing at the airport
- Realistic and reliable departure times for aircraft allowing:
  - better planning of airline schedules (aircraft, pilot and crew rotation)
  - better turnaround management (e.g. time of boarding)
  - support of process-planning in adverse conditions (de-icing)

Note: In A-CDM, there is a conceptual distinction between pre-departure and departure sequencing. The former relates to the planning of departures that have not yet gone off-block whereas the latter relates to the planning of departures that already have.

### 5.3.2.6. Passenger Management

Compared to previous airside related TAM projects, one of the major developments of TAMS is the integration of landside processes into the overall planning process. The gate was thereby identified as the significant and central interface. Reliable information about current and predicted passenger status especially at the gate therefore are essential. As a consequence, new timestamps are defined representing the passenger process chain, particularly the timestamp “Estimated Passenger at Gate Time” (EPGT). While it is feasible to attain reliable actual times (APGT) or calculate scheduled times (SPGT) nowadays, estimated times (EPGT) could so far only be based on rough estimates adapted from experience. The newly developed Passenger Manager (PaxMan) shall be able to predict the EPGT rather accurately on base of the actual situation throughout the terminal by monitoring...
the different passenger processes and general activities at different service facilities. This shall allow for considerably improved accuracy as well as timeliness of passenger status information and thus consolidate landside and airside planning for Total Airport Management. By integrating landside processes into the TAM planning process the interdependencies between airside and landside (cf. Figure 2-2) are incorporated into performance-based airport operations.

The PaxMan shall be a tool to support the management of processes within the airport terminal on all levels and with focus on the passengers. Therefore, the PaxMan shall mainly support the terminal management of the airport operator and furthermore shall be able to provide aircraft operators with helpful information and functionalities for efficient passenger handling. The PaxMan hence shall consider the timeframe from Pre-tactical Short Term Phase over Trajectory Execution Phase until Post Flight Phase. To comply with the specific requirements arising from rough over detailed planning until operating terminal processes, the PaxMan shall be able to provide information in two timelines: aggregated predicted passenger flows and utilisation of terminal resources and a detailed view related to the actual operations.

The provided assistance shall increase situational awareness as well as prediction quality. It shall also improve capacity utilisation of relevant process points and shall give planning and decision support in the area of passenger flow and allocation of terminal resources. This means that all relevant information of terminal activity and passenger movements from entering the terminal area until reaching the gate shall be provided. The derived PaxMan requirements, for both the predicted and the actual situation, are:

- The PaxMan shall use terminal surveillance data to monitor actual passenger flows and provide an overview of capacity utilisation of relevant process points. Furthermore, on the basis of the actual situation the PaxMan shall predict expected passenger flows and resource utilisation up to 12 hours in the future.

- The PaxMan shall support information sharing among the stakeholders and shall increase the common prediction quality of the AOP (cf. chapter 4.2) by providing the AOP with relevant landside data. Information is provided both for passenger related aspects and for resources in two different time horizons (actual and predicted). For example, on the one hand the actual status of passengers related to flights highlights the progress of passengers in their process flow. On the other hand monitored or predicted waiting queues at service facilities could be detected and managed.

- The PaxMan shall provide relevant landside data in order to support the calculation of selected KPIs (see chapter 4.3).

- The PaxMan shall automatically provide alerts and notifications for the Agents in the APOC either on the Video Wall or the working positions if critical problems or deviations from the AOP occur (cf. chapter 4.4). Alerts and notifications will be generated for the different planning levels of the AOP (cf. chapter 4.2). Their respective thresholds will be defined internally within PaxMan.

- The PaxMan shall increase the situational awareness of all agents in an APOC (cf. chapters 4.5 and 4.6.1) by presenting a colour coded terminal map with information about the current terminal situation as well as supporting a timeline on the Video Wall by providing information about the predicted terminal situation over up to the next 12 hours.

- The PaxMan shall increase in particular the situational awareness of Airport and Airline Agent by providing an HMI as part of the Airport or Airline Working Position
(cf. chapters 4.5 and 4.6.2). The PaxMan-HMI for working positions shall support the Agent with detailed information on the terminal situation as well as passenger flow and status. The PaxMan-HMI shall further provide tools for the management during normal operations as well as during disturbances or delays in the terminal area thus enabling timely counter measures. All functionalities shall thereby be restricted to the agents area of responsibility (e.g. an Airline Agent will only get information on own flights)

○ The PaxMan shall support the TAMS Collaborative Airport Planning by providing both, single and joint what-if functionalities (cf. chapter 4.5.3). This means that on the basis of a given (current or future) situation alterations in the operational plan shall be fed into the forecast module to determine how a future scenario would impact the passenger processes and hence whether the changes to the AOP would help to resolve the situation and to what extent.

○ The PaxMan shall store terminal data of operations and predictions for post flight analyses. The analysing functionalities shall at least compare predicted with actual times.

5.3.3. Performance Management

The Airport Performance Manager (APM) is the TAMS application responsible for performance management. It shall calculate KPIs, flows and support overall process planning with a long look ahead horizon.

5.3.3.1. Airport Performance Management

The Airport Performance Management (APM) shall provide the following functionality in TAMS:

1. Pre-tactical prognosis (prediction of flight times and airport performance on a time horizon of up to 24 hours into the future)
2. Pre-tactical capacity/demand analysis with computation of possible flows through the runways
3. Summarizing display of tactical process time predictions computed by the tactical applications (XMEN)
4. Support for what-if probing and strategy capability of TAMS
5. APM shall be a core building block of Siemens’ APOC airport and airline workplaces and Siemens’ contribution to the APOC Video Wall display.

APM is the key application for the seamless integration of pre-tactical and time horizon in TAMS. The forecasted times provided by APM will be overwritten by the tactical systems at the moment a tactical tool calculates the same time; this shall be ensured by a suitable data hierarchy mechanism. However, APM shall support a longer prognosis time horizon, so it shall be able to make predictions before any “tactical” calculation is available. Therefore, airport stakeholders are able to draw benefit for their planning by considering this information, particularly w.r.t. an effective usage of their resources.

In the following discussion, we refer to the sections of chapter 4 to describe the usages of APM in TAMS in some more detail.
**APOC support (chapter 4.1, 4.6.)**

APM shall support the APOC on two levels: APOC Video Wall displays and APOC workplaces.

**APOC Video Wall display (chapter 4.6.1)**

APM shall provide the following contributions for the APOC Video Wall:

- KPIs for surveillance of Quality of Service – present and future ("spider diagrams"),
- prediction of possible traffic flow through runways. Capacity and demand will be compared, so that e.g. planned runway closures will be visible.
- prediction of queues (dwell times) caused by insufficient runway capacity,
- display of KPIs showing the effect of measures/strategies within a what-if analysis,
- display of strategy parameters, runway capacity and configuration and of performance goals (e.g. punctuality) within what-if or "real life" mode.

APM should also support the display of the currently active strategies (see “APM contribution to airline workplace” below)

![Figure 5-3: Spider diagram for QoS](image)

It shall be possible to edit KPI target values/ranges within APM.

APM does not provide general or agent-specific messages (however, AMS has this capability).

**APOC workplaces (chapter 4.6.2)**

**APM contribution to Airline workplace (chapter 4.6.2, 4.5.4)**

The APM application should be present at all agent workplaces. It shall offer the views and dialogs described below.

1) Flight-specific process times

APM shall provide both flight-specific and non-specific process control data for the airline workplace. The flight-specific data consist of schedule, target, estimate and actual times for the main handling process steps shown in the diagram below.

![Figure 5-4: Display of CDM-related process times by APM](image)
Schedule times (center top position in each square) shall be taken from the operational flightplan, while target times (center bottom) mean so-called “normative targets”, which shall be computed by APM itself. They essentially characterize the targets processes at the airports should achieve under the given current conditions; for instance, if a plane arrives already with a significant delay, target times for the processes at the airport will be shifted accordingly. Normative targets are not to be confused with standard target times such as TOBT or TTOT, which have an entirely different meaning.

Estimates (right top and bottom) shall be displayed as provided by the relevant XMAN application. APM shall also be able to compute its own estimates, but according to the data hierarchy principle these shall always be overwritten in TAMS by XMAN calculations, which are considered as more precise. Actual times shall be visible in the left column (top and bottom), if they have already occurred; else, the remaining time to schedule (top) or target (bottom) shall be displayed. Colour codings shall serve as alerts in case schedule or target times are violated (actual times) or at risk to be violated (estimates). Colour code evaluation of actuals and estimates shall take place by comparison both with schedule times (top line) and target times (bottom line). White colour shall signal that it is either too early for any judgement or the time is way ahead of schedule/target. Green shall signify full schedule/target compliance. Yellow shall indicate a mild violation, and red an unacceptable violation.

2) User-Driven Pre-Tactical Sequencing UDPS

APM shall support a pre-tactical sequencing of departures, to achieve the following goals:

- Planning stability: By means of its capability to compute the possible (runway) throughput und given capacity and demand conditions, APM shall be able to determine very early on (on a pre-tactical horizon) achievable departure times. The airlines can then adjust their planning accordingly at a time when they still have flexibility, and the final departure times will normally not differ strongly from APM’s early estimate.

- Consideration of airline preferences: APM shall take into account airline preferences w.r.t. individual flights of their fleet. This means that the order of flights can be changed and preferred departure times can be entered. Moreover, it should be possible to enter flight cancellations, so that these flights will not appear in the departure sequence.

APM shall combine the airline preferences with the flow calculation and return an optimized off-block (or takeoff) sequence. This sequence shall be communicated to the ATWP and the times shall serve as a guidance for the tactically computed pre-departure sequence. How strongly APM’s pre-tactical perspective will influence the tactical results depends on a variable coupling strength, which shall be configurable and may be chosen differently for different kinds of situations. For instance, within time windows of low demand, the coupling can be chosen rather strong, to enforce planning stability. In times of over-demand, the XMEN’s ability to increase the possible throughput by fine-tuned, synchronized short term planning may be more important than planning stability, and the coupling should be chosen less strongly. The current system concept does not allow for a “separation of concerns”, however, where airline preferences and flow considerations have separate coupling strengths.

It should be possible to enter the following data on the UDPS GUI:

- Preference and possibility windows for departure times
○ priorities for flights (each airline for its own flights)
○ flight swap (order change, within given airline)
○ flight cancellation
○ TTOT or TOBT commitment (TBD)

Airline-specific filters shall be provided, so that each airline will see and be able to edit flight details only for its own flights. The fairness principle (chapter 4.5.4) shall be supported by APM in that preferences set by an airline for its flights will “cost” it an appropriate amount of bonus points. The mechanism to win bonus points by cooperative behaviour is part of the concept, but will not be realized within TAMS.

3) KPI displays

APM shall display the KPIs described in the corresponding section below at the airline workplace.

4) What-if probing and strategy implementation

The what-if functionality described in the corresponding section below shall be offered by APM at the airline workplace. Additionally, the workplace shall provide the possibility to trigger the activation of the parameters used for the what-if scenario into “real life” operational settings. Active strategies shall be suitably displayed.

5) Reporting

APM should support reports for the KPIs under its control, with standard aggregation capabilities as offered by the tool used.

**APM contribution to Airport workplace (chapter 4.6.2)**

The contribution of APM to the airport workplace is the same as for the airline workplace, except that the UDPS functionality is not relevant here.

**Contribution to AOP management (Chapter 4.2)**

APM shall compute its KPIs on the basis of the currently active AOP, so that changes to the AOP, whether in “real life” or in a what-if context, are immediately reflected in changed KPI values.

Moreover, since not only flight and resource planning, but also strategies such as capacity assignments and performance goals such as punctuality are part of the AOP, APM shall play an active role in managing the AOP. APM shall be the location in TAMS where performance goals are displayed, and shall participate in the evaluation of strategies by what-if probing.

The module UDPS (User Driven Pre-Tactical Sequencing) of APM shall support stability of the AOP by determining a near-to-optimal departure sequence very early, which then is used as a guideline for the subsequent tactical calculations.

APM is thus involved in AOP management on a performance level (performance goals), flow level (strategies, UDPS), and event level (computation of flight-specific process times)
Achieved flow levels and performance shall be measured in terms of APM's KPIs and shall be compared with AOP targets. Similarly, on the event level, estimates and normative target times shall be compared with schedule times. Computations shall be updated driven by relevant update events (e.g. new information relevant for estimates/normative targets) and by comparison of current time with schedule/target.

The different levels shall be consistently integrated, so that event level data are aggregated to flow level evaluations, and eventually, to performance KPIs. The data hierarchy principle shall ensure that always the best available information is used (see AODB section).

Specifically, the following AOP data shall be supported by APM in the sense that APM displays them and provides editing functionality:

- Performance goals (edit and display)
- Runway capacity (edit and display)
- Possibly: runway configuration (edit and display)

Note that the above data are not outputs of KPI calculations, but inputs or target values for comparison. They are part of the AOP and as such, are distributed also to partner applications where required. We now turn to the output data, i.e. the dynamically changing KPI values as computed by APM.

**KPIs provided by APM (chapter 4.3)**

The following KPIs shall be provided by APM:

**a) performance level KPIs**

- Absolute punctuality (AIBT/EIBT vs. SIBT and AOBT/EOBT vs. SOBT)
- Local delay (delay caused by airport) – analogously
- Predictability (deviation of estimates from actual times, integrated over time)

**b) flow level KPIs**

- Available total runway capacity vs. cumulated demand. Cumulated demand means demand including the contribution from backlogs.
- Capacity usage: available total runway capacity vs. cumulated demand.
- Dwell times for delays caused by insufficient runway capacity

![Figure 5-5: Design draft for flow level KPI display](image)

Cursive text indicates correspondence to KPIs defined in Eurocontrol Implementation Manual; there are, however, partly some differences regarding details of the definition.
Alert management (chapter 4.4)

APM shall compare target and actual/estimated values and indicate target violations by colour coding. This applies to performance, flow and event level displays in general. On the event level, “mild” deviations of estimates or actuals from schedules or targets shall be marked in yellow, strong deviations in red.

APM shall allow to set possibility and preference windows, corresponding to green and yellow colour coding. This applies in particular to the comparison of schedule or (normative) target times with estimates and actuals on the event level.

Within the generation of pre-tactical “guidance times” for the pre-departure sequence (UDPS module), a similar mechanism shall be employed – deviations of the times computed by the ATWP from the guidance times shall be differently penalized in the evaluation function according to whether they fall into the preference window, the possibility window, or neither of them.

5.3.4. CDM-process and Joint What-if (chapter 4.5.3)

5.3.4.1. SMAN What-If Probing

The SMAN shall provide a single what-if probing used only by the ATC-Agent.

The ATC-Agent shall get the impact to the SMAN prediction and planning results by changing:

1. local operating procedures, e.g. different taxiroute patterns,
2. availability of the taxiway infrastructure,
3. runway capacity,
4. runway in use,
5. allocation of aircrafts to runways,
6. meteorological conditions (e.g. CAT I, II, III, visibility conditions, surface condition).

The SMAN shall provide a joint what-if probing used by all other agents (coordinated by the APOC moderator). The APOC-Agent shall get the impact on the SMAN prediction and planning results by changing by changing:

1. runway capacity
2. runway in use
3. allocation of aircrafts to runways
4. metrological conditions (e.g. CAT I, II, III, visibility conditions, surface condition)
5. allocation of aircrafts to parking positions
6. operational airport strategy (e.g. capacity, punctuality, eco friendliness, etc.)
7. Remote de-icing required
8. EOBT / TOBT / ELDT

5.3.4.2. APM participation in What-if Probing

APM shall support what-if probing both on the single what-if and joint what-if level. One needs to distinguish between the setup of a what-if scenario and the subsequent evaluation
of its operational consequences in terms of KPIs and process times.

Setup of What-if Scenarios

What-if analysis is based on varying performance, flow or event level parameters; APM’s support for these parameter variations shall be as follows:

- **Performance level**: APM shall allow to activate performance goals such as punctuality or throughput. It should be possible to display variable relative weights and a time window of validity.

- **Flow level**: APM shall allow to edit total runway capacity, separately for arrivals and departures (but not in a runway-specific way), as a function of time within a certain window.

- **Event level**: APM does not manipulate individual process times for setting up what-if scenarios.

As a support for the setup of scenarios, the AODB should keep templates with certain default parameter settings.

What-if scenario evaluation

After having defined a what-if scenario, the subsequent task is to compute the resulting process flow and to evaluate the results on all 3 levels.

APM shall provide the following functionality:

- **Prognostic, model based computation of the process flow based on flow level parameter settings (pre-tactical horizon)**

- **Evaluation in terms of flow level KPIs (capacity vs. cumulated demand, dwell times, see above)**

- **Evaluation in terms of performance level KPIs (punctuality, local delay, predictability see above)**

- **Evaluation in terms of event level process times, as computed by APM itself (according to the data hierarchy principle, these shall be used in TAMS only if no XMAN-data are available – therefore, they are relevant only for single what-if probing)**

Single What-if Probing

For single what-if probing, APM shall carry out the entire workflow from scenario setup to evaluation. Of course, this requires that the parameters varied have a meaning in its process model. The flow level capacity-related parameters above are of this type, but the performance-level parameters are not. Moreover, the computations required for evaluation of the scenario shall also be performed by APM alone. This is to say, APM shall carry out a pre-tactical analysis based on varying runway capacity/configuration parameters and show the result in terms of performance level KPIs, flow level KPIs and flight-specific process times computed by its own estimation algorithms.

Joint What-if Probing

The following text is preliminary; the feasibility of the functionality described below, especially the participation of APM in the display of the results of joint what-if probings, under given cost
and time constraints is not clear at the present moment.

For joint what-if probing, APM plays a more restricted role. In contrast to the single what-if case, it will not carry out its own prognostic calculations and instead will rely on the XMEN for this purpose. However, it shall always participate in the evaluation of the results by collecting the process times computed by the XMEN, just as in the “real life” case, and by computing from them flow and performance level KPIs. It shall also display the process times within its scope of managed process steps. This is exactly the same functionality as in the “real life” case, for the tactical time horizon. This makes joint what-if probing most suitable for analysis on a tactical time horizon, so that from APM’s point of view, single and joint what-if are complementary w.r.t the time horizons covered.

What-if scenarios based on performance goals shall be activated by APM, but APM does not carry out any prognostic computations based on these parameters. The XMEN will, however, react to such performance goal settings and will change their tactical planning accordingly. The resulting process times, and only these, shall be used by APM as explained above.

Joint what-if probing also may involve tactical, event level parameter variations. For instance, the AMAN may start a joint what-if analysis by a changed arrival sequence. If only a few flights are changed, the display of individual flight process times may be more important in this case than the display of KPIs.

5.3.5. Strategy Capability

As pointed out in chapter 4.2, parameters in the AOP can be changed by the operations manager, for instance in order to counteract unwanted future operational developments, or they may be tuned to achieve specific operational targets. Specific settings of AOP parameters to achieve certain goals will be called strategies in the following. In order to react to typical problem situations quickly and efficiently, the system should be equipped with the possibility of activating pre-defined strategies, possibly after suitable modification.

The iteration 2 TAMS system is equipped with functionality suited to manage flight handling on a tactical level. However, Total Airport Management is hardly conceivable without a pre-tactical layer. Instead of trying to make the best out of a given operational situation, the goal on the pre-tactical level is to treat foreseeable resource bottlenecks and operational perturbations in a pro-active manner, ideally avoiding the occurrence of negative performance impacts altogether. A further goal of pre-tactical process management is performance optimization w.r.t. certain criteria such as punctuality, throughput, cost or environmental impact. Any kind of pre-tactical guidance can be seen as the implementation of a strategy, similar to the usual distinction between tactics and strategy. The pre-tactical/tactical departure side coupling (UDPS-DMAN-coupling) can be considered as an example of a very specific kind with a focus on the enforcement of plan stability and airline preferences.

In TAMS, we will distinguish two levels for strategies:

Performance Goals (Performance Level Strategies)

Performance level strategies correspond to performance goals such as punctuality, throughput, environmental impact or cost minimization, or more generally of a weighted superposition of several goals. Which goals should be pursued, depends on the operational situation – in times of overload, throughput and punctuality are of highest importance, while in a weak load situation, cost and environmental impact minimization should come to the foreground. A performance level strategy can be pursued independent of IT support, in principle. However, system intelligence is helpful in order to identify the best levers for the realization of the goals and to operate them in a coordinated, optimized way. In the long run,
the IT system may be able to go as far as generating an entire Airport Operation Plan (AOP) automatically\textsuperscript{40}; however, this is not only technically very difficult, but also the lack of transparency inherent in fully automated planning will make it hard to gain acceptance by the responsible human operations managers.

A somewhat more modest, but realistic approach with better user acceptance is to leave the operation of the “levers”, i.e. the critical control parameters/resource assignments, under human responsibility. For performance level strategies, this means that operations managers will decide, by manual change of suitable control parameters/resource assignments (inside the XMEN or in other tools), how certain goals should be achieved. In future, it is conceivable that the system provides decision support functionality to assist and guide this process, for instance by making proposals or setting boundary conditions for parameter choices. Within TAMS, the current plan is only to display agreed performance goals on the control room Video Wall. The operations managers will then have to make suitable choices for control parameters/resource assignments and take operational decisions. However, TAMS offers a general support mechanism, described in a separate concept paper, for validating such choices: so-called what-if analysis. By means of what-if analysis (also applicable to the flow level strategies described below), certain choices and decisions can be evaluated by using the prognostic capabilities of the TAMS system. Performance level goals could thus be approached in an iterative manner, testing alternatives before implementing the final decision.

**Flow level strategies**

Flow level strategies are defined as sets of time-dependent control parameters and resource assignments, which influence the processes on a flow level. Important examples consist of capacity and capacity-related parameters, such as runway capacity or runway usage mode, and of stand assignments. However, prioritization rules such as preferring certain types of flights over others\textsuperscript{41} also are to be considered as flow level strategy control parameters. Notice that certain parameters, particularly resource assignments, may not have to be set explicitly, but may follow as a consequence of other parameters and can be computed by the modules.

Flow level strategies can be understood simply as methods to achieve performance goals; that is, they represent procedures to realize performance level strategies. However, the relation between goals and realization methods is not simple and well-defined. For example, while it may be helpful in a given situation to increase the A/D ratio in order to achieve a higher throughput, doing just the opposite may work in another. Still it is true that an experienced human operations manager will know in a given situation which levers to use with a good chance of achieving his goals. Therefore, the idea is natural to offer IT support for operating the levers, which is exactly what we mean by flow level strategies.

### 5.4. Video Wall

The Video Wall as the expression of a common APOCHMI is the result of the need for a high degree of flexibility to combine easily tailored information from a fitting selection of displays and sources around a core HMI. It is necessary to ideally serve the purpose of different use

\textsuperscript{40} The initial TAMS concept tried to make a step in this direction.

\textsuperscript{41} Within the given legal boundary conditions, of course. Certainly, such prioritizations, where they concern more than one stakeholder, must be agreed beforehand by a negotiation process.
case situations with varying needs. Good examples for an enabler of such a solution are the Control Room Management Suite of Barco and the eyevis solution used by DLR.

The main principles of this approach is to:

- **Connect**
  enabling users to easily connect to a multitude of sources, regardless of where the information has to be presented

- **Control**
  to control and manage displays and sources

- **Collaborate**
  by freely configurable control room collaboration with different concepts of perspectives with the purpose of sharing user-defined information views with colleagues more efficiently.

For interaction with their respective organizations, the APOC agents will each be using their own specialized HMIs at their APOC working positions, which best fit their purposes. It is more appropriate to enable those systems with the possibility for interaction with the APOC visualization (e.g. focusing on alert areas) than to introduce new tools.

The APOC HMI will be used by the APOC supervisor and all APOC agents, i.e.:

- APOC Supervisor/Moderator,
- ATC Agent,
- Airport Agent,
- ATFCM Agent,
- Ground Handler Agent,
- n Aircraft Operator Agents.

Additional Agents, such as Immigrations, Border Police, Medical Services, Public Transport, etc. will develop and be given a role in the future.

Their collaboration, either within a physically centralized control room, or with the same aggregated view in front of them in a virtual control room will be governed by clearly described roles.

### 5.4.1 Visualization of APOC steering information

Their means of influencing the local airport operational situation from the APOC will be to alter parameters in one or more of the three areas

- Traffic volume – by asking the airlines to keep flights on the ground at the upline airport,
- Throughput – by reducing, or opening up available runway capacities and/or,
- Punctuality – by adjusting the traffic volume within possible capacity use until a higher degree of punctuality can be reached.
5.4.2 Visualization of interest overlap
In order to support this, the APOC HMI will have to show those problem and solution visualization parts of the three management domains

- ATC Management,
- Surface Management and,
- Turnaround Management,

which are or should be common to the representatives of each one of the domains for their joint decision making.

5.4.3 Visualization joint what-if
In order to fully understand the potential impact of a choice of upcoming decisions before they are applied by the personnel of an APOC a third category for visualization should be available – the visualization of joint what-if results.
Category 1 – APOC Steering Information

In this first category the information to be visualized is of strategic quality like:

- Traffic flow (volume),
- Airport capacity (throughput) and,
- Airport performance (punctuality).

Necessary strategy changes within any of these steering areas will translate into changing the entire way of working for the tactical level and the information about which strategic intentions are currently valid, the ongoing measurement of compliance with them and to be anticipated levels of risk for plan adherence are to be visual at all times for the experts within the APOC.

Consequently, this part of the APOC HMI layout should not be changed – the essentials available and visible at the same spot at all times. Therefore this could be deemed a static layout area.

Category 2 – Visualization of Interest Overlap

This part of the APOC HMI is dedicated to show context information of the organizational three main process control circle:

- ATC management,
- Turnaround management,
- Surface management.

The information in this area is about giving an overview about situational irregularities at a time when countermeasures can still be executed.

Ideally it would be based on a geographical view with drill down and focus capability showing the current and upcoming operational situation in the surrounding airspace, on the taxiways and for the turnaround at the stands and gates. In this area those kind of alerts from the different areas of control should be shown, which indicate a problem of a joint nature.

In case of a joint solution attempt the need will arise quickly where a focus on the area of the problem to be resolved becomes necessary. Looking at the same problem – not just at the effects it has on the neighboring organization fosters common insight and understanding and
in the long run will enable a joint team to better anticipate the needs of each other.

Consequently, this part of the APOC HMI layout should be more variable in its adaptability on different problem based use cases.

Category 3 – Visualization of joint what-if analyses results

This part of the APOC HMI is to be used as a visualization area for joint problem resolution discussions and the foresight about the effects an attempted solution tactic may have on the partner situations. This insight about the to be expected effects for the overall situational operational development can be seen in a “tactical sandbox” before it is applied to remedy an upcoming irregularity.

Consequently, this part of the HMI will be applied on a case by case basis only – for the short periods of analyses it can be superimposed on the Interest Overlap area.

![Figure 5-9: APOC HMI Layout – combined views](image)

### 5.5. Agent Working Position

#### 5.5.1. Airport Agent Working Position

The airport agent working position shall enable the airport to:

- obtain a performance overview for processes in the responsibility of the airport,
- obtain information on the status and projected progress of all flights,
- participate in what-if probing,
- execute flight and resource planning in so far as under the airport’s responsibility (this may be seen also as a support to strategy capability). This concerns in particular stand assignment, participation in runway capacity planning and ground handling planning,
- obtain an overview about the status inside the terminal and the status of passengers in their process chain related to flights,

The following applications will be present at the airport agent working position:

- Airport Performance Manager (APM): For a description of the functionality provided to fulfil the above requirements, see chapter 5.3.3.1.
- Airport Management System (AMS), Airport Performance Manager (APM): For a description of the functionality provided, see chapter 5.3.1.2.
○ Turnaround Manager (TMAN): For a description of the functionality provided, see chapter 5.3.2.4.

○ Passenger Manager (PaxMan): For a description of the functionality provided, see chapter 5.3.2.6

5.5.2. ATWP as Part of ATC Agent Working Position

Besides the general requirements upon an Agent Working Position within an APOC like the creation of common situational awareness and the enabling of what-if probing, subchapter 4.6.2.4. states additional requirements on the ATC Agent Working Position. In TAMS this working position is called ATWP – Airside Tactical Working Position. Derived from subchapter 4.6.2.4 are the following requirements:

○ The ATWP shall provide features to achieve awareness about the predicted traffic load of airspace resources of the airport and within it’s TMA.

○ The ATWP shall provide the actual regional traffic situation to enhance the situation awareness of the ATC Agent.

○ The ATWP shall provide a view for pre-departure sequencing to enable collaborative airport planning.

○ The ATWP shall provide input options to enter capacity strategies and ATC operating procedures.

○ The ATWP shall provide possibilities to communicate to operation centres like Approach Control, Tower Control, Ground Control, Clearance Delivery, CFMU/ATFCM. Note: This requirement is out of scope in TAMS, because controller working positions will neither be designed nor be simulated.

○ The ATWP should support the display of its data on the Video Wall to improve the situation awareness of all agents and to discuss these operating procedures among the other agents.

Note:

One of these general requirements usually will break down into many more requirements. E.g., the generally required what-if probing implies the following requirements:

○ The ATC Agent shall be able to alter the sequence in the what-if probing.

○ The ATC Agent shall be able to set a new operation mode.

Each of these requirements can be further broken down, e.g. what-if probing:

○ The ATWP shall be able to calculate a conflict free sequence with all constraints applied (AMAN, SMAN and DMAN needed, for further requirements see 5.3.2.1, 5.3.2.2, and 5.3.2.5.).

○ The ATWP shall be able to switch between different scenarios (data sets) to enable a joint what-if probing.

Because of the complexity of the operational procedures and deriving requirements that such a new working position poses, a concept was written for the ATWP [13] which shall be the baseline for further technical design and implementation. This concept will continuously be upgraded as soon as new consolidated findings appear that have to be considered.
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Abbreviations

For a glossary please refer to the global TAMS glossary [61]. All abbreviations used in this document are listed below:

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACARE</td>
<td>Advisory Council for Aeronautics Research in Europe</td>
</tr>
<tr>
<td>ACARS</td>
<td>Aircraft Communications Addressing and Reporting System</td>
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<td>A-CDM</td>
<td>Airport Collaborative Decision Making</td>
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<td>ACIS</td>
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<td>ACISP</td>
<td>Airport CDM Information Sharing Platform</td>
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<td>AIBT</td>
<td>Actual In-Block Time (equivalent to Airline/Handler Actual Time of Arrival)</td>
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<tr>
<td>ALDT</td>
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<td>AMAN</td>
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<tr>
<td>AOBT</td>
<td>Actual Off-Block Time (Equivalent to Airline/Handlers Actual Time of Departure)</td>
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<td>AODB</td>
<td>Airport Operational Database</td>
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<td>Airport Operation Plan</td>
</tr>
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<td>Actual Passengers at Gate Time</td>
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</tr>
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<td>Airport Operation Centre</td>
</tr>
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<td>ARDT</td>
<td>Actual Ready Time (for Movement)</td>
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<td>ARR</td>
<td>Arrival</td>
</tr>
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<td>ASAT</td>
<td>Actual Start Up Approval Time</td>
</tr>
<tr>
<td>ASBT</td>
<td>Actual Start Boarding Time</td>
</tr>
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<td>ASMA</td>
<td>Arrival Sequencing and Merging Area</td>
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<td>A-SMGCS</td>
<td>Advanced Surface Movement Guidance and Control System</td>
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<td>ASSET</td>
<td>Aeronautic Study on Seamless Transport</td>
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<td>A-SWIM</td>
<td>Airport - System Wide Information Management</td>
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<td>ATC</td>
<td>Air Traffic Control</td>
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<td>ATFCM</td>
<td>Air Traffic Flow and Capacity Management</td>
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<td>ATFM</td>
<td>Air Traffic Flow Management</td>
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<td>Definition</td>
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<td>ATM Airport Performance</td>
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<td>ATRiCS</td>
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<td>ATWP</td>
<td>Airside Tactical Working Position</td>
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<td>BMWi</td>
<td>Bundesministerium für Wirtschaft und Technologie (German Federal Ministry for Economics and Technology)</td>
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<td>Business Use Case</td>
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<td>CAP</td>
<td>Collaborative Airport Planning</td>
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<td>CDAC</td>
<td>A-CDM in Adverse Conditions</td>
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<td>CDM</td>
<td>Collaborative Decision Making</td>
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<td>CFMU</td>
<td>Central Flow Management Unit</td>
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<td>CHMI</td>
<td>Human Machine Interface (HMI) of Central Flow Management Unit (CFMU)</td>
</tr>
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<td>COFU</td>
<td>Collaborative Management of Flight Updates</td>
</tr>
<tr>
<td>CPDS</td>
<td>Collaborative Pre-Departure Sequence</td>
</tr>
<tr>
<td>CTOT</td>
<td>Calculated Take Off Time</td>
</tr>
<tr>
<td>CTRP</td>
<td>Airport CDM Turnaround Process</td>
</tr>
<tr>
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<td>Demand Capacity Balancing</td>
</tr>
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<td>DEP</td>
<td>Departure</td>
</tr>
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<td>DFS</td>
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<td>DLR</td>
<td>Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center)</td>
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<tr>
<td>DMAN</td>
<td>Departure Manager</td>
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<td>DPI</td>
<td>Departure Planning Information messages (as ATC, Cancel, Early or Target)</td>
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<td>ECAC</td>
<td>European Civil Aviation Conference</td>
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<td>EIBT</td>
<td>Estimated In-Block Time (equivalent to Airline/Handler Estimated Time of Arrival)</td>
</tr>
<tr>
<td>ELDT</td>
<td>Estimated Landing Time (equivalent to ATC Estimated Time of Arrival = landing)</td>
</tr>
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<td>Estimated Off-Block Time (extracted from the filled ATC flight plan and ATC flight plan modification messages)</td>
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<td>European Operational Concept Validation Methodology</td>
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<td><strong>Definition</strong></td>
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</tr>
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</tr>
<tr>
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<td>Estimated Ready Time</td>
</tr>
<tr>
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</tr>
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</tr>
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</tr>
<tr>
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<td>Estimated Takeoff Time</td>
</tr>
<tr>
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<td>European Union</td>
</tr>
<tr>
<td>EXIT</td>
<td>Estimated Taxi-In Time</td>
</tr>
<tr>
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</tr>
<tr>
<td>FAMOUS</td>
<td>Future Airport Management Operation Utility-System</td>
</tr>
<tr>
<td>FIDS</td>
<td>Flight Information Display</td>
</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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<td>Flight Update Messages</td>
</tr>
<tr>
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</tr>
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<td>Human Machine Interface</td>
</tr>
<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
</tr>
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<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
</tr>
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<td>IDD</td>
<td>Interface Description Document</td>
</tr>
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<td>Key Performance Area</td>
</tr>
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<td>Key Performance Indicator</td>
</tr>
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</tr>
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<td>LoS</td>
<td>Level of Service</td>
</tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>OS</td>
<td>Operational Scenario</td>
</tr>
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<td><strong>Definition</strong></td>
</tr>
<tr>
<td>------------</td>
<td>---------------</td>
</tr>
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</tr>
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</tr>
<tr>
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</tr>
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<td>Possibility Window</td>
</tr>
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</tr>
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</tr>
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</tr>
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</tr>
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</tr>
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</tr>
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<td>Runway</td>
</tr>
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<td>SAD</td>
<td>System Architecture Description</td>
</tr>
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</tr>
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</tr>
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<td>SFP</td>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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<td>Surface Management</td>
</tr>
<tr>
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</tr>
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</tr>
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</tr>
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</tr>
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</tr>
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</tr>
<tr>
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<td>Turnaround Integration in Trajectory And Network</td>
</tr>
<tr>
<td>TMA</td>
<td>Terminal Manoeuvring Area</td>
</tr>
<tr>
<td>TOBT</td>
<td>Target Off-Block Time</td>
</tr>
<tr>
<td>TSAT</td>
<td>Target Start Up Approval Time</td>
</tr>
<tr>
<td>TTOT</td>
<td>Target Take Off Time</td>
</tr>
<tr>
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<td>Definition</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
</tr>
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<td>UDPS</td>
<td>User-Driven Pre-Tactical Sequencing</td>
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<td>Universal Time Coordinated</td>
</tr>
<tr>
<td>VIP</td>
<td>Very Important Person</td>
</tr>
<tr>
<td>VTTC</td>
<td>Variable Taxi Time Calculation</td>
</tr>
<tr>
<td>w.r.t.</td>
<td>With respect to</td>
</tr>
<tr>
<td>XMEN</td>
<td>Tactical applications, like AMAN, DMAN, TMAN, PaxMan or SGMAN</td>
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