VCD

TAMS
Validation Concept Document

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1 Aim and Purpose of this Document

This document resulted out of activities, which were executed within the scope of Work Package 1.1.3 of the lighthouse project “Total Airport Management Suite” (TAMS).

In a concentrated manner, this document summarizes the concepts, which can be validated within TAMS (see Chapter 2).

This document subsumes the TAMS validation activities regarding the overall TAMS conceptual elements of integration of air- and landside processes and the consideration of tactical and pre-tactical planning phases. Within the scope of TAMS, several industrial partners are involved in the implementation of the TAMS operational conceptual elements. These companies have differing interests in TAMS and their related products and, thus, different information and validation needs. However, small-scale validation activities regarding single or only some tools pursued by some partners, and therefore not the whole TAMS-concept, are not within the scope of this document.

Subsequently, this document points out the TAMS validation strategy (Chapter 3.1), which is not only based on the European standard “European Operational Concept Validation Methodology” (E-OCVM, [1]), but also considers the experiences made by DLR in other projects such as EMMA2 (“European Airport Movement Management by A-SMGCS, Part 2”). The TAMS validation strategy is, thus, a combination of a well accepted European standard and best practice. To work out the validation strategy, the stakeholders will be defined as well as their specific interests. More specifically, the open questions and central issues will be introduced, which answers are highly relevant to all stakeholders. Subsequently, the current and targeted maturity level of the TAMS system as well as its underlying concept will be classified.

After having introduced the validation strategy, the methodological approach taken to yield valid answers to the validation questions will be discussed (Chapter 3.2).

After encountering several difficulties within the project’s progress and especially influencing the task of performing the validation of the TAMS system prototype, a late adaptation of this document was necessary to incorporate the original plan and its constantly occurring revisions due to unpredictable availability of the components to be validated. Therefore, in the remainder of the document, sections have been created using future tense to express the original plan and past tense to clarify the adherence to or deviation from it. It has been attempted to describe the plan in an objective manner, even though at the time of revision of this document, the plan was already outdated and void.

Additionally, several passages from earlier revisions of the Validation Concept Document [30] have been omitted from this final release due to the project’s course. The work that has been put into the specification of those aspects (see chapter 3.2) are not available for project external use though.

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2 Description of the Operational Concept

2.1 Definition of the ATM Problem and Causes

Efficient and ecologically compatible mobility is a key aspect for today's high tech society. Whether or not this desired high level mobility is achieved, is significantly influenced by the punctuality of airports, which are a central interface between ground and air traffic and, thus, impact the total transportation system and its quality [2].

That today's airports are a bottleneck and meaningfully reduce the desired efficient and ecologically compatible mobility is impressively demonstrated by statistics: Unpunctuality rates of airports reach about 20% [2]. The majority of these delays can be traced back to an inefficient use of the airports' capacities. A main reason therefore is certainly the low level of interconnection between the great number of processes owned by the various parties of an airport [2]: Each stakeholder (such as Air Traffic Flow Capacity Management (ATFCM), Air Traffic Control (ATC), airport company, ground handlers, airline companies) has its own operational centre (OC), in which its processes are planned in a manner, which insufficiently considers the plans of other operational centres. In addition, the OCs do not necessarily communicate relevant data and information on their plans to other OCs. This lack of (up-to-date) information makes it difficult to harmonize the planned operations and to estimate the impact of the own planned schedule on the effectiveness of the complete airport.

2.2 Solution Approach

As the description of the ATM problem and potential underlying causes demonstrate, the efficiency of airports can be optimized by

(1) improving information exchange between the different parties involved in managing the processes at an airport and

(2) enabling collaborative and proactive elaboration of an airport operation plan (AOP), which is implementable, which considers its effect on the airport, and which can be accepted by all stakeholders.

To provide improvement, EUROCONTROL elaborated on a basic approach of how information could be exchanged in airborne operations [3]. This concept has been subsumed under the keyword "Airport Collaborative Decision Making" (A-CDM). Within the scope of the concept "Total Airport Management" (TAM), DLR closely collaborated with EUROCONTROL and further developed A-CDM [4]. TAMS specifies this concept to some extent [5]: It integrates air- **and** landside processes and considers the tactical **and** pre-tactical planning phase. In addition and for the first time, parts of a holistic control and plan centre, which is deduced from the TAM concept, will be implemented.

The holistic control and plan centre (Airport Operations Center, APOC) is a key element of the TAMS concept [6][28]. Within this centre, bottlenecks will be identified in an anticipatory manner and solved in close cooperation of those parties, which are responsible for the processes affected by the bottleneck. To do so, representatives of all stakeholders, that is, APOC agents, are present in the APOC. The APOC agents will be provided with up-to-date dynamic information on the current and future traffic situation at the airport. In addition, appropriate automation support will be provided to the APOC agents especially for elaborating or updating an operations plan, which is comprehensive in the sense that it covers all air- and landside processes at one airport (Airport Operations Plan, AOP). Additional technical and organizational tools will assist by providing airport performance analyses or seamlessly coupling pretactical and tactical assistance systems, such that an AOP can also be realized practically.

The operational concept of TAMS [28] lists ideas for coping with the difficulties when elaborating and maintaining an AOP, which

- is generally accepted by all stakeholders, which
- is practically implementable, and which
- improves the efficiency of today's airports.

In the following sub-chapters, these ideas are introduced and discussed.

2.2.1 Generation of an appropriate Airport Operations Plan

An airport is an open and complex system. Its future states can currently not be fully predicted in a dependable and reliable manner, as the environment and from the airport independent but influencing factors change continuously. This is why an airport cannot be operated on the basis of a static fixed plan, which all stakeholders agreed upon once. Instead, continuous adaptations need to be undertaken especially if the plan execution should directly enhance the airport's efficiency and indirectly improve the European transportation system.

An important operational goal is, thus, to define mechanisms that enable to elaborate an AOP, which meets the above introduced requirements.

Therefore, the operational TAMS-concept [28] proposes to support the process of elaborating an AOP. The stakeholders define performance boundaries and will be alerted, if these boundaries are violated. Then, the stakeholders may initiate a manual negotiation phase (see also [7]), during which appropriate means of visualization and what-if probing (see below) will be applied. Hence, a proactive AOP planning process is pursued, which considers the preferences and constraints of the different stakeholders.

It is expected that such a high-level Airport Operational Plan, which collaboratively plans, evaluates and determines all airport processes, significantly improves the efficiency of an airport and, thus, contributes to successfully solving capacity issues at an airport.

2.2.2 Support of a Common and Consistent Understanding of the Overall Traffic Situation

To optimally take advantage of an AOP and its expected benefits, an appropriate communication platform needs to be provided. Such a platform can be used

- to distribute knowledge about the status of current and future airport processes and resulting demands,
- to foster the generation of new insights regarding the airport's current status and expected, future situations and resulting needs, and
- to facilitate the formation of a common situation awareness.

A high level of situation awareness is crucial to enable the stakeholders to quickly understand the current situation and to solve potential issues with the airport's performance.

One method which is expected to significantly enhance common situation awareness is an appropriate display of relevant information on a videowall and on separate and individual APOC working positions. This videowall is integrated into the APOC and is easily visible by all APOC agents.

According to the operational concept of TAMS [6], information on events and the performance of the complete airport should be displayed on the videowall. For instance, a weather forecast is provided as are predicted future bottlenecks at airport resources (e.g., de-icing, check-in).

Another method to facilitate the negotiation is the so-called *what-if probing*. This probing is stakeholder-specific and demonstrates the impact of the own planning process and operation options on the system "airport" and its efficiency while considering the currently active operations chosen by all other stakeholders. This process is expected to support forming common situation awareness as it explicitly demonstrates

(1) the impact of stakeholder specific operations on the overall airport and its efficiency and

(2) the interconnections of all processes.

2.2.3 Support of Collaborative Decision Making

As indicated in Section 2.2.1, the negotiation process of all APOC agents contributes to the success of an AOP, which has the capability to improve the airport's key performance expressed in measured indicators. This negotiation process could, for instance, be initialized by the stakeholders, if their preferred performance boundaries are violated. In addition, a negotiation process can result, if one or more stakeholders wish to define new and especially stricter boundaries.

The negotiations take place in the APOC, in which an independent and neutral moderator is present besides the APOC agents [6]. During the negotiation, the agents share information, preferences, and thoughts. Solution approaches are collected and evaluated with regard to related chances and risks. On this basis, a decision for one AOP will be made and the updated plan will be activated and implemented. With the activation of a new plan, the negotiation phase is completed.

Reaching consensus on a new plan is not always easy: The collaborative decision making process is complicated if there are inconsistent and even contradictory opinions on issues and courses of action. If this dissent is only based on lack of information, this can easily be solved by appropriate communication and information exchange between all stakeholders (see also Section 2.2.2). Such communication and information exchange has the potential to significantly facilitate forming common situation awareness, which can be sufficient to reach consensus between all decision makers. If, however, basic discrepancies and related conflicts between stakeholders become apparent during the communication process, the decision making can be significantly complicated. To solve such conflicts and to reach a consensus, which is for all stakeholders satisfying, is, however, crucial, as unsolved issues might endanger future communication and collaboration when negotiating an AOP update.

What can further complicate the collaborative negotiation and decision making process is the relationship between different stakeholders. It is to be considered that conflicts between stakeholders will always exist and cannot be avoided. For instance, airlines at the same airport compete with one another. Such a relationship can result in a competitive conflict, which, of course, impacts the negotiation process. Hence, it cannot be the goal to generate a conflict-free zone, but to create an optimal state of tension, which uses conflicts productively.

Collaborative decision making can be determined by the stakeholders' capability to be open to compromise. Hence, the roots for the stakeholders' readiness to compromise should be taken care of during the negotiation phase. One way to do so is identifying a solution, which results in accepted performance data but does not reflect an optimal solution for one stakeholder.

3 Validation

Validation is a generic and widely spread term, for which a great number of meanings exist (cf. [1] [9]). Within the scope of TAMS, the - of the European Community - agreed-upon and in the standard E-OCVM [1] propagated definition will be applied, which subsumes all activities under the term "*validation*", which investigate whether the right system is currently build. Hence, it is to be investigated whether the system concords with the stakeholders' views. Stakeholders are those parties, which are significantly involved in practically implementing and realizing the system at hand.

In contrast to validation, *verification* activities determine whether a system is built correctly, that is, whether it runs without error according to the specifications. A successfully completed verification is an important prerequisite for the validation: Before a system can be validated, it needs to be verified and the verification needs to be successful!

The TAMS validation activities will mainly follow the procedure advocated in E-OCVM, which will, however, be slightly adapted according to the experiences made by DLR. The resulting validation procedure is, thus, a best practice approach on the basis of E-OCVM.

This best practice approach considers elaborating a validation strategy in a first step (see Section 3.1). In a second step, a detailed validation exercise plan will be worked out (see Section 3.2).

3.1 Validation Strategy

To define the validation strategy, the stakeholders, which are relevant for TAMS, will be identified in a first step (see Section 3.1.1.). In a subsequent step, the stakeholders' specific interests will be worked out, which will be in the focus of the validation activities (see Section 3.1.2). On this basis, the current and future TAMS-concepts will be classified according to their level of maturity (see Section 3.1.3) and the validation objectives regarding the relevant key performance areas (KPAs) will be defined (see Section 3.1.4). Considering the available systems and the validation objectives the TAMS validation strategy (see Section 3.1.5) will be worked out and introduced.

3.1.1 Definition of the Stakeholders and of their Specific Interests

As already described, the major aim of validation activities is to answer relevant stakeholder questions, which go beyond technical and/or mathematical operational tests [1]. The answers are expected to contribute to the successful market introduction of potential TAMS products. The stakeholders are, thus, the parties, whose support, cooperation, and advice contribute to the practical implementation of the operational concept.

Within the scope of TAMS, a variety of industrial companies are deeply involved in the implementation of the TAMS operational concept [5] [28]. These are

- Siemens AG ("Siemens"),

- Inform GmbH ("Inform"),
- Barco Orthogon GmbH ("Barco"),
- Flughafen Stuttgart GmbH ("Flughafen Stuttgart") and
- ATRiCS Advanced Traffic Solutions GmbH & Co. KG ("ATRiCS").

Further stakeholders are DLR, the Federal Ministry of Economics and Technology, and the TÜV Rheinland Group acting as project administrator for the Ministry.

Besides these stakeholders, those parties which will significantly be affected by the actual implementation of TAMS also need to be considered in appropriate validation activities and their feedback used for improving the TAMS concept / system. However, within the current TAMS project, the validation activities will focus on the views of the above mentioned industrial partners.

As the following description demonstrates, each stakeholder has differing interests in TAMS and related products and, thus, different information needs.

The benefit resulting from coupling tactical assistance systems is a primary validation interest for *Siemens*, as this stakeholder is mainly interested in developing an integration platform [14]. This system architecture can be considered a backbone of the coupling between the various assistance systems. In addition, it is of major importance to Siemens to develop the airport performance management system (APM), which is used to predict relevant key performance indicators. According to [28], on performance level the APM provides the KPIs "absolute punctuality", "local delay" and "predictability" and on flow level the APM provides "available total runway capacity vs. cumulated demand", "capacity usage: available total runway capacity vs. cumulated demand" and "dwell times for delays caused by insufficient runway capacity".

Inform is mainly interested in extending the developments of its tactical assistance system, that is, a turnaround manager (TMAN) for the airline, ground handler and airport users, as well as for a common situation awareness on the APOC level, combining the handling process progress statuses of all three stakeholder groups in a common critical path relationship visualization further [13] within the context of TAM and the APOC philosophy. In addition, it should appropriately visualize joint turnaround and A-CDM bottlenecks and herewith enable planning and executing countermeasures These additional development efforts are related not only to adding information on landside airport processes but also to provide appropriate interfaces such that the TMAN can easily communicate with the ATC tactical assistance systems. Hence, validating the impact of such a coupling is of major interest for Inform. Besides, Inform is interested in the concept development of the APOC HMI (videowall) itself and in major assistance functionalities, i.e., what-if probing as the technical support basis for any APOC negotiation process and the development of an airline delay avoidance cost model, which will result in system supported airline preference suggestions which can be communicated directly in an integrated manner to the other XMAN. It is of importance to Inform to yield information on the expected operational and conceptual benefit of all three features.

According to the TAMS project specification documents, *ATRiCS* is, in a first step, interested in pressing the development of its tactical assistance system (surface manager, SMAN) ahead [10], such that it can easily be integrated into an overall “TAMS-system”. Therefore, interfaces need to be developed and realized such that the SMAN can directly communicate with other tactical assistance systems. ATRiCS expects a significant benefit from such a seamless coupling and more specifically an improvement of a number of relevant key performance areas and indicators. While the pure coupling can be tested with appropriate verification methods, analysing the added-value of such a coupling is a relevant validation question.

Barco is interested in further developing and coupling of the arrival manager (AMAN) and the departure manager (DMAN). A combined arrival and departure sequence shall lead to a more stable and reliable planning. Furthermore it is expected that the integration of the surface manager improves the quality of take off times. The validation of the coupled tactical assistance systems shall ascertain an added value for airport relevant parameters [11].

A second concern of Barco is the conceptualization and implementation of the airside tactical working position (ATWP) for the ATC agent in the APOC. The new developed ATWP shall enable the ATC agent to achieve given operating figures by providing good common situation awareness on ATC processes (e.g., runway sequence) and parameters (e.g., operation mode). A joint what-if probing shall enable the ATC agent finding solutions in a negotiation process with the other stakeholders.

Another essential point of interest for both, ATRiCS and Barco, is related to developing a graphical user interface for the airside tactical working position (ATWP) ([10] and [11]). The requirement is that the interface can be integrated into the APOC. In addition, it should appropriately visualize bottlenecks and herewith enable planning and executing countermeasures. Considering the TAMS operational concept (see Section 2 and [28]), this issue is related to an appropriate information display such that the generation of a high level of common situation awareness is facilitated. Within the scope of the validation activities (see Section 3.1.3), the information display (videowall, working positions) should, thus, be validated.

The stakeholder *“Flughafen Stuttgart GmbH”* is mainly interested in whether or not the implementation of the TAMS concept has the potential to significantly enhance the punctuality of airports and of the transportation system [12].

Besides, the technical, communicational and organizational issues related to a comprehensive plan and control centre is for the Flughafen Stuttgart relevant [12]. To enable a high quality of the resulting TAMS system, not only empirically analysing the potential business models, which foster the collaborative decision making processes, is crucial but also validating the information representation on the videowall and the what-if probing, which are both expected to support a high level of situation awareness and improved communication structures.

A summary of the stakeholder-specific interests and resulting validation questions is given in Table 1.

Table 1: Summary of the Stakeholder Analyses

Stakeholder	**Specific Interest in TAMS**	**Resulting Validation Question**
Siemens	Development of an integration platform and integration of all system components	Does the coupling of pre-tactical and tactical assistance systems bring the expected added value?
	Development of the airport performance management system	Does the information displayed in the APOC foster a high level of situation awareness?
Inform	Extension of the TMAN	Does the coupling of pre-tactical and tactical assistance systems bring the expected added value?
	Definition of a what-if probing functionality	What is the expected benefit from a what-if probing functionality?
	Design of an APOC	What is the operational and conceptual added value of an APOC?
ATRiCS	Extension of the company's SMAN such that it can be considered a TAMS-assistance system	Does the coupling of pre-tactical and tactical assistance systems bring the expected added value?
	Provision of a graphical user interface for the airside tactical working position identifying bottlenecks, supporting planning of appropriate countermeasures, and of ordering their execution	Does the information displayed in the ATWP foster a high level of situation awareness?
Barco	Conceptualization and implementation of the ATWP	Does the information displayed at the ATWP foster a high level of situation awareness?
	Development of functions for decision support especially in situations which require the different APOC agents cooperating for finding an appropriate solution	Does the what-if probing bring the expected added-value?
	Extension of the AMAN and DMAN	Does the coupling of pre-tactical and tactical assistance systems bring the

		expected added value?
Flughafen Stuttgart	Increase of the operational efficiency	Does the coupling of pre-tactical and tactical assistance systems bring the expected added value?
	Technical and organizational elaboration of a comprehensive and integrated airport control station	Does the information displayed in the APOC foster a high level of situation awareness?
		Does the what-if probing bring the expected added-value?

3.1.2 Identification of the Systems' Current and Desired Levels of Maturity

Determining the concepts' and systems' maturity levels is essential for fine-tuning and adjusting validation activities accordingly: Depending on the maturity level, different types of validation activities are feasible. In addition, the information needs of the stakeholders vary depending on the development status of each system.

According to the E-OCVM six levels of maturity can be distinguished [1]:

- V0 (ATM Needs): A concept with the maturity level V0 consists of a detailed description of the ATM problem, which is to be solved. This description covers not only a statement on the desired (and currently not achieved) performance level but also a thorough analysis of why this performance level is not achieved with today's systems.
- V1 (Scope): In contrast to a concept with maturity level V0, an operational concept is available for one with V1. The operational concept describes the mechanisms in great detail, which will enable to reach the desired and already specified performance level. The operational concept must not yet be complete. It, thus, may contain open questions.
- V2 (Feasibility): The operational concept is complete in the sense that a detailed and thorough description of the system is available. The operational acceptance has also been approved by executing and evaluating according empirical tests.
- V3 (Integration): A pre-industrial prototype is available. Its functionality equals the one described in the operational concept.
- V4 (Pre-operational): An industrial prototype has been built up, which is ready for implementation.
- V5 (Implementation): An operational system at a specific site is available.

The comprehensive control and plan centre, which is a focus of TAMS, can be considered a complex socio-technical system, which development is organized in iterations [28]. According to the project plan [15], four iterations can be distinguished, during which a TAMS concept will be developed as is a functional APOC prototype:

As Table 2 demonstrates, this concept and system development starts with *Iteration 1*, which ran from February 2009 to May 2010 and during which a first operational concept was worked out [15]. This operational concept [16] does not only contain a description of a relevant ATM problem, which is to be solved in TAMS, but also potential reasons of why this problem currently exists are discussed. The operational concept strongly builds on preparatory works conducted within other projects such as A-CDM or TAM. This is why some parts of the operational concept have a higher level of maturity as others, which leads to the fact that first technical work packages were implemented in parallel to further elaborating those parts of the operational TAMS concept, which – at the stage of Iteration 1 – had a lower level of maturity. For instance, the operational concept [16] and the system requirement document [17] describe in detail the ATM problem a coupling of tactical assistance systems should solve and how this can be achieved. In contrast, the operational concept [16] only rudimentarily describes the ATM problem the videowall should deal with. Therefore, first technical implementations were initiated, such that a pre-industrial prototype with limited functionality results early in the project's progress. These first technical implementations refer, for instance, to the coupling of the tactical assistance systems (AMAN, DMAN, TMAN, SMAN), the integration platform, and DLR's simulation. Considering the above introduced levels of maturity of an operational concept and of a prototype as well as the criteria underlying certain levels of maturity (s. also E-OCVM [1]), the TAMS operational concept at Iteration 1 [16] has the maturity level V0: While the concept does contain a detailed description of a current and desired performance level, mechanisms which are expected to reach the desired performance levels have not yet been specified in detail. In contrast, parts of the operational concept are very concrete such that they enable building up a pre-industrial prototype, which can be used for validating the coupling of the tactical assistance systems. Hence, the prototype, which only has a limited functionality, has the maturity level V3.

In May 2010 *Iteration 2* was launched and additional conceptual work was conducted until December 2010. At the end of Iteration 2 at beginning of May 2011, a new version of the operational concept was introduced [24], which describes rudimentarily how the desired performance level shall be reached and the underlying ATM problem solved. Yet, some open questions remain. For instance, it had not been decided which information should be displayed in what format on the videowall. Due to these open questions, the operational concept's level of maturity was assessed to be V1. In parallel to pushing the development of the operational concept further, technical developments focused on further integrating functionality into the pre-industrial prototype. For instance, the air- and landside processes were integrated in one simulation. Hence, the maturity level of the actual prototype did not change.

The output of *Iteration 3 [15]* (May 2011-December 2011) was a final version of the operational concept. This version contains answers to all questions, which remained open after Iteration 2. Hence, a complete and detailed operational concept is available such that the concept's level of maturity is V2. As more details have become available, the development of the pre-industrial prototype was pushed forward: On the one hand, functionality was provided which enabled the tactical assistance systems to impact the simulation. On the other hand, additional functionality was provided. For instance, the APM was supposed to be technically integrated during Iteration 3 and logically during Iteration 4 into the pre-industrial prototype of the overall system. Although the technical development of the prototype was finalized within Iteration 4 (January 2012-May 2012), the prototype still has the maturity level V3 and the APM was not logically integrated into the overall system. In Iteration 4 the focus was put on the creation of the mobile demonstrator that includes the planned TAMS functionality. This demonstrator has the potential to demonstrate the practical solution of the ATM problem at hand. However, standards and rules have not yet been defined, which will enable to transfer the TAMS system into reality. The system employed for the validation exercises does not mirror the availability of the APM. Nevertheless, the system can be used to validate the practical solution of the ATM problem as described above. Working positions for APOC agents have been developed during the last Iteration 4 and have been implemented into the TAMS mobile demonstrator.

Table 2 summarizes the above introduced concepts and systems at the end of each TAMS iteration as well as their functional description and resulting level of maturity.

Table 2: Summary of the TAMS systems and their levels of maturity

System		**Functional Description**	**Level of Maturity of the Operational Concept**
APOC	Iteration 1	*1) Operational Concept* - Operational TAMS concept describing the ATM problem and potential causes.	V0 (Scope)
		2) Prototype Development - Integration of the tactical assistance systems, the integration platform and the simulator.	V3 (Integration)
	Iteration 2	*1) Operational Concept* - Operational TAMS Concept describing how the ATM problem will be solved. Open questions remain.	V1 (Scope)
		2) Prototype Development - Extension of the communication between the tactical assistance systems via the integration platform	V3 (Integration)
	Iteration 3	*1) Operational Concept* - Operational TAMS Concept describing how the ATM problem will be solved.	V2 (Feasibility)
		2) Prototype Development - Feedback from the tactical assistance systems to the simulation and vice versa. - Communication between the APM and the	V3 (Integration)

	simulator. - First visualizations of the prediction of future performance values and future traffic situation on the videowall. - First versions of the APOC agents' working position running.	
Iteration 4	*1) Prototype Development* - Implementation of pre-tactical tool. - APOC agents' working positions are being developed (including what-if probing). - Implementation of the demonstrator	V3 (Integration)

3.1.3 Strategy and Goals of the TAMS Validation Activities

As the Chapters 3.1.1 and 3.1.2 demonstrate, the operational TAMS-concept [28] contains a description of the future system in a level of detail, which is sufficient for identifying those mechanisms that enable to solve the ATM problem at hand. Due to the preliminary conceptual works conducted in other projects, parts of the operational concepts [6] [15] [28] yield a certain level of maturity, which exceeds the one of the complete concept. This is why it has been started in parallel to build up a pre-industrial prototype, which enables conducting validation activities as well.

Considering the different levels of maturity of the operational concepts and the pre-industrial prototype as well as the stakeholders' questions, the validation goals for the complete lifecycle of the TAMS project can be summarized as follows:

- Quantification of the added-value of the coupling of tactical and pre-tactical air- and landside assistance systems with regard to selected key performance indicators,
- Quantification of the relevance and the timeliness of the information displayed on the videowall and on the APOC agents' working positions (e.g., ATWP), which is expected to foster a high level of situation awareness,
- Quantification of the benefit, which what-if probing has on decision making.

As this description of the validation goals already demonstrates, two different types of validation activities are required to answer all relevant stakeholder questions:

1. While nearly all validation goals require feedback from potential users (i.e., APOC agents), other validation goals do not require a deep involvement of users. The latter is especially the case for the first validation goal: To assess the impact of a coupling of assistance systems on key performance indicators such as punctuality can be measured without a human-in-the-loop-simulation. Instead, fast- or real-time simulations can be applied to measure the efficiency of processes with and without coupled assistance systems and measure the impact of the coupling.

2. In contrast, whether certain information displayed in the APOC is relevant and / or timely requires a human-in-the-loop simulation, during which the users' reaction needs to be assessed, for instance, with or without the videowall.

The validation strategy, thus, follows a multi-method approach and combines early fast-time or real-time with later human-in-the-loop simulations. How this multi-method approach will be executed will be described thoroughly in the following section.

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3.2 Validation Exercise Plan

In the project TAMS, Validation Exercises are planned to achieve insights regarding the above three validation goals. Within the project, a technical set-up is realized, together with an operational concept, describing the idea of Total Airport Management as well as a partially automated assistance system. Three validation goals were identified (see Chapter 3.1.3). Due to the late verification of the TAMS Iteration 3 system and the resulting time constraints, the TAMS validation had to be reduced to cover only the first and most important validation goal (*Quantification of the added-value of the coupling of tactical and pre-tactical air- and landside assistance systems*), to which all stakeholders agreed to in a project meeting in November 2011 (see [32]). The other two goals identified and described in chapter 3.1.3 (1. *Quantification of the relevance and the timeliness of the information displayed on the videowall and on the APOC agents' working positions*; 2. *Quantification of the benefit, which what-if probing has on decision making*) were discarded due to the project's occurred limitations. The remaining validation goal will be explained in more detail in the following sections. The other two validation goals were roughly planned and described in former versions of this validation concept document [30].

3.2.1 Benefit of Coupling Tactical and Pre-Tactical Air- and Landside Assistance Systems

This goal will be examined in two steps:

1: Benefit of Coordinated Airside Planning

In a first step, the impact of Coordinated Airside Planning on selected KPIs will be measured with real-time simulations. It is hypothesized that due to more extensive and prompt information exchange between the assistance tools the coupling of assistance systems leads to more efficient processes compared to a baseline with only one-way information transfer. At this stage, no optimization of landside processes is taken into account.

2: Benefit of Collaborative Airport Planning (Integration of PaxMan & APM)

In a second step, the added value of coupling tactical and pre-tactical air- and landside assistance systems on selected KPIs will be assessed with real-time simulations. The gathered data of step one can be used as a baseline for step two. It is hypothesized that fully coupling air- and landside assistance tools with an Airport Performance Management system has a positive effect on selected KPIs compared to step one.

3.2.1.1 Detailed description

The definitions and utilizations of the time horizons referred to in the following subchapter are explained in detail in chapter 5.1 of the TAMS OCD [28].

3.2.1.1.1 Tactical assistance systems

Tactical assistance tools are the so-called “XMAN”, where “MAN” refers to Manager, and the X refers to the different Airport Processes, that are managed and optimized. An overview of flight phases and the according (tactical) assistance tools as realized within the TAMS industrial system is given in Figure 1.

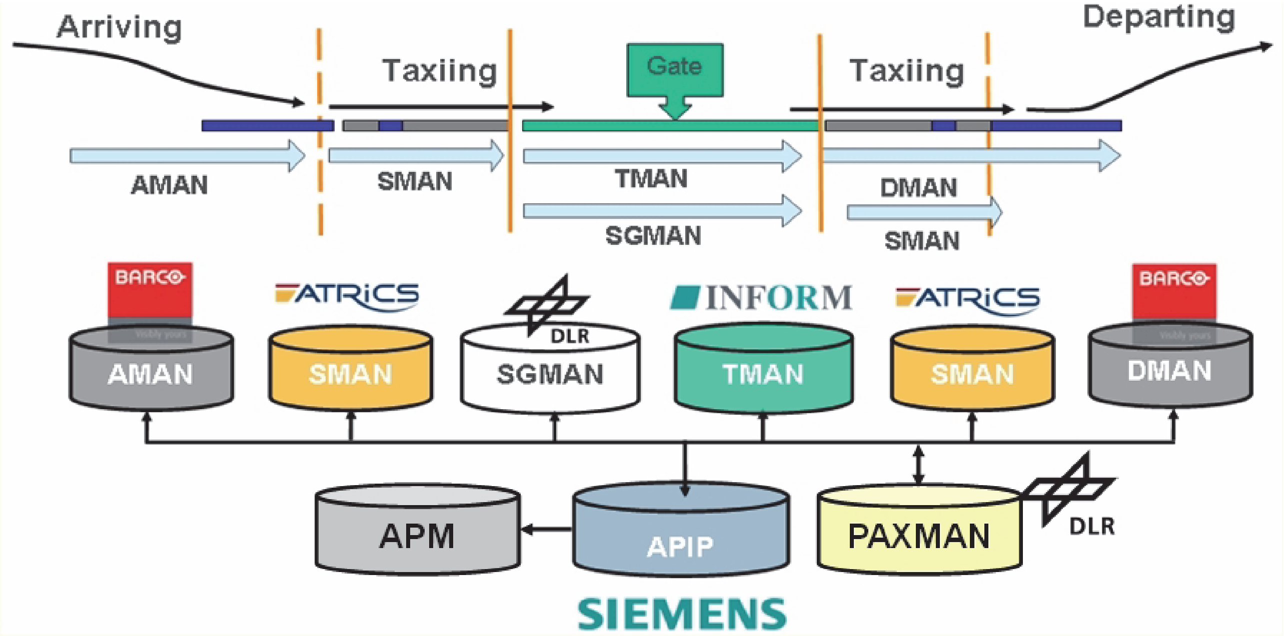

Figure 1: TAMS chain of tactical assistance tools [24] (PaxMan and APM added for completion)

Following, a condensed and high level overview of functionality and purpose of the management system within the TAMS industrial system is given in Table 3. Through the last two categories, it is differentiated between tools solely providing functionalities of data interchange and the simulation of airport processes, and the functionality of planning and optimizing processes, e.g., through calculating an optimized sequence. All information provided here refers to [24]. Although these tools are called “tactical”, the considered time horizon of them is not limited to the tactical phase. In fact, most of the “tactical” tools begin forecasting in the pre-tactical time phase.

Table 3: Overview of functionality and purpose of the tactical and resource management tools used within TAMS (see Chapter 5 in [28])

Tactical assistance tool	**Full Name**	**Functionality (not intended to be exhaustive)**	**Purpose in TAMS system***
AMAN	Arrival Manager	„The calculated ETO/ELDT in turn result in an optimized flight sequence proposal of the AMAN“ ([6] p. 26) Advisories regarding Holding, Vectoring, Speed etc.	Optimization
SMAN	Surface Manager	Calculation of Variable Taxi Times (VTTC), planning of surface	Support (Information Flow, Improve Information Precision)

		trajectory, pre departure-sequencing and A-SMGCS Functionality	
SGMAN	Stand-Gate-Allocation Manager	Detection and resolution of stand/gate conflicts “calculation of conflict free parking positions considering the type of aircraft, standard turnaround times, stability of position in case of a new planning, and other constraints” ([17] p. 25) calculation of usage rates of certain position areas ([17] p. 25)	Planning/ Optimization
TMAN	Turn-Around Manager	Real time overview of turn-around process; integration of data of other XMAN in a complete joint critical path calculation of all land- and airside processes having any impact on the TOBT prediction and monitoring	Planning, Optimization and Support (Information Flow, Improve Information Precision)
DMAN	Departure Manager	Planning / optimization of departure sequence (Off-Block and take-off times)	Planning Optimization
AMS (FP & RMS)	Airport Management System (Flight Planning & Resource Management System)	AMS shall provide GUIs which present the AOP to users. On the event level AMS shall provide an overview of all flight states and times. AMS shall support the APOC on two levels: APOC video wall display and APOC workplaces.	Support
PaxMan	Passenger Manager	Supports the TMAN with actual and forecast information Planning / optimization of terminal resources Real time overview of terminal processes	Planning, Optimization and Support (Information Flow, Improve Information Precision)

* The differentiation between Optimization/ Planning and Support follows the theory of “Levels of Automation” [22]: “Support” provides more and better information (typically time stamps), that are used by other tactical tools. “Planning” has an influence on the use of airport resources and actively changes the use of resources. “Optimization” uses a strategy/ goal for decisions regarding the use of airport resources.

3.2.1.1.2 Prediction tools for the pre-tactical phase

Within the project TAMS, the actual “state-of-the-art” assistance via tactical systems (XMAN) is extended regarding the planning horizon by means of prediction tools and / or functionalities for the pre-tactical phase. Although the pre-tactical tools are called “pre-tactical”, the considered time horizon of them is not limited to the pre-tactical phase. In fact, the APM begins in the pre-tactical time phase but extends its operation into the tactical phase and afterwards into the post flight analysis.

In the following, an overview of the integrated pre-tactical assistance tool is given (Table 4). For a detailed description of functionalities and purpose of the pre-tactical assistance system within the TAMS system, see [28].

Table 4: Overview over prediction tools for the pre-tactical phase

Pre-tactical assistance tool	Full Name	Functionality (not intended to be exhaustive)	Purpose in TAMS system
APM	Airport Performance Management	Prediction of Timestamps for process times within pre-tactical horizon, prediction of KPIs, e.g. for capacity and demand within pre-tactical horizon Strategy capability: activation and monitoring of "strategies" = sets of time-dependent control parameters, within what-if analysis and "real world" process control.	Prediction

3.2.1.1.3 State-of-the-art at international airports

Nowadays, it is common state-of-the-art that stakeholders at (international) airports use tools that provide accumulated information integrated into an graphical overview of airport processes to support management processes. At few large airports (in Germany), assistance tools with integrated decision support functionality, like AMAN and DMAN, TMAN or SGMAN, are used.

3.2.1.1.4 System configurations and definition of baseline

Following the *validation goal described above,* the benefit of coupling tactical with pre-tactical air- and landside assistance tools has to be demonstrated. As an intermediate *validation goal,* the benefit of Coordinated Airside Planning has to be evaluated. To generate a fair baseline for state-of-the-art airport processes, coupling of some assistance tools has to be configurable. This is necessary as, in reality, there are uncoordinated processes and delayed information flows (or ad-hoc information flows) that do not allow for optimizing or pre-planning but only for re-action of each stakeholder. The decision for switching off has to be based on real circumstances at the Generic International Airport (GIA) in case the simulation baseline should be compared to a real airport. For a technical realization, data flow in the technical system should be configurable to represent different qualities of information flow and coordination (see Figure 2).

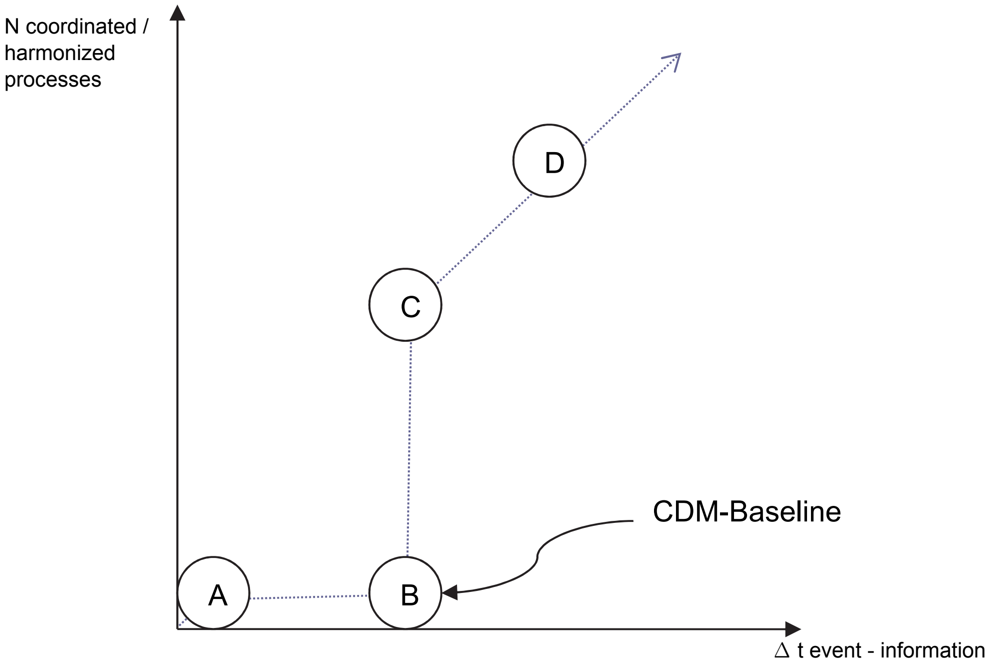

Figure 2: Schematic classification of the four system configurations “A”, “B”, “C” and “D”

On a technical level, this means that for the interfaces of the XMAN, filters should be developed that adapt the data flow according to the configurations given in Table 5 and Table 6. A detailed description for a technical realization of the system configurations “A” and “B” is also given in [29]. The necessary XMAN filters should be implemented in each tool. A detailed description for a technical realization of system configuration “C” is not given in Table 6 because system configuration “C” equals to the TAMS Iteration 3 system used without APM. This system configuration is described in the System Requirement Description document (SYRD, [17]). The TAMS Iteration 4 (SYRD, [18]) system equates to the Iteration 3 system with the additional PaxMan prototype and its advanced features (forecast and dynamic resource management) and with a technically integrated APM. System configuration “D” is the TAMS Iteration 3 system, this time including PaxMan with its advanced features.

Table 5: General description of system configurations planned to use for the TAMS validation

	System configuration	Functional description
”A“	Baseline (“ad-hoc” information flow)	Information is submitted in the information chain when a process has ended for the “stakeholder” responsible for the process before.
“B”	A-CDM Baseline	Represents A-CDM implementation (SWIM: real time process data sharing; but no collaborative planning)
“C”	Coordinated Airside Planning	Tactical coupling between all tactical tools, optimization between tools (equates to TAMS Iteration 3 system, without APM and PaxMan)
“D”	Collaborative Airport Planning (Integration of PaxMan)	Complete tactical coupling between tools, including PaxMan but without APM

Table 6: Technical solution for system configurations “A” and “B”

	System configuration “A”	**System configuration “B”**
Simulation	ATC data from IFPL, FUM is used to send an ELDT update 30 minutes before landing	ATC data IFPL and FUM are sent normally. ELDT update 30 minutes before landing (see configuration “A”).
AMAN	ATC data from IFPL, AMAN performs normal sequencing and acts as a pseudo air traffic controller. Filter: no estimates	As described for system configuration “A”.
DMAN	Not used	Sequencing based on TOBT, DMAN needs information from AMAN regarding free times on runway (ELDTs from AMAN). Output is TTOT (only internal usage in DMAN). DMAN gives startup approval (TSAT) matched to sequence (VTTC). Filter: no TTOT
SMAN	SMAN acts as a pseudo air traffic controller and guides aircrafts to the parking position respectively runway. SMAN gives every approval for departures (startup, take-off). Startup is granted with ARDT, Taxi-clearance takes place after startup/pushback. Aircrafts are allowed to take-off as soon as their slot is attained. An aircraft which is too early at holding position delays traffic. If	SMAN calculates EIBT from VTTC-table and A(E)LDT, which can be used by TMAN. SMAN gives startup approval to the DMAN calculated TSAT.

	necessary, SMAN is allowed to delay startup, if the aircraft is considerably too early at holding position. If an aircraft misses its slot, it starts nonetheless. It is pretended, the aircraft has a new slot. Slot violations are recorded and can be analysed Filter: no EIBT, no VTTC	
TMAN	TMAN determines EIBT from SIBT until ELDT update (see above), subsequently ELDT plus fixed standard-taxitime is used until landing. TMAN gets boarding information from the passenger simulation and status information from the turnaround simulation. TMAN ensures that a defined departure is possible even with incomplete boarding. [1] Filter: no TOBT	TMAN uses EIBT from SMAN. In addition to status information, TMAN gets predictions from TAMODES and determines TOBT. TOBT is forwarded to the Integration Platform.

3.2.1.2 Acceptance Criteria and Performance Requirements

The TAMS concept claims the improvement of airport performance through pre-tactical planning of processes and the integration of landside processes. Therefore, within the exercise the influence of including a pre-tactical planning functionality into airport management on airport performance is investigated.

An alternative solution to coupling pre-tactical and tactical air- and landside assistance systems is the coupling of airside assistance systems to realize “Coordinated Airside Planning”. To evaluate the benefit of this “small” solution, the added value of “Coordinated Airside Planning” has to be measured first. The hypothesis “the performance of configuration ‘C’ has to be better than the performance of configuration ‘A’ and ‘B’“ has been stated. But more importantly, it is expected that the performance of configuration “D” has to be better than the performances of configurations “C”, “B”, and “A”.

To fulfil the objectives, a quantifiable benefit for **at least** one key performance indicator has to be demonstrated. Performance goals that were identified are (a) the potential to reduce emissions, (b) the potential to reduce waiting times for passengers, (c) the potential to reduce additional buffer times, and (d) the potential to increase punctuality. The emission goal and the reduction of buffer times and passenger waiting times are derived through post data analysis of key performance indicators concerning the punctuality of flights. For data acquisition within the validation campaign, indicators listed within the OCD [28] will be used. A selection of relevant KPIs is listed in Chapter 3.2.1.4 and Table 7.

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[1] Airline agent: Boarding cut-off takes place when at least one of the following rules becomes true:

- All passengers are on-board
- Scheduled boarding time is over, more than 90% are on-board, and nobody boarded within the last two minutes
- Simulation time exceeds the 15 min after scheduled boarding time cut-off threshold

Furthermore:

- Planned boarding time is over and there are no information on passengers (e.g., if TOMICS is inactive)

3.2.1.3 Validation Requirements

For the validation campaign, only the technical set-up of the TAMS industrial system was used. For a description of that system refer to the TAMS SYRD [18] and the TAMS OCD ([28]). The exercise was planned to consist of two steps using different system integration configurations.

The first part of the exercise was planned to be conducted with the industrial system having integrated the airside tactical assistance tools. With this set-up, a baseline was created as well as a reference for "Coordinated Airside Planning". Therefore, this step should include the three system configurations "A", "B", and "C". As soon as these three system configurations would have been verified, they would have been validated in conjunction. A verified system configuration "C" is a prerequisite for the verification of system configuration "A" and "B". Apart from filtering data flows as described in Table 6, system configuration "C" shall not be modified to guarantee comparability between system configurations "A", "B" and "C". The second step of the exercise should be conducted with PaxMan integrated additionally (configuration "D"). The data gathered here should then be compared to the baseline configurations created before.

For the purpose of this objective, no human operators are required in the process, as it can be guaranteed that the provided XMAN are verified regarding their information processing and evaluated regarding their operational feasibility, which means they produce meaningful results. In this case, the XMAN with their automatic decision making modules replace human operators at a real airport. Their output should, regardless of the before necessary verification, be evaluated. Data acquisition shall be conducted in real-time. The traffic scenario (named scenario 1) used for simulation is derived from a real flight plan with arrival and departure peak situations with a slight overload regarding airport capacity. This flight plan is modified to generate five different scenarios. Therefore, ten flights during peak times will be changed randomly. This is necessary to create variance in the resulting data, which is important for later statistical analyses. Additionally, a landside bottleneck based on the following assumptions will be implemented in all scenarios: The resource plan for the landside process stations (e.g. Check-In, Security Channels) is tuned to cover the demands due to the passenger load of the scheduled flight plan. The bottleneck is then caused by an unforeseen tightening of security check requirements due to authorities' reaction on an actual security incident. This leads to an increased average process time for security checks at all security lanes by 20%. Therefore, initial resource planning is no more sufficient and passengers are delayed. This bottleneck will be present over all scenarios and for the 4h+ simulation time. The so generated five flight plans are the same for each system configuration. The correlating traffic scenario shall be evaluated in advance that it has a potential for optimization; this means that the demand is high enough so that there is an initial need to optimize processes.

A passenger simulation ("TOMICS", DLR internal development) is used in every traffic scenario and for each system configuration. The passenger simulations will be generated in a way that they are in accordance with the flight plans.

3.2.1.4 Indicators and Metrics

ICAO defines benefit as "reduced cost to the user (to the ATM community as a whole) in the form of a saving in time and/or fuel; increased revenue; and/or an improvement to safety" [26]: Within the scope of TAMS, benefit can be measured through measuring "saving of time" as compared to a baseline. Saving of time has

to be broken down as relevant savings for every future stakeholder using the TAMS system. The overall benefit, following the philosophy of TAMS, should be visible on an index of different KPI.
As KPA of particular interest for TAMS the KPA-Group “Operational Performance” was identified, including the KPA Capacity & Delay, Cost Effectiveness, Efficiency, Flexibility and Predictability & Punctuality. Since not all KPA groups can be measured within this project, for the validation campaigns, these three KPAs were selected: Traffic Volume & Demand, Capacity and Punctuality (the full list of KPAs and KPIs is listed in [28], p.48, the selected set can be seen in Table 7).

Table 7: Selected KPAs and KPIs (selection from table 4-2 of [28], page 48)

KPA	*KPI*	*Metric*	*Source*
Traffic Volume & Demand	Handled Traffic	Number of flights arrived and departed to and from an airport in a given time period.	ATMAP
	Handled Pax	Number of arriving and departing passengers processed in a given time period	Defined for TAMS
Capacity	Airport Declared Capacity[a]	Average number of airport slots per hour	ATMAP
	Slot compliance	Number of TOBT not compliant with CTOT Number of flights departing outside assigned CTOT Number of flights departing outside airport slot Aggregated Comparison CTOT to ATOT for regulated flights (-5min/+10min)	A-CDM Manual
	Terminal Capacity[a]	Average number of available process stations in a given time	Defined for TAMS
Punctuality	Arrival Punctuality	Comparison AIBT to SIBT, Percentage of flights arriving no more than 15 minutes (alternatively 3 mins) late compared to scheduled arrival times	A-CDM Manual, ATMAP
	Departure Punctuality	Comparison AOBT to SOBT Percentage of flights departing no more than 15 minutes (alternatively 3 mins) late compared to scheduled departure times	A-CDM Manual, ATMAP
	Early arrivals	Percentage of flights arriving 15 minutes or more ahead of schedule	ATMAP
	Departure delay causes[a]	Percentage of contributory cause to departure delays (based on airline reported IATA delay codes)	ATMAP
	Waiting time at runway	Aggregated Comparison ATOT to [AOBT+Taxi time]	Defined for TAMS

KPA	KPI	Metric	Source
	Boarding Punctuality[b]	Aggregated Comparison of ASBT to ESBT for different times of measurement	Defined for TAMS
	Transfer Connectivity	Percentage of missed connections (transfer passengers) in a given time	Defined for TAMS

[a] The KPI "Airport Declared Capacity", "Departure delay causes" and "Terminal Capacity" will not be analyzed in the TAMS validation campaign.

[b] To express the boarding punctuality as a single number quantifying the service quality with regards to the passengers, the aggregated difference between ASBT and SSBT will be used in the validation campaign since the punctualities are always comparing schedules against actuals.

Further performance indicators such as "Departure Taxi Time", "Engine Running Time", "Waiting Time at Runway" or "Ready Waiting Time" will be used and analysed. Additionally, further descriptive analyses regarding the experimental scenarios and performance indicators concerning the predictive capability and quality and the exchange of estimates and target time stamps within the TAMS system configuration "D" will be performed.

3.2.1.5 Methods

For data acquisition the technical set-up of the industrial system is used. For this purpose the above described XMAN are integrated according to the TAMS OCD [28] and TAMS SYRD [17] and real-time-simulations are conducted. In order to derive a fair baseline (state-of-the-art information flow and coordination), the data flows of the system might need to be adapted according to the experimental design. For the simulation of the system configurations "A", "B" and "C", the tool PaxMan with its advanced features is not integrated due to the late verification of the PaxMan in December 2011. For a description of the system configurations see also Table 5 and Table 6 and [29].

Due to difficulties in the verification process, no exact time frame for the first validation step as described in Chapter 3.2.1.3 has been determined yet. During two weeks, 15 unattended, automatic simulation runs (consisting of the five scenarios per system configuration described in Chapter 3.2.1.3) shall be performed (4.5 hours per run for a 4 hour scenario). If an error condition occurs, the run will be repeated. With this procedure for each system configuration "A", "B" and "C" data of five runs each will be available. System configuration "D" will be simulated in a second validation step in February 2012.

The result data sets of the experiments will be split over various log files and partially will be obtained from the central AODB as a database dump and exported into comma separated value format (csv) text files. Within these the flight events are documented, ranging from stand (re-)assignment to flight event time stamp sequences for all flights, allowing a repetition of what happened when to the flights, building the basis for data analysis for the validation. On GIA's landside, the recorded data sets will include all necessary information of the passenger processes and the passengers itself.

The simulation runs will additionally be recorded with screen video capture software. The videos can be used to support analysis in case of dubious system behaviour when the KPIs appear to be doubtful.

The resulting data files will be filtered and prepared for later statistical analyses with SPSS using Matlab by calculating KPIs for each simulation run. In a second step, statistical analyses will be performed with these pre-analysed and aggregated data.

3.2.1.6 Hypotheses

The validation hypotheses describe the expected KPI performance according to the given system configuration and system behavior. Breaking down the 2-step-approach described in the previous subchapters, the following hypotheses mirror this approach.

These hypotheses are

- H_0: $\text{IndexKPA}_A = \text{IndexKPA}_B = \text{IndexKPA}_C = \text{IndexKPA}_D$
  (no influence of different system configurations on selected KPIs or a KPA index, as described in chapter 3.2.1.4)
- H_1: $\text{IndexKPA}_B - \text{IndexKPA}_A > 0$
  (Benefit of providing information more in advance on selected KPIs or a KPA index, CDM Baseline)
- H_2: $\text{IndexKPA}_C - \text{IndexKPA}_B > 0$
  (Benefit of Coordinated Airside Planning on selected KPIs or a KPA index)
- H_3: $\text{IndexKPA}_D - \text{IndexKPA}_C > 0$
  (Benefit of coordinating all processes in the “chain” by coupling tactical and pre-tactical air- and landside systems on selected KPIs or a KPA index; Benefit of Collaborative Airport Planning with integration of PaxMan and APM)
- H_4: Traffic parameters (potential of optimization) have a different impact on selected KPIs or a KPA index, depending on factor level.

3.2.1.7 Experimental Design

Basically, there are two independent variables: timing of information (Δt event - information; how much in advance information is provided to the other assistance tools) and number of coordinated, optimized processes. The factor “timing of information” has two levels: ad-hoc vs. in-advance. The factor “number of coordination processes” has three levels: none – some – all. But it has to be noted that the factor “number of coordination processes” is not entirely independent from the factor “timing” (nested factors). Coordination (and planning of own processes) needs time, so information needs to be available in advance. Hence, these two factors will be combined in one factor, called “system configuration”, with four levels (“A”, “B”, “C”, “D”; see also Figure 2). In chapter 3.2.1.1.4, these system configurations are described in detail. These system configurations are therefore considered as the predictor (or independent variable).

Table 8: TAMS validation campaign experimental design

	TAMS validation campaign step 1 (validated as soon as A, B and C are verified)			TAMS validation campaign step 2 (02/ 2012)
Scenarios (Traffic kept stable)	Scenario 1 to 5	Scenario 1 to 5	Scenario 1 to 5	Scenario 1 to 5
System configuration (according to Table 5)	Baseline (“A“)	A-CDM (“B”)	Coordinated Airside Planning (“C”)	Collaborative Airport Planning (Integration of PaxMan) (“D”)
Information and Coordination Process	Ad-hoc, none	In-advance, none	In-advance, some	In-advance, all

In Table 8 the row “Information and Coordination Process” subsumes the different combinations of the two factors. The first part describes the timing of information and the second part the number of coordinated, optimized processes: “Ad-hoc, none” vs. “in-advance, none” vs. “in-advance, some” vs. “in-advance, all”. A detailed description of the technical solutions regarding the four system configurations can be found in Table 5, Table 6 and [29].

The criterion (dependent variable) is the benefit. Benefit is measured through different KPIs and as an index of the three KPA Traffic Volume & Demand, Capacity and Punctuality.

Therefore:

Predictor = “System configuration”

Criterion = Benefit (measured through different KPIs or a KPA index)

As outlined in the validation requirements (chapter 3.2.1.3), the traffic situation has an influence as there needs to be a potential for optimization. Thus, traffic is one factor but will be kept stable in this experiment. As described in the validation requirements chapter above, all five different scenarios have the same number of flights. The only change in the traffic situation results due to the different timing of flights in the scenarios. Overall a 5 x 4 experimental design will be conducted (see Table 8).

The influence of traffic/ scenario on the planning process should be examined in advance to verify the potential of optimization of scenario 1.

Prior to the validation campaign, a statistical a priori power analysis was performed to calculate the necessary sample size for a two-factorial (system configuration; scenario) repeated measures analysis of variance intended to use for later statistical analyses of the resulting validation data.

In this analysis, flights are treated as participants and the different system configurations are considered as “treatment”. The effect of the different “treatments” (“A”: Baseline, “B”: A-CDM, “C”: Coordinated Airside Planning) on the flights regarding different KPIs (e.g. Punctuality, Taxi Time) is analyzed. Power analyses are a necessity in statistical research studies to unambiguously interpret results of statistical analyses such as analysis of variance ([31], [33]). To perform an a priori power analysis, the Type I error probability (α), the Type II error probability (β) and the size of the effect, that is to be detected, has to be specified. Typically, the α-level is set to .05 and the β-level is set to .20 (resulting in a desired power-level 1-β of .80, which is a probability of 80% to detect an effect if the effect exists in the population). The chosen effect size was ε=.20, which is considered a small to medium effect. With these parameters specified, it is possible to calculate an optimal sample size of flights. Given the three different system configurations “A”, “B” and “C” considered for the first step of the two step approach, at least 26 flights (arrival and departure respectively) in five different scenarios are necessary. This is considered the minimum requirement for the experimental design of the first step. Because of the uncertainty concerning the passing of the required verification of system configuration “D” for the second step of the validation campaign, system configuration “D” was not part of the sample size calculation described above.

3.2.1.8 Validation Scenarios

The validation scenario needs to have a challenging traffic (demand peaks, etc.) so that there is potential for optimization that can be measured through the index of KPA. The potential for optimization is described in an example: When the demand is only one flight per 30 minutes the flights will be punctual regarding the airport processes because there is no shortfall of airport resources (if the flight is not delayed because of the departure airport). A coupling of air- and landside tactical systems and a pre-tactical planning will have no meaningful influence on KPIs because the traffic is optimal. The initial traffic set-up should be suboptimal, e.g., 20 scheduled departures for 08:00 o’clock am. Therefore, a real flight plan will be used as a basis.

This applies also for the passenger simulation where the PaxMan will have no optimization potential if the passenger flow is modelled without overload situations. For this purpose, a landside bottleneck, as described in Chapter 3.2.1.3, will be implemented.

The traffic scenario is derived through an operational flight plan from a real airport. An initial flight plan is derived from GIA. This flight plan is used for a simulation with the technical system in system configuration “A”. The XMAN will change/adapt the planned time stamps and generate actuals. In case the actuals seem to be meaningful, this simulation run provides the baseline.

For generating the data, a time frame of four hours will be used. If using real-time simulations, 4.5 hours are required for one simulation including half an hour forerun.

3.2.2 Data Analyses

For analyzing the data, first KPIs for each scenario will be calculated (relevant KPIs: see Table 7), regarding the whole day of operation/ simulation as well as for time intervals. In the following, some possibilities for evaluating the impact of the system configurations on airport operations are listed:

- Single KPI for time intervals;
- Comparison of KPAIndex for whole time frame (e.g. 4 h) vs. intervals of 30 min or 1h
- Comparison of selected sample flights: with pre-tactical planning vs. without pre-tactical planning
- Comparison of raw-timestamps (EOBT, AOBT) instead of aggregated KPI

As described in chapter 3.2.1.5 both, airside data will be (pre-)analysed by utilisation of various DLR tools and specifically designed software and landside data will be (pre-)analysed by means of a specialised tool. In a second step, statistical analyses with COTS statistics software will performed with these pre-analysed and aggregated data.

3.3 Summary

3.3.1 Overview

Table 9: TAMS validation goals

Validation Goal	Sub Goal	High Level Val. Obj.	Low Level Va. Obj.	Metrics	Methods	System Requirements
1. Quantification of the added-value of the coupling of tactical and pretactical air- and landside assistance systems with regard to selected key performance indicators	Quantification of the impact of Coordinated Airside Planning on key performance indicators Quantification of impact of Collaborative Airport Planning with integration of PaxMan & APM Evaluation of the impact	Performance	Predictability Capacity Efficiency (Flexibility)	KPAIndex	Real-time simulation (or 2 times faster than real time if possible) (without human influence)	Coupling of assistance tools implemented, stable and verified regarding data streams Internal validation of single assistance tools
2. Quantification of the relevance and the timeliness of the information displayed on the videowall and on the APOC agents' working positions (e.g. ATWP), which is expected to foster a high level of situation awareness		*Information Services*	*Situation Awareness* *Team Situation Awareness*	*Situation Awareness Score*	*Qualitative Feedback of Stakeholders (Relevance, Timeliness)* *Process Analysis*	*Videowall and Agents WP implemented*
3. Quantification of the benefit, which what-if probing has on decision making	*Better Quality on individual level* *Overall better quality of collaboratively agreed on decision*	*Quality of Collaborative Decision Making*	*Efficiency of Decision* *Effectiveness of Decision*	*Quality of Decision Index*	*Qualitative Feedback of Stakeholders* *Length of decision* *Predicted impact on airport KPI*	*Prior validation of goal 1 and 2*

Validation goals 2 and 3 will not be considered during the TAMS validation campaign due to the project's time constraints, see chapter 3.2 for further information.

3.3.2 Aggregated Time Plan (May 2011)

Until August 2011:

Realize configurability of information flow within system.

August – September 2011:

Verification of the complete system set-up; Verification of system configurations (“A”, “B”, & “C”).

Due to unplanned difficulties, the verification of system configuration “C” is delayed. A verified system configuration “C” is a prerequisite for the verification of system configuration “A” and “B”. Up to now, the date for the first step of the TAMS validation campaign is unknown. As soon as all three system configurations are verified, they will be validated. As soon as system configuration “D” is verified, it will also be validated.

17.02.2012: End of TAMS validation campaign

3.3.2.1 Time Plan Revision (May 2012)

As of May 2012 the above time plan was not entirely successful in its implementation. The information flow within the system was realized as planned, but the development and especially the verification of the system components took until April 2012.

The validation experiments took until late May 2012.

3.3.3 Aggregated System Requirements

3.3.3.1 General System & Data Logging

In general for all validation goals it ideally should be possible to start and end the whole system automatically by pressing one button. Within this automatic start procedure it should be possible to start the different assistance systems with different configurations.

The whole data logging has to be physically located at DLR in order to hold restrictions regarding data safety. Raw data from the validation campaign is not distributed. Data and log files from AODB, NARSIM, PaxMan Database and TOMICS should be stored for each simulation run in a separate folder that is named unambiguously. Data files should be named accordingly: all data files from one simulation run should be named same, distinction between sources is enabled through different filename-endings; e.g. <Team>_<Run>_<Agent>_<Condition>.<method>, e.g. “eye”, “aman”, “sim”, “flights”. Data logging should be synchronized between all systems; means use one global simulation time.

3.3.3.2 System Requirements Validation Goal 1

The whole system has to be evaluated against the possibility to conduct 2*faster-than-real-time simulations. If 2*faster-than-real-time simulations will not be feasible, real-time simulations will be conducted.

For each system within the TAMS network a script to start and end the system automatically is requested. Furthermore a log file is needed to verify proper system behaviour. After each run one file should be generated that contains all flights within that scenario with according operational data, especially actual times and estimates.

3.3.3.3 System Requirements Validation Goal 2

This information is omitted from this document because validation goal 2 will no longer be part of the TAMS validation campaign (see chapter 3.2). For a detailed description of system requirements for validation goal 2 see former versions of this validation concept document [30], chapter 3.2.3.

3.3.3.4 System Requirements Validation Goal 3

This information is omitted from this document because validation goal 3 will no longer be part of the TAMS validation campaign (see chapter 3.2). For a detailed description of system requirements for validation goal 3 see former versions of this validation concept document [30], chapter 3.2.4.

3.3.4 Aggregated Roles and Responsibilities

The availability (local, per telephone) of contact persons from every partner during the pre-tests and the validation campaign has to be guaranteed in order to timely help in case of problems with the technical system.

3.3.5 Aggregated Risks (May 2011)

- Time pressure regarding definition of core functionalities (e.g. coupling pre-tactical & tactical systems)
- Time pressure for system integration in time:
- Unknown difficulties,
- Work-arounds
- Additional “configuration” of information flow to generate experimental conditions of the system → time & resources available
- Timely verification of system
- System stability

- Fast-time simulation is not stable
- Data can not be gathered in an automated way

3.3.5.1 Aggregated Risks Revised (May 2012)

Several anticipated risks have occurred and their impact has been described in chapter 3.2. Consequently, only parts of the validation goal 1 have been researched by the campaign and the goals 2 and 3 have been skipped entirely.

4 Appendix

List of Abbreviations

A-CDM	Airport Collaborative Decision Making
AMAN	Arrival Manager
AOP	Airport Operations Plan
APIP	Airport Process Integration Platform
APM	Airport Performance Monitor
APOC	Airport Operations Centre
ATC	Air Traffic Control
ATFCM	Air Traffic Flow and Capacity Management
DMAN	Departure Manager
DLR	Deutsches Zentrum für Luft- und Raumfahrt
EMMA2	European Airport Movement Management, Part 2
E-OCVM	European Operational Concept Validation Methodology
GIA	Generical International Airport
KPA	Key Performance Area
OC	Operational Centre
SMAN	Surface Manager
TAM	Total Airport Management
TMAN	Turn-Around Manager
TAMS	Total Airport Management Suite

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