Best practices for the implementation of Extended AMAN

Supporting Material to SDP Implementation

Control sheet

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1 Introduction

1.1 Background

The SESAR Deployment Manager is established in Reg. (EU) n. 409/2013 with the purpose to, inter alia, develop and maintain the SESAR Deployment Programme. According to Section 2 Article 11 of said regulation, the Deployment Programme shall provide a comprehensive and structured work plan of all activities necessary to implement technologies, procedures and best practices required to implement common projects.

The SDP Supporting Material complements the SESAR Deployment Programme aiming at increasing the clarity of the SDP itself, as well as providing guidance for the implementation of the functionalities defined in Regulation (EU) n. 2021/116, better known as CP1 regulation.

One the ATM functionalities defined in Regulation (EU) n. 2021/116 is AF1 Extended Arrival Management and Integrated Arrival Management/Departure Management in the High-Density Terminal Manoeuvring Areas and its sub-functionality 1.1.1: Arrival Management extended to en-route airspace. This sub-functionality prescribes the implementation of Extended AMAN in the defined geographical scope, where the AMAN horizon is extended to at least 180 nautical miles from the arrival airport.

1.2 Scope of the document

This document is part of the SDP Supporting Material for the implementation of CP1 sub-functionality 1.1.1 Arrival Management extended to en-route airspace. It provides best practices based on feedback from research and early implementations. Some of these best practices integrate concepts, developments and procedures that go beyond the scope of CP1 regulation, but they are included in this document to guide stakeholders when considering their implementation. The document focuses on the extension of the AMAN horizon, and not on classical AMAN implementation topics, even if certain aspects like the management of in-horizon and pop-up flights are mentioned, as they become more relevant with an extended AMAN horizon.

It must be noted that these best practices are very dependent on the geographical environment and the operational context. Not all practices fit all the cases of extended arrival implementation. However, some indications are provided on which practice might better fit which case.

All along the document, the term "eligible airport" refers to the airports mandated by the CP1 regulation to implement extended AMAN functionality.

2 Considerations for extended AMAN implementation

This section summarizes the different aspects that need to be considered for the implementation of extended AMAN.

2.1 The vision from the different stakeholders

The implementation of the extended AMAN requires a stable arrival planning adhered to by all stakeholders in the chain, from en-route to TMA airspace down onto the runway threshold, including the airspace users. This consistent shared plan challenges different visions, objectives and interests which might seem conflicting, but which need to be all accommodated. The implementation of extended AMAN will imply a trade-off between different objectives in order to achieve a common goal for the network.

All actors in the chain, Network Manager, en-route sectors, extended TMA sectors, TMA sectors, and aerodrome work on the basis of the same arrival plan for each specific eligible airport, and this plan needs to be feasible for all actors, and namely for the airspace user. This requires the availability of an efficient and uniform cross border coordination.

This section provides the visions, objectives and high-level principles of the different concerned stakeholders. It aims allowing a common understanding on the different concerns, necessary to address challenges and to find the most appropriate trade-off for the extended AMAN implementation.

2.1.1 The vision from the extended AMAN airport

From the eligible airport, the objective is to push delays out of the TMA into the extended TMA and en-route sectors, thus creating a more efficient overall operation with planned arrival trajectories and a minimum of holding. The main driver is clearly to avoid congestion.

Ideally an accurate estimate of the landing time must be available to the AMAN system in the final stage of the cruise phase, in essence at about 15 minutes before the top of descent. The availability of accurate landing time estimates 15 minutes before top-of-descent is the first Extended AMAN requirement, from the eligible airport viewpoint, to achieve the extended AMAN vision.

The second principle that needs to be met to achieve the extended AMAN vision is that the planning horizon must, ideally, be uniform. This means that planning data of all arriving traffic must be available at the same time regardless of the arrival direction. But at the same time, different constraints such as sector boundaries and different local methods of operation need to be considered.

And the third principle that needs to be met to achieve the extended AMAN vision is that the planning information needs to have a uniform quality. Despite the availability of certain enablers as air-ground data link, ADS-B and ADS-C, it must be assumed that the extended AMAN implementation will have to deal with mixed equipage levels on the airborne side, in particular when it comes to capabilities of flight management systems. Therefore, to achieve uniform planning data quality, it is assumed that trajectory prediction depends mostly on ground-based systems.

2.1.2 The vision from the en-route in-horizon ATSUs

From the en-route view the extended AMAN vision centres around optimisation of traffic management towards the major airports. The primary enabler for optimized aircraft descents towards the major airports is the availability of arrival management information from these major airports. The goal from the en-route viewpoint is to prevent, as much as possible, delay absorption in lower airspace, without impacting too much on the en-route sector capacity. As aircraft have limited flight envelopes during the cruise phase, en-route sectors must be able to anticipate delays in lower airspace sectors in an early stage. Early anticipation of delays is necessary to meter aircraft for an undisturbed descent towards the airport. To summarize, the extended AMAN vision lays on five main principles described hereafter.

The First Principle: Stable and Reliable Planning Information.

The first principle that needs to be met in order to achieve the extended AMAN vision is the availability of stable arrival management information from the eligible airports in an early stage of the flight. Airports must have sufficiently stable runway planning within the extended horizon before the estimated landing to benefit from extended pre-sequencing. This requires accurate information, especially for the traffic departing from inside this planning horizon. Extended AMAN may receive accurate departure information via A-CDM and Network Manager systems (ETFMS data) for all departing traffic from inside this planning horizon. Currently, the easiest way of getting this information is using ETFMS data from Network Manager, enriched with DPI information, even if other ways are also possible, namely when the ATSU in charge for departing traffic in the planning horizon and the ATSU responsible for the extended AMAN airport operations share the same FDP system. However, in some geographical environments, this is not sufficient to ensure a stable and reliable arrival sequence.

The Second Principle: Consistency with the network operations.

The second principle, linked to the first one, is the availability of Network Manager Operations data to support the extended AMAN concept. As delay absorption capabilities in the en-route phase of flight is limited, it is essential to detect imminent airport delay as early as possible For a more effective en-route delay absorption capability, in some environments with a 40-to-50-minute maximum planning horizon in the major airports, the network management trajectory predictions of all airborne aircraft in the ECAC airspace might be used by the AMAN function to detect temporary demand excesses (traffic bunching) at the major airports. This information can be used to perform pre-sequencing tasks, in order to smooth traffic flows towards these airports.

The Third Principle: A Shared View and Responsibility for Delay Absorption across ATSU's.

The third principle is that all involved sectors (upstream and downstream) commit themselves to the arrival management plan for a particular airport of destination to create consistent operations and inform the others if the commitment cannot be met. En-route delay absorption should be part of this arrival plan and communicated automatically to the downstream unit(s) when there is a need for those units to be provided with operational feedback. Unfortunately, this requirement is currently not well supported by technical implementations, as explained in further sections.

The Fourth Principle: A consistent Modus Operandi in the ATC OPS room.

The fourth principle is that the arrival management information which is generated by the eligible airports should support a consistent method of operation. Whatever this method of operation, for the en-route controller the arrival management information should be converted into a single format and should be managed in a uniform manner, thus avoiding complexity and additional workload.

The Fifth Principle: Consider ATCO Capacity and Workload Impact.

Finally, and closely linked to the fourth principle, the fifth principle is that the impact of extended arrival management on the workload and capacity of involved sectors is to be considered in the tactical and planning phases of the ATFCM processes. Possible solutions to meet this principle are described in section 3.7.

2.1.3 The vision from the airspace users

The extended AMAN vision is expected to create major benefits for the airspace users, by increasing predictability of their planning, flying more efficient trajectories and thus reducing fuel consumption and emissions. However, the application of the concept requires ATC instructions not necessarily expected by the crew. In most of the cases, these instructions imply speed adjustments which might alter the aircraft preferred (optimum) trajectory for that flight. Until TBO is implemented, pilots and ATCOs will continue to work on two separate instances of flight trajectory with limited opportunity for synchronization. This limitation might be alleviated with the progressive implementation of advanced ADS-C features on the ground.

For the airspace user extended AMAN must follow a consistent concept of operations where measures to be implemented on the flight are coherent and not contradicting among the subsequent ATSUs along the route. Ideally, the measures should meet as close as possible the preferred airspace user trajectory, but, until TBO concept is implemented, , despite some EPP usage implementations currently existing, this will rely on a good communication between ATCO and pilot. Therefore, it is important that the crew understands the purpose of the measures instructed by the ATCO and that the ATCO understands the consequences that ATC instructions can trigger in the airborne side.

2.2 The operational context

The operational context will determine how the extended AMAN will be implemented, i.e. how far the extended horizon will go and what will be the most appropriate working methods and procedures to apply. The extended AMAN operations need to be consistent with, and well-integrated into, the existing operational landscape. Therefore, special attention needs to be paid to airspace characteristics and complexity, proximity and nature of other airports, traffic density and complexity, traffic flows patterns, existing procedures and operating methods, workload, capacity, constraints, and limitations.

2.3 The technical context

AMAN technical implementation must consider current technical capabilities, limitations and constraints but with a view to future implementations, both already planned and necessary for the evolution of the systems as a whole will have an impact into on the technical implementation of extended AMAN. The extended AMAN implementation needs to be considered in a consistent way within the global technical landscape. Local specificities may impact cross-border implementations, especially when different stakeholders are involved. It is suggested to perform an impact analysis with all involved stakeholders in order to achieve the most appropriate solution to accommodate each other's requirements.

2.4 The regulatory context

The implementation of extended AMAN is prescribed by regulation and needs to meet regulatory requirements. Therefore, the regulatory aspects must be carefully considered. It is essential to have a common understanding of the regulation between all involved stakeholders and namely with the regulatory bodies. A good practice consists of coordinating with the national regulator about the implementation as early as possible and agreeing on main principles such as scope, interpretation and applicability of the regulatory requirements, implementation dates and potential deviations or exemptions.

2.5 The organisational and financial context

The implementation of extended AMAN is often integrated in a global implementation roadmap where other functionalities are also considered. It is important to identify as early as possible the dependencies and potential synergies between the different implementations. The vision of a global roadmap and the need for optimizing investments might determine certain implementation choices. In addition, some aspects like the dependency on legacy systems at the end of their life cycle (e.g. AMAN, flight plan systems, OLDI message brokers, CWP HMIs) need to be carefully considered.

Eventually, the exchange of extended AMAN information by means of a SWIM arrival sequence service must be the target, even if some intermediate steps might have been implemented with legacy technology.

2.6 Other implementation aspects

Extended AMAN implementation often requires an important cross-border cooperation, and it is never done in one shot, but on step-by-step basis, depending on the availability of the concerned stakeholders. In some cases, the interests of different neighbours or the implementation choices might slightly diverge, and a closer coordination is required. Whenever several stakeholders are involved, it is useful to maintain a common agreed roadmap and to coordinate regularly.

As the extended AMAN implementation usually expands over the time, the transition aspects and the possible evolutions during the implementation period cannot be neglected. Initial assumptions might change during the deployment of the concept, e.g., traffic patterns or any other element of the operational context might change, technical capabilities might evolve, etc. Therefore, it is important to monitor the extended AMAN implementation over the time, even after completion, and to prepare for future adjustments or modifications if needed.

3 Best Practices

This section provides a collection of best practices and recommendations based on available analysis, research, and feedback from early implementers.

3.1 Implementation strategy

The implementation strategy adopted should consider all the aspects mentioned in the previous section. However, there are some aspects more determining than others, and some activities that need to take place before others. This section lists the main ones.

3.1.1 Define the limits of the extended AMAN horizon

The CP1 regulation mandates an AMAN horizon extension to a minimum of 180NM at 20 major European airports. But this does not need to be necessarily the exact value. Theoretically, the wider the horizon, the higher the probability of increasing the performance of the AMAN. In Europe there are some implementations of extended AMAN that go beyond 200NM and even 300NM. However, the wider the horizon, the higher the risk of uncertainty and instability of the sequence.

The selection of the right horizon is a trade-off between many factors: sequence stability, predictability, en-route capacity, runway throughput and operational efficiency. It is suggested to carefully consider all these factors and analyse different scenarios before choosing the right value. This selection is often not a one-shot exercise, but the outcome of an iterative process that involves the two activities listed hereafter.

3.1.2 Coordinate with relevant stakeholders

Once a first proposal of horizon is decided by the ATSU responsible for the implementation of extended AMAN on an eligible airport, it is important to identify the upstream ATSUs concerned by the extended horizon and start discussing with them about the details of the implementation, e.g. which traffic flows are concerned, who will be involved in the delay absorption, how much delay is expected to be absorbed under what operational conditions, etc. During those discussions, new elements will enrich the initial analysis and might lead to adjustments of the target horizon. This coordination will lead to the definition of the CONOPS, as explained in 3.2 below.

3.1.3 Coordinate with regulatory bodies

As soon as a clear implementation strategy has been established and agreed with the relevant stakeholders, it is suggested to inform the concerned regulatory bodies about the plans and to build with them a good cooperation in order to facilitate the implementation.

As the implementation of extended AMAN constitutes a change to the functional system, a safety assessment needs to be performed on the implementation and submitted for approval to the competent authority. In the case of cross-border operations, multiple competent authorities will likely be concerned. As the safety cases are usually performed early in the implementation process, it is a good practice to include in the safety assessment relevant information concerning the implementation plans and details as early as possible.

3.2 CONOPS Definition

For any implementation, and particularly if it implies cross-border operations, it is strongly recommended to build a common CONOPS as early as possible. The CONOPS should be the basis for the implementation and guide all further activities, including the technical implementation, and not the other way round.

A good CONOPS should contain the definition of the geographical context, the AMAN horizon and the description of the operational working method, as well as the rationale behind. It should also describe general rules to be applied by all concerned stakeholders, their roles and responsibilities, the type of information exchanged between the concerned stakeholders, the strategy for delay apportionment and detailed operational procedures for nominal and exceptional cases.

3.3 Working methods

Tactical instructions for safe traffic separation must always have priority over extended AMAN instructions. On the other hand, extended AMAN instructions imposing additional workload on the en-route ATCOs, their application will depend on the ability of the en-route sectors to cope with this additional workload without impairing sector capacities and/or inducing undue delays. The application of AMAN advisories being without prejudice to ATC core tasks of maintaining safe separation and sector capacities is sometimes referred to as the "best effort principle" and it constitutes a sound basis for extended AMAN working methods in all implementations. However, certain aspects listed hereafter need to be considered.

It is also important to decide on the type of extended AMAN information exchanged (e.g. total TTL/TTG, apportioned TTL/TTG, time over metering point or COP, etc.) between concerned stakeholders and the expected action thereon. In case of cross-border operations, it is an essential practice to reflect these decisions in the corresponding LoA. To be noted that, as per OLDI specification, the use of AMA message mandates the definition of the conditions in the LoA.

The working method also defines the interaction between different roles and the coordination means between them, as detailed in the sections hereafter. This coordination might involve one particular flight, a group of flights or a traffic flow.

3.3.1 Upstream coordination and information transmission

Different methods can be adopted, depending on the agreements between different parties.

3.3.1.1 Working method at ATSU responsible for Extended AMAN airport

In some implementations, the extended AMAN operations depend on the actions of an arrival manager role (sometimes played by an FMP operator or by a TMA coordinator), who manages the sequence and makes all necessary manual adjustments to optimize it. In certain cases, he/she might select or filter out from the sequence the flights for which delay must be absorbed by a specific upstream ATSU.

In other implementations, there is no specific human role responsible for the management of the sequence, instead any TMA ATCO can act thereon, and the transmission of the extended AMAN information is triggered automatically without any prior human filtering.

In some cases, the ATSU triggering extended AMAN operations might anticipate a period of congestion requiring actions on many flights and inform in advance upstream ATSUs, which may also inform in response on their ability to cope with additional delay absorption. In contemporary operations this information is commonly transmitted by phone, usually between FMPs or operational supervisors. A good support for such situations would be a cooperation tool like the XMAN Portal tested in the SESAR PJ25 trials.

3.3.1.2 Working method at upstream ATSU expected to absorb the delay

In some implementations, the extended AMAN information is provided directly to the ATCOs on the CWP. In such cases it can be provided either to all ATCOs in the ATSU, or to all ATCOs concerned by the flight or only to the ATCO responsible for a specific sector (e.g. the first sector or the last sector in the sequence, or the one identified in the CONOPS and related procedures for a particular traffic flow).

In other implementations, the extended AMAN information is provided to an intermediate role, usually played by FMP, by an operational supervisor or by a sector group coordinator, who analyses the applicability of the requested measure and, if appropriate, forwards the information to the appropriate ATCO for action. When this role is played by the FMP or by the operational supervisor, he/she can assess the sector workload, decide whether to forward or not the request to the concerned sector.

3.3.2 Downstream coordination and information transmission

Whereas the transmission of extended AMAN information is well defined in the CP1 implementation requirements, it is not the case for the operational acknowledgement of the Extended AMAN constraint, in other words whether a constraint has been actually applied or not. The fact that extended AMAN operations are based on "best effort" might lead to consider that is not necessary to inform downstream ATSUs about whether the extended AMAN plan has been met or not.

However, despite the lack of guidance to address this topic, there might be a need for downstream ATSUs to know if the delay has been absorbed upstream or if it will have to absorb it. And, in general, it is best practice to provide feedback on a request for better situation awareness, even if the application of the request is not mandatory. Currently, there is no standard way defined to transmit such information, even if the OLDI SDM message has been proposed as a workaround only valid for point-to-point information to the downstream ATSU unit.

When the downstream coordination concerns different ATSUs managed by the same ANSP and sharing the same system, internal means can be used to make aware the downstream ATSUs on the actual application of an extended AMAN constraint and share a monitoring view of the delay absorption between ATSUs, as it is the case in some European countries. It is the case, for example, with the 4Me tool, which is used in all French ACCs and allows visualizing the extended AMAN requests actually applied by each sector. (). In case of cross-border operations, other means are generally used, such as verification of Mode S IAS/Mach number at downstream ATSU against the expected value. However, such means are available too late, when the flight is already within the downstream ATSU radar coverage.

Sometimes, the upstream ATSU might be temporary unable to cope with extended AMAN requests from any airport, or on a specific traffic flow, for several reasons (e.g. adverse weather, capacity limitations, technical downgrade, etc.). In such cases, it is useful to inform the ATSUs responsible for extended AMAN eligible airports about their inability to perform extended AMAN operations. In such cases, this information is transmitted by phone, usually between FMPs or operational supervisors. A good support for such situations (including simultaneous coordination among multiple actors that requires the implementation of extended AMAN strategies) would be a cooperation tool like the XMAN Portal.

3.3.3 Information transmission to airspace users

Extended AMAN advisories are usually passed to pilots as ATC instructions and/or clearances on the frequency, via RT communication means. However, in order to reduce ATCO workload, it is a good practice to issue the instructions by CPDLC, as far as practicable. Pilots might be sometimes surprised or reluctant to receive unexpected instructions, especially speed instructions, and might challenge them. When transmitting the instructions by RT, it is important to provide a short explanation on the reason in case of questions from the crew, e.g., to avoid holding at destination airport. It is also important to consider pilots concerns and accommodate them. For that reason, it is a good practice that local units implementing extended AMAN operations communicate with the airlines to explain them the benefits.

3.3.4 Management of extended AMAN associated workload

Extended AMAN procedures influence sector workload through 2 main aspects:

1) Workload associated with acting upon extended AMAN advisories
   - reading and interpreting extended AMAN information
   - RT load
   - Exit Conditions set up (and changes to the plan already made)
   - Consequence on traffic (extended AMAN and non-extended AMAN)

This workload depends on the operational procedure selected and the available system support and automation. For instance, the instruction of fixed speed reduction generates less workload than the instruction of time over a COP. Certain automation means can reduce significantly the ATCOs workload, such as displaying to the ATCO the speed advisory instead of the TTL from which ATCO will deduce the speed reduction or enabling the instruction by CPDLC.

The workload associated to extended AMAN advisories can be monitored via a direct indicator providing, for each sector, the number of extended AMAN actions per unit of time or can also be integrated as an element of a global complexity indicator.

2) Occupancy load variation due to the effect of extended AMAN operation on the 4D trajectory
   - Potential bunching effect in some areas

This aspect can be monitored via classic entry counts and occupancy load graphs.

The implementation of an efficient Strategy Management taking the ATCO workload into account will increase the likelihood that ATCOs in en-route centres will apply extended AMAN advisories.

It is assumed that the workload associated with extended AMAN procedures is linked to the number of advisories, but not only. It can also be related to the traffic load and complexity and to the way the application of extended AMAN procedures impacts the global traffic picture.

In centres that are handling inbound flows to multiple airports applying extended AMAN procedures (i.e. mainly UACs) the cumulative effect may lead to capacity problems. Simulations performed as part of the FABEC-SESAR XMAN Simulation 696 showed that a sector becomes a hotspot as from 7 extended AMAN actions per 20 minutes. This value applied to the simulated environment but provides certain indication.

It is the responsibility of each ATSU to assess its workload and the effect of extended AMAN procedures on its sectors' occupancy. It is also left at the ATSUs' discretion to initiate a CDM process to optimize arrival management and flight profiles with acceptable consequences on workload.

Practically, this means that extended AMAN procedures are integrated in the flow manager's assessment process. The consideration of extended AMAN procedures in ATFCM is addressed in section 3.7.

3.4 Delay apportionment

The aim of the delay apportionment strategy is to define how the total delay on a specific flight is split into several parts to be sequentially achieved by different ATSUs involved. Delay apportionment is to be applied on a "per flight" basis, however some global flow application may be described in the Method of Operation. In particular, this kind of global flow action may be used in cases such as high delays with Expected Approach Time-EATs in force, runway closure, bad weather, etc. where Minimum Clean Speed would be requested for all inbound flights.

Different strategies can be chosen. Theoretically, the ideal situation would be splitting all delay between all concerned ATSUs, but this is not always possible. The more units are involved in the delay absorption, the higher the risk of inconsistent instructions against the delay absorption strategy: tactical instructions for safe traffic separation at one ATSU may contradict or jeopardize the extended AMAN instructions provided by another ATSU on the same flight. Other constraints to split delay absorption into multiple ATSUs is the insufficient accuracy of the trajectory and the limited means to inform the downstream units of the actual delay absorption, which makes extremely complex the necessary coordination between all concerned ATSUs to ensure the adherence to the common plan.

Due to these limitations, there is often a need to select which upstream ATSUs will share the delay absorption with the TMA of the extended AMAN airport, amongst the ones crossed by the flight. This decision should be driven by operational performance and based on the capability of the ATSUs to absorb delay for the flight in the most efficient way. This capability will depend on many factors:

- overflight time (the en-route linear absorption capability is estimated at a maximum of around 5 minutes per flight hour),
- associated workload,
- risk of induced conflicts,
- risk of creating bunching effects on one airport while applying extended AMAN advisories for another one,
- other considerations (consistency with the global operational concept, capacity constraints, etc).

Ideally, it would be possible to select a reference strategy and a set of alternative strategies for delay apportionment between ATSUs. The use of the alternative strategies would be coordinated through a CDM process between the different ATSUs involved. Generally, the strategies would be activated for a defined period of time (i.e. affecting a whole flow) but ultimately it would also be possible to coordinate cherry picking measures for individual flights. However, this approach is seldom used, as it requires a complex level of coordination between different actors, which is almost impossible to achieve without an adequate system support, like the XMAN Portal.

As a result, in general, the delay is shared between a maximum of 2 different partners exchanging data and information. In cases of very fragmented airspace, this is often translated into a delay apportionment between a maximum of 3 ATSUs per flight: the TMA of the eligible airport, the ACC/UAC feeding the TMA and one upstream ATSU in the extended horizon (in general, an ACC or an UAC). In other cases, the

ACC/UAC feeding the TMA of the eligible airport is big enough to include the AMAN extended horizon or most of it, and sufficient to absorb efficiently all the delay. This is the easiest situation, but it is seldom the case in the core area of Europe, where flights in the extended AMAN horizon often cross several ACCs/UACs managed by different ANSPs. In most of the cases, the delay absorption requires cross-border delay apportionment.

There are two types of philosophy for the selection of the delay apportionment strategy:

- If delay is mostly absorbed at the earliest (top-down strategy), the focus is to increase the probability that the delay will effectively be absorbed while minimising the fuel burn, but there is more uncertainty on what will happen downstream.
- If delay is mostly absorbed at the latest (bottom-up strategy), the focus is on optimising runway throughput and minimizing sequence error, but it also increases the risk of holding and that the resulting flight profile will be less than optimal.

There is no right or wrong strategy. The choice will depend on the operational environment and will be the result of a trade-off between predictability, efficiency, capacity, and runway throughput. In general, it's easier and more realistic fixing a maximum delay to be absorbed at the TMA and then absorb the remaining delay upstream, at the ATSU where it is more efficient and feasible to do it.

3.5 Management of traffic from in-horizon airports

The management of the traffic from in-horizon airports will depend on many factors, such as the contribution of the in-horizon airport to the eligible arriving airport, its proximity, the interdependency of the traffic flows, the technical capabilities, etc.

As far as practicable, it is important to integrate well the arriving traffic from in-horizon airports into the extended AMAN airport arrival sequence as early as possible. If the in-horizon airport is a CDM airport (A-CDM or AAT), and unless there are other direct means of obtaining the departure time information (e.g. if in-horizon airport shares the same FDP as the extended AMAN airport), it is recommended to use the ETFMS data enriched with DPI messages to estimate their airborne time and accommodate them in the sequence accordingly and/or to display it to the ATCO, as it is the case, for instance, in Zurich AMAN, where the airborne status of flights included in ETFMS data is indicated by means of a blue leader line in the AMAN timeline (see Figure 1).

Figure 1 Example of in-horizon airport flights display in Zurich AMAN provided by skyguide

However, in some cases, this information is not available or not sufficiently accurate. A departure will then present to the AMAN as a "pop-up flight" where accurate information on the flight is only obtained when already airborne.

There are different strategies to accommodate those flights in the arrival sequence, depending on the operational context and the technical means available. In some cases, pop-up flights are integrated automatically in the sequence, based on pre-defined rules. In other cases, phone coordination between the ATSU managing the departure airport and the downstream ATSUs and manual actions to integrate the pop-up flights in the sequence might be required.

In most of the cases, it is not efficient to apply extended AMAN measures on flights departing from in-horizon airports, unless they are applied on the ground. But delaying a flight while on the ground, even if it is the most fuel-efficient measure, is not always possible due to airport constraints. On the other hand, the delay to be absorbed should not come into conflict with an imposed slot regulation and it cannot be guaranteed that, even if the delay is absorbed on the ground, the flight is not further delayed while airborne, cumulating undesirable delays. A strong dependency between the arrival plan of one airport and the departure tactical operations of another one might induce risks that currently are difficult to prevent. However, if feasible and suitable, the delay absorption while the flight is on the ground is suggested as a good practice. This is the case for some city-pairs where coordination procedures are well established between all ATSUs in the chain and the risk of further delay on the flight is extremely low.

3.6 Operational procedures and methods to absorb extended AMAN delay

Different operational procedures might be used for extended AMAN operations, depending on the CONOPS. The procedures describe the delay apportionment strategy between ATSUs and the way this delay is absorbed, meaning the ATC instructions that will be issued to the pilot to absorb the delay. These measures are very variable and are often chosen as a trade-off between efficient extended AMAN operations and applicability of the measures.

From the pilot perspective, it is easier to receive instructions on time to absorb until or time to be at a specific point (metering point or coordination point), but from the ATCO's perspective, such instructions are difficult to manage as there is little knowledge and control of what the aircraft is doing before reaching the specific point at the expected time, which impairs their situation awareness on the overall traffic picture. This can be mitigated by continuous monitoring of enhanced mode S information, when available, but induces additional workload and does not seem very realistic operationally. Such procedures could only be applicable if traffic was very low and not very complex.

Some research studies have analysed the feasibility of route, level and combined instructions, such as modifying the position of the top of descent or the profile of the descent to efficiently absorbed delay. However, there is not yet a concluding result from that research.

Currently, the instruction of a speed reduction is the most widely used method of absorbing delay and represents a good compromise between operational feasibility and ATCOs workload. Another advantage of such method is that the application of extended AMAN procedures for different airports by the same ATSU is easier to accommodate, as the method is always the same (a speed reduction), even if the value of the speed might differ.

There are different methods to apply speed reduction. In some implementations, a fixed speed reduction is given to the flights selected for extended AMAN delay absorption. In other cases, the speed reduction depends on the value of the TTL to be absorbed. Procedures based on variable speed instruction induce additional complexity and therefore increase ATCO workload. In such cases, it is recommended that the provision of the appropriate speed value to the ATCO is automated.

3.7 Consideration of extended AMAN procedures in ATFCM

To prevent that the application of extended AMAN procedures lead to a capacity reduction in en-route sectors, in some environments it should be suitable to predict the expected extended AMAN activities for the coming hours (circa 2h) and to perform monitoring of the modified sector occupancy, as done for "normal" flows.

Based on the predicted occupancy/complexity, a CDM process can then take place between the different units by using Network Coordination tools and/or dedicated tools. This would allow extended AMAN strategy scenarios to be put in place: prioritisation of some extended AMAN flows, action on other flows, restrictions, etc.

A solution for this could be the implementation of a monitoring tool for the current and expected number of flights impacted by extended AMAN operations within a sector in combination with the sector occupancy counts. This could be realised by a dedicated shared tool or by separate ATFCM tools which integrate relevant extended AMAN information, such as the IODA tool used by Paris FMP (see Figure 2).

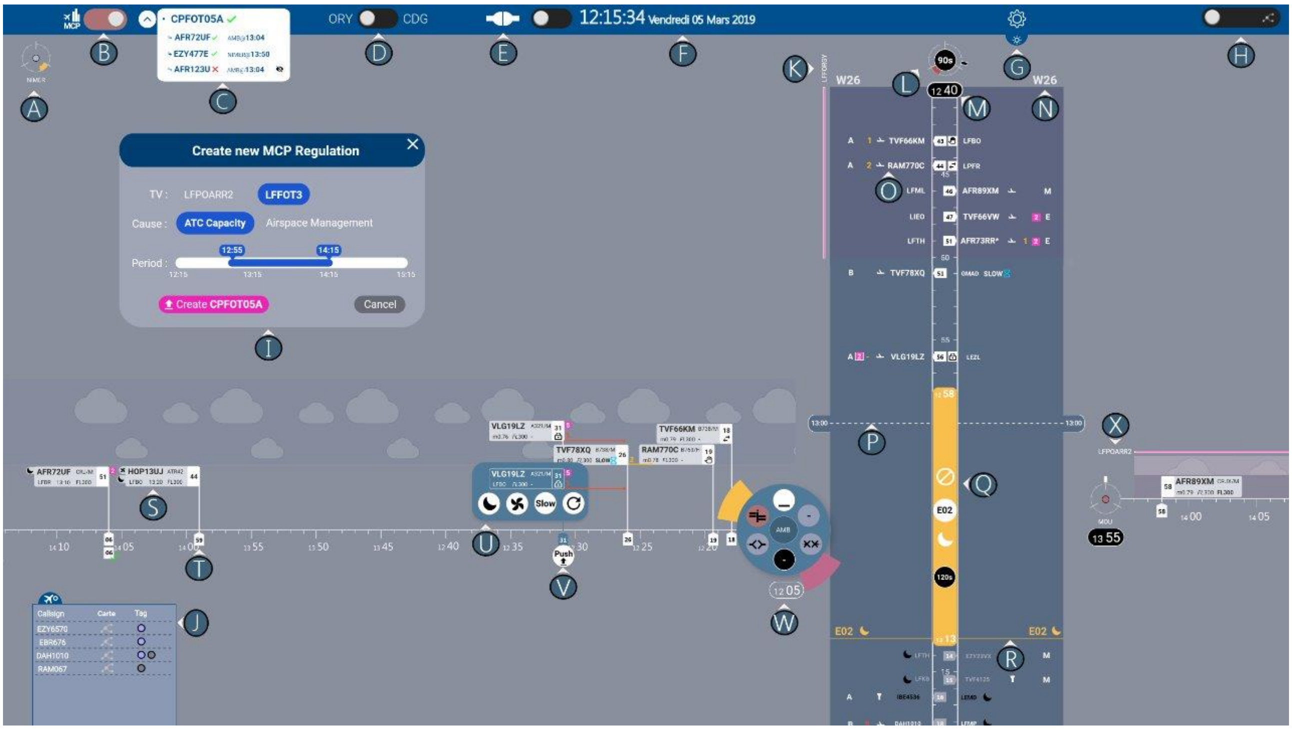

Figure 2 Example of IODA Tool provided by DSNA

3.8 Display of extended AMAN information to concerned ATCOs

Extended AMAN advisories should be made available so that ATCOs of the upstream ATSUs can issue the required instruction to the pilot as appropriate. Depending on the agreed concept and the ATCO role, the output from extended AMAN planning offers the following items of data liable to be displayed:

- Sequence
- Time over Metering point (TOM)
- Time to Lose (TTL) or Time to Gain (TTG)
- Time over Coordination Point
- Speed advisory to meet TTL/TTG
- Route advisory to meet TTL/TTG

In general, the sequence information is more relevant for TMA ATCOs and arrival managers whereas the en-route ATCOs are rather interested in the concrete advisories to be applied to a particular flight. In general, it is better to display the advisory directly than the TTL/TTG, as it induces less ATCO workload.

Depending on working procedures and system capabilities every connected upstream centre will decide on the chosen display variant. The display method and technique must serve the operational concept, and not the opposite. The variants currently existing are the following:

- AMAN Timeline on the main air situation display
- AMAN Timeline on a support monitor
- AMAN Information in the radar label
- AMAN Information on flight lists on the main air situation display
- AMAN Information on the flight lists on a support monitor
- AMAN Information – List of constrained flights - on support monitor. This is the case, for instance, of the 4Me tool from DSNA, which allows interaction with the extended AMAN, such as accept, reject or partially apply the request (see Figure 3).

A combination of different display means is also present in some implementations.

Presenting the information in the radar label is recognised to be the most efficient way, as it allows to better integrate it into the main tool supporting ATCO situation awareness. When displaying the information in the radar label, the goal is to show it in the least intrusive manner possible. Some variations exist:

- In certain cases, only a visible symbol is displayed on the label to warn the ATCO that there is a request for an extended AMAN advisory and then the ATCO can access the details of the request by interacting on the symbol. This is the case in MUAC (see Figure 4).
- In other cases, the concrete advisory is directly displayed on the label. This is the case in Zurich ACC (see Figure 5).
- In some cases, there is an additional interaction (e.g. accept or reject), and the possibility to transfer the request to another sector or to share information with other sectors within the same ATSU, as it is the case in DSNA sectors with 4Me tool or in Zurich ACC.

When advisories are displayed directly to the ATCO, and in order to make the extended AMAN process as transparent as possible to them, it might be needed to allow a Supervisory role (e.g. local Centre supervisor) to enable/disable the display of those advisories when the unit is not taking part in extended operations (or taking part partially).

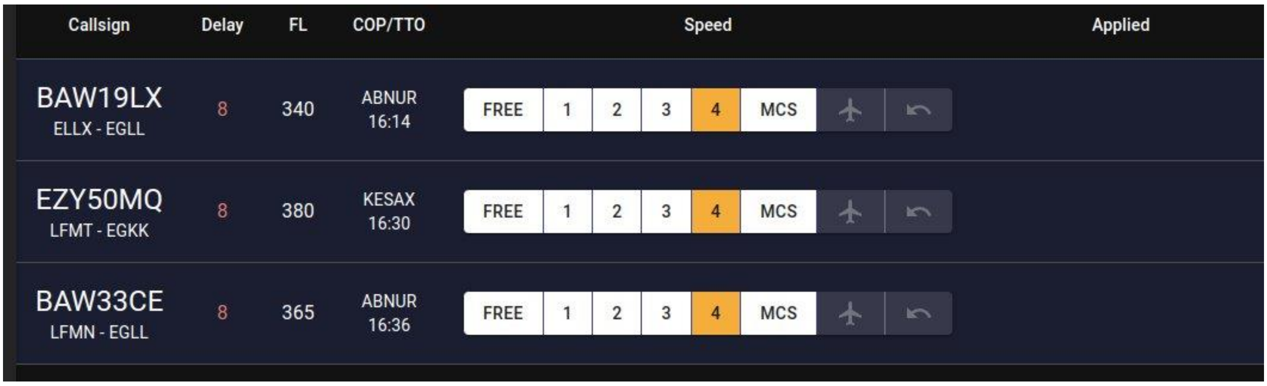

Figure 3 Example of 4Me tool providing extended AMAN request display and interaction to DSNA ACC ATCOs

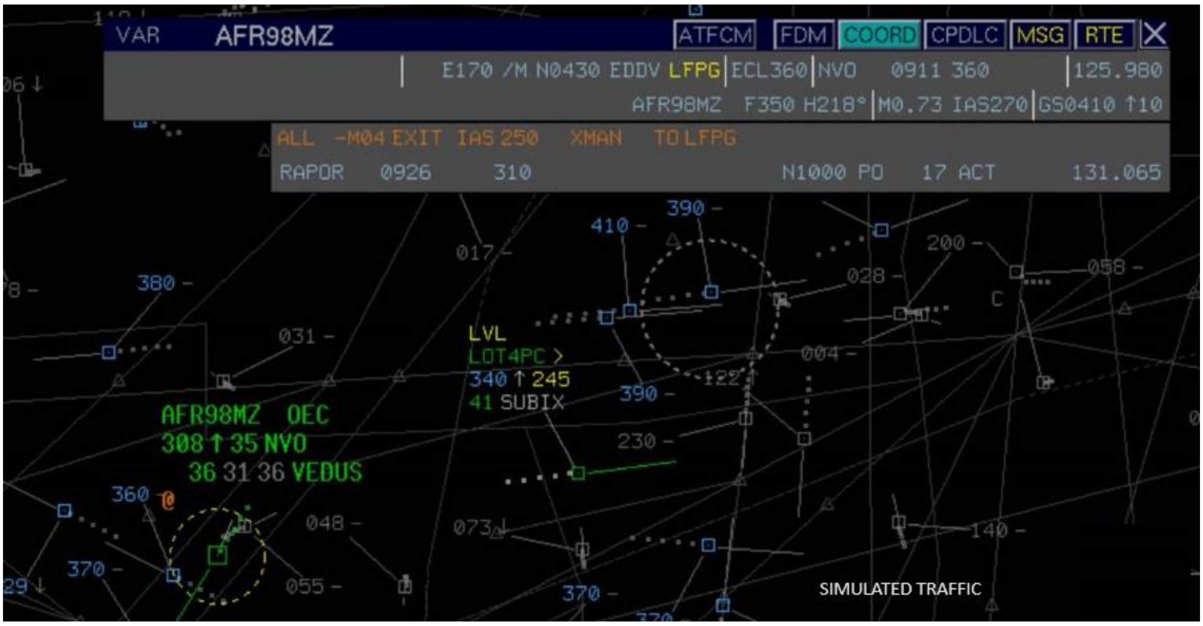

Figure 4 Example of extended AMAN request display to MUAC ATCOs

Figure 5 Example of extended AMAN request display to Zurich ACC ATCOs

3.9 Display of extended AMAN information to other actors (arrival manager, coordinators, FMP and OPS Supervisor)

The display of extended AMAN information to FMP and OPS Supervisor will be very dependent on the role they play in extended AMAN operations. The display of information needs to support efficiently that role.

In general, FMP and OPS Supervisor are rather interested in the global impact of extended AMAN operations than in concrete extended AMAN advisories. The extended AMAN information provided to those roles is typically integrated in ATFCM and monitoring tools and enable FMP and OPS Supervisor to monitor the effect of extended AMAN operations in the ATSU capacity. Some applications exist in Europe of such displays.

In the case of roles ensuring the distribution and filtering of extended AMAN information to the appropriate sectors within the upstream ATSUs, the display should support this function, provide the received extended AMAN information and allow to filter and dispatch it to the appropriate sector.

At the ATSU responsible for the extended AMAN eligible airport, FMP (or other actors like OPS Supervisor, arrival manager or coordinator) might be required to manage and trigger extended AMAN operations by acting on the sequence. The display must support that role, by providing information on the whole sequence and, ideally, a geographical visualization of the traffic flows involved.

In a concept of multi-partner coordination, the display provided by tools such as the XMAN Portal (see Figure 6) allows the actors from different ATSUs sharing information on extended AMAN requests and the ability of ATSUs to accommodate them and coordinating thereon.

Figure 6 Example of XMAN Portal provided by MUAC during PJ25 trial

3.10 Monitoring of extended AMAN performance

In all extended AMAN implementations, it is important to consider the need for monitoring the performance of the extended AMAN operations, on one hand, to verify whether the expected performance benefits are achieved, and, on the other hand, to plan the necessary modifications and evolutions when it is not the case.

In many cases, a performance case has been developed prior extended AMAN implementation, based on initial assumptions. It is a good practice verifying regularly, after implementation, that the initial assumptions are correct, and, otherwise, review the performance case.

In order to do that and to monitor the performance of the extended AMAN operations, it is recommended to maintain regular statistics of extended AMAN requests received and applied and cross-check them with traffic figures and performance indicators used in the performance case. These performance metrics can be typically direct indicators like occupancy of holding stacks, holding time, ASMA time or indirect indicators such as fuel consumption and CO2 emissions.