Appendix I Demonstration Exercise EXE-VLD-07-001 (Paris-Orly Extended AMAN) Report

This appendix is a report concerning the execution of the Demonstration Exercise EXE-VLD-07-001.

This exercise had been implemented with one configuration and executed one or more times as depicted in the figure below:

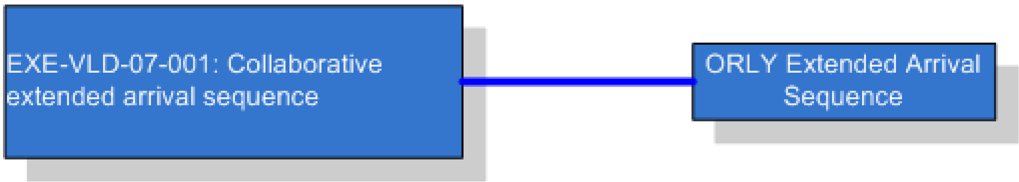

Fig. 1: Implementations of EXE-VLD-07-001 "Paris Paris-Orly Extended AMAN" scenario"

I.1 Summary of the Demonstration Exercise EXE-VLD-07-001 Plan

I.1.1 Exercise description and scope

The « Paris-Orly Extended AMAN » trials are applying the Extended AMAN concept to Paris-Orly arrivals, using an extended arrival sequencing tool called "iAMAN".

This tool is only used by Paris FMP and by Paris Orly Sequencer to compute an arrival sequence with its own algorithm using NM's B2B data at the Metering Fix, then using statistical "time-to-go" from the Metering Fix to the runway to obtain a more accurate ELDT, depending on the landing runway in use in Paris-Orly airport, as depicted in Fig. 2:

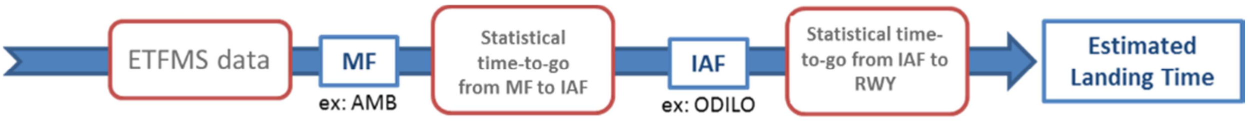

Fig. 2: ELDT computation in iAMAN

The use of this new E-AMAN tool fed with this enhanced data allows the extension of the AMAN horizon of action from 120NM to more than 200 NM.

When building an arrival sequence using the Extended AMAN (iAMAN) at a horizon of more than 200NM or at ELDT-50 mins minimum, the main expectations are to:

- Reduce ASMA delay in Paris ACC terminal sectors and in Paris-Orly TMA,
- Reduce the workload of Paris ACC terminal sectors & Paris-Orly TMA,
- Communicate speed advisories to the upstream ACCs/sectors to resorb delay,
- Have the upstream ACCs/sectors participate in delay-sharing efforts,
- Provide an optimal & efficient feed of arrivals to the TMA and to the runway.

The horizon extension of Paris Orly AMAN using iAMAN is depicted below:

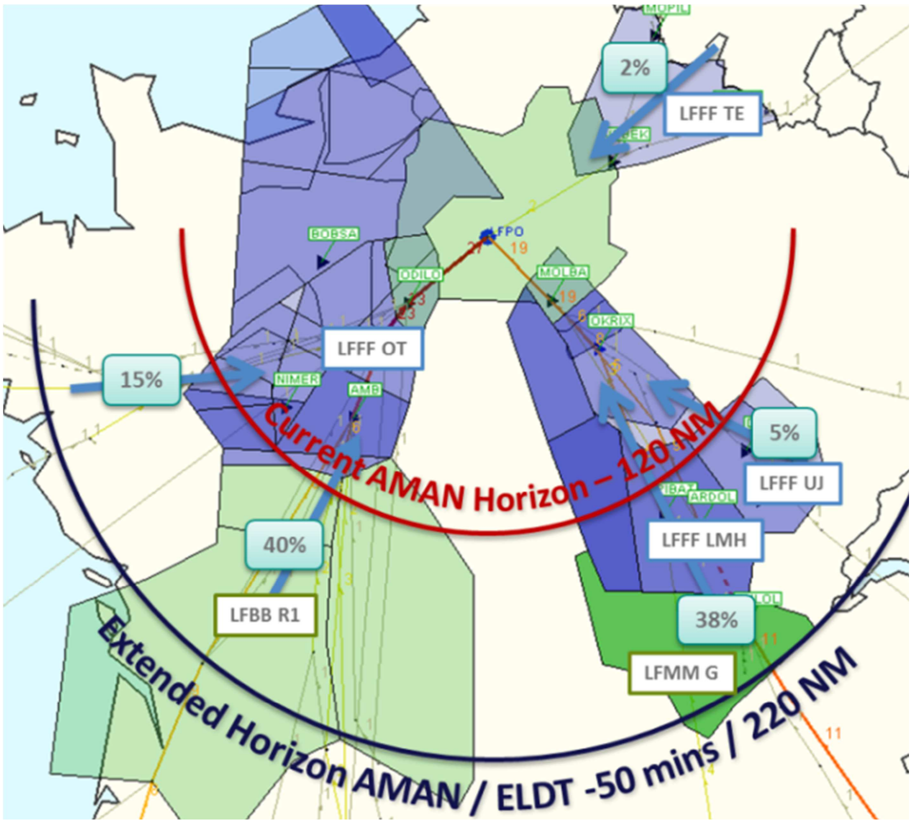

Fig. 3: Paris Orly AMAN horizon extension

During the late morning peak called "Peak 2" (11:00 - 13:30LT), the clear majority of the flows (80% as detailed in the table below) to Paris-Orly fly:

- Via Bordeaux ACC sector R for the southwest flows,
- Via Marseille ACC sector G then Paris ACC LMH sector for the southeast flows.

Upstream UAC	Percentage of arrival flow	Metering Fixes	Initial Approach Fix	Paris ACC / Upstream ACC boundary from Paris-Orly airport
Bordeaux ACC	40%	AMB	ODILO	120 NM
Brest ACC	15%	NIMER		120 NM
Marseille ACC / Paris ACC	38%	PIBAT ARDOL	MOLBA	180 NM
Reims ACC	5%	DJL		180 NM

Maastricht UAC	2%	RENSA MOPIL	VEBEK	130 NM

Table 1: Traffic distribution of ORY arrivals between 11:00 and 13:30LT

During the trials, Orly experimenters manned a “Sequencer position” in the Orly Control Tower to collaborate with Paris FMP to update the iAMAN tool. Orly Sequencer had access to the iAMAN HMI installed on the sequencer position.

A description of the HMI is shown in the figure below Fig. 4:

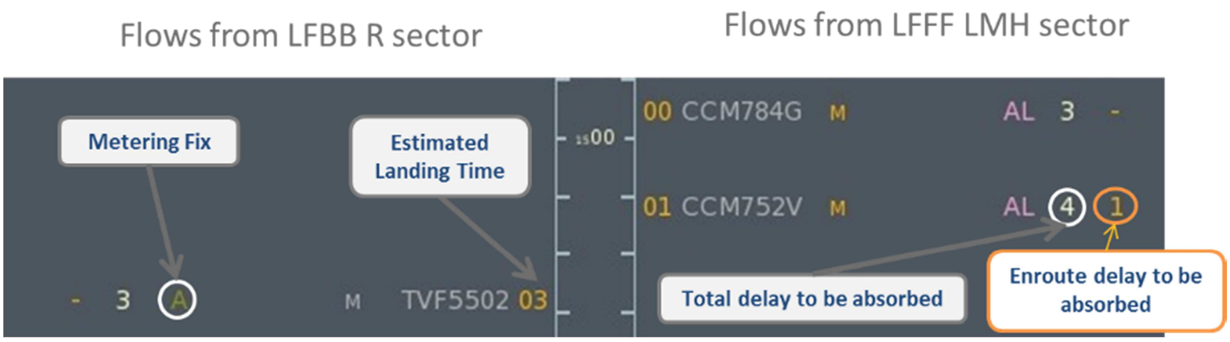

Fig. 4: Description of iAMAN HMI

The Extended AMAN process is then described as follows (see also the corresponding CONOPS WP7 document) in Fig. 5: and described below.

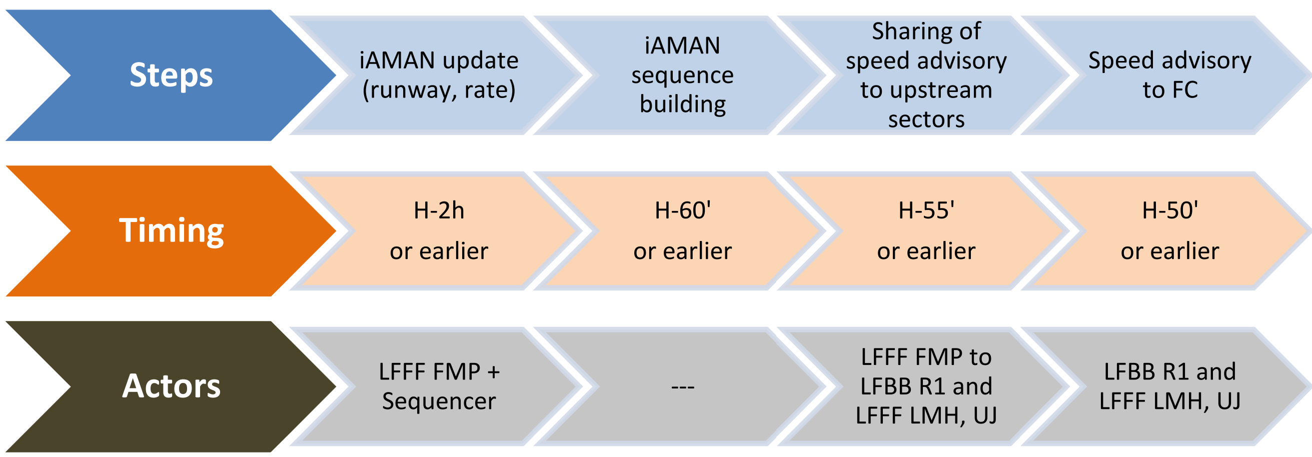

Fig. 5: Trial process for Extended AMAN Orly

Note: H is referring to the airport hotspot.

- H-2h: iAMAN is configured at least 2 hours before the arrival peak with the runway in use and the arrival rate. The arrival sequence is then built and stable enough approximatively 50 to 60 mins before the arrival peak when almost all flights are airborne.

- H-60'/H-50': Once the arrival sequence is built, it is displayed on iAMAN in Orly & Paris ACC. iAMAN enables the sequence to be shared using a WebService to other partners (AU, UAC, Airport…). Using the iAMAN HMI in Paris ACC, Paris FMP coordinates via phone with the concerned upstream sectors (R in LFBB ACC or LMH or UJ in LFFF ACC) a speed reduction by Mach 0.04 to start absorbing the selected flights' calculated enroute delay as shown in Fig. 5: Paris FMP may also tag the flight with "SLW" on iAMAN as a reminder that an XMAN action has been requested for the selected flights.
- H-50': The upstream sectors' ATCO then transmits the speed advisories to the concerned flights.

For situation awareness purposes, Paris FMP also informs Paris ACC ATCOs of the flights being slowed down by the upstream sectors.

Once the speed advisories are given to the UAC, no further revisions are transmitted.

- H-30': When the flights enter the regular AMAN horizon, flight trajectories & AMAN delay are handled as usual by Orly Approach and by Paris ACC terminal sectors using the regular AMAN installed on Paris ACC CWP and on Orly Approach CWP.

I.1.2 Summary of Demonstration Exercise EXE-VLD-07-001 Demonstration Objectives and success criteria

The Objectives and success criteria for EXE-VLD-07-001 are provided in the xStream DEMOR main document, in chapter 3.4 "Summary of xStream Demonstration Plan".

I.1.3 Summary of Demonstration Exercise EXE-VLD-07-001 Demonstration scenarios

This exercise had been executed on the following dates and daytimes:

Period	Peak	Time period	Number of actual trial days	Total number of flights with XMAN action
From July 25, 2017 to August 30, 2017, weekdays only	Peak 2	11:00 to 13:30 LT	17	165
From June 01, 2018 to July 20, 2018	Peak 2	11:00 to 13:30 LT	1	4
	Peak 3	18.30 to 20.00 LT	0	0
From November 20, 2018 to June 14, 2019	Peak 1	07h00 to 8h30 LT	5	26
	Peak 2	11:00 to 13:30 LT	6	46
	Peak 3	18.30 to 20.00 LT	1	4

Table 2: Description of planned trial periods and actual trial days

The EXE-VLD-07-001 scenarios concerned Paris-Orly arrivals during different periods and different peaks in 2017, 2018 and 2019 as described in Table 2:

However, only the planned 2017 trials from 11h00 LT until 13h30 LT during runway works that degraded the airport capacity were significant in terms of the total number of flights with XMAN action.

During the reference (baseline) scenarios, Paris-Orly AMAN is already connected to Paris ACC, leading to a horizon from 100 to 160 NM. This allows to absorb up to 8 minutes of delay in Paris ACC sectors (linear holding), plus around the same in airport TMA.

- The reference scenario #1 is based on the peak hours of Paris-Orly arrivals, from 11:00 LT to 13:30 LT, during summer 2016 planned runway works (July 18th to Aug 28th) that degraded the airport capacity and led to an increased use of holding patterns and additional ASMA time.
- The reference scenario #2 is based on the peak hours of Paris-Orly arrivals, from 11:00 LT to 13:30 LT, during summer 2017 planned runway works (July 25th to Aug 25th), when EXE-VLD-07-001 was not active (e.g. weekends), when there was no additional degradation of the performance due to weather or other issues.

During those two reference periods, runway configuration is identical. (Closure of North runway 06-24 due to resurfacing work).

The solution scenario focuses on extending the Paris-Orly AMAN to upstream UACs (>200 NM), using all available data such as ETFMS Flight Data messages (EFDs), to share computed AMAN delay with upstream ACCs when it exceeds Paris area available buffer and to start absorbing AMAN delay in upstream ACCs.

The solution scenario has been designed to be applicable on any peak hour of Paris-Orly arrivals. As mentioned before, planned runway works degraded the airport capacity during summer 2017.

I.1.4 Summary of Demonstration Exercise EXE-VLD-07-001 Demonstration Assumptions

The assumptions concerning EXE-VLD-07-001 are provided in the xStream DEMOR main document, in chapter 3.4 “Summary of xStream Demonstration Plan”.

I.2 Deviation from the planned activities

When planning the EXE-VLD-07-001 activities end of 2016 and early 2017, the arrival flows to Paris-Orly during the concerned peak hours were analysed and showed that most of the flows come from Bordeaux ACC and Marseille ACC (see Table 1).

Consequently, as the flows from Brest ACC, Reims ACC and Maastricht ACC were a clear minority, it was decided to focus mainly on acting on arrival flows from Bordeaux ACC and Marseille ACC, which account for 78% of the arrival flows.

Moreover, since the arrival flows from Marseille ACC and Reims ACC are already handled by Paris ACC more than 200 NM from the airport, it was not necessary to include Marseille ACC or Reims ACC in the demonstration exercise, as the flights can be slowed down directly by Paris ACC enroute sectors LMH and UJ at the targeted horizon.

Overall, more than 80% of the flights beyond 200 NM from the airport were eligible to a speed reduction in line with the planned demonstrations during the trials.

I.3 Demonstration Exercise EXE-VLD-07-001 Results

In the following chapter, the results of the trials performed from 25th of July 2017 until 20th of August 2017 during Peak 2 are described in detail in this document as they are the most significant.

For assessment & benchmarking matters, only "comparable" days, with no weather or other issues degrading the ATC performance, were considered if not otherwise stated.

The results of EXE-VLD-07-001 trials planned in 2018 and 2019 are not described in this chapter due to:

- Lack of trial days with actual XMAN action on arrivals (e.g. due to low traffic demand).
- Lack of comparable baseline.
- Weather issues (e.g. thunderstorms).
- Technical issues (e.g. E-AMAN tool inoperative).

I.3.1 Summary of Demonstration Exercise EXE-VLD-07-001 Demonstration Results

See Also Main Document 4.1.2.1

In this chapter, EXE-VLD-07-001 is analysed during the 2017 trial period during peak 2 in Paris-Orly, concerning flights having an ELDT between 11:00 and 13:30 LT.

During these planned trials, 165 flights bound for Paris-Orly received XMAN action during the 17 days when the trial was activated.

Upstream sector	Number of flights with XMAN action	Average detected Mach number reduction	Average notice from ELDT the flight was tagged on iAMAN	Average time and distance from runway a speed reduction was detected	Average E-AMAN enroute delay when XMAN action is requested	Average time lost enroute between XMAN action and reaching Metering Fix
LFBB R	73	0,04	56 mins	50 mins 250 NM	5 mins	60s
LFFF LMH	90	0,05	57,5 mins	40 mins 210 NM	5 mins	25s
LFFF UJ	2	Not computed				

Table 3: Description of flights with XMAN action per upstream sector during EXE-VLD-07-001

Flights with XMAN action coming from LFBB R sector:

- Were reduced by an average of M0.04 according to automatic Mode S detection;
- Requests were tagged on iAMAN tool 56 mins from the ELDT by the FMP, meaning they were transmitted by telephone from Paris FMP to LFBB R sector;
- Were detected to be actually reduced around 50 minutes before ELDT at an average distance of 250 NM from the runway;
- At the time of the request, the average enroute delay computed by the E-AMAN tool was about 5 minutes;
- Per BADA calculation, the flights were slowed down before reaching the metering fix by around 60 seconds.

Flights with XMAN action coming from LFFF LMH sector

- Were reduced by an average of M0.05 according to Mode S detection;

- Requests were tagged on iAMAN tool 58 mins from the ELDT by the FMP, meaning there were coordinated orally or by telephone from Paris FMP to LFFF LMH sector;
- Were detected to be actually reduced around 40 minutes before ELDT at an average distance of 210 NM from the runway;
- At the time of the request, the average enroute delay computed by the E-AMAN tool was about 5 minutes;
- Per BADA calculation, the flights were slowed down before reaching the metering fix by around 25 seconds.

The difference between the iAMAN tagging of the flights and the actual speed reduction comes from the fact the flight was actually slowed down by Paris ACC when entering LMH sector after handoff from Marseille ACC, around 210 NM from the runway.

The difference in time lost between flights coming from LFFF LMH sector and LFBB R sector comes from the length difference between the MF-IAF distance in the Southwest (LFBB R) and the south east (LFFF LMH) as it is shown in the figure below.

After reaching the Metering Fixes, the flights enter regular AMAN horizon and are subject to the usual speed restrictions given by Paris ACC to absorb Paris-Orly AMAN delay.

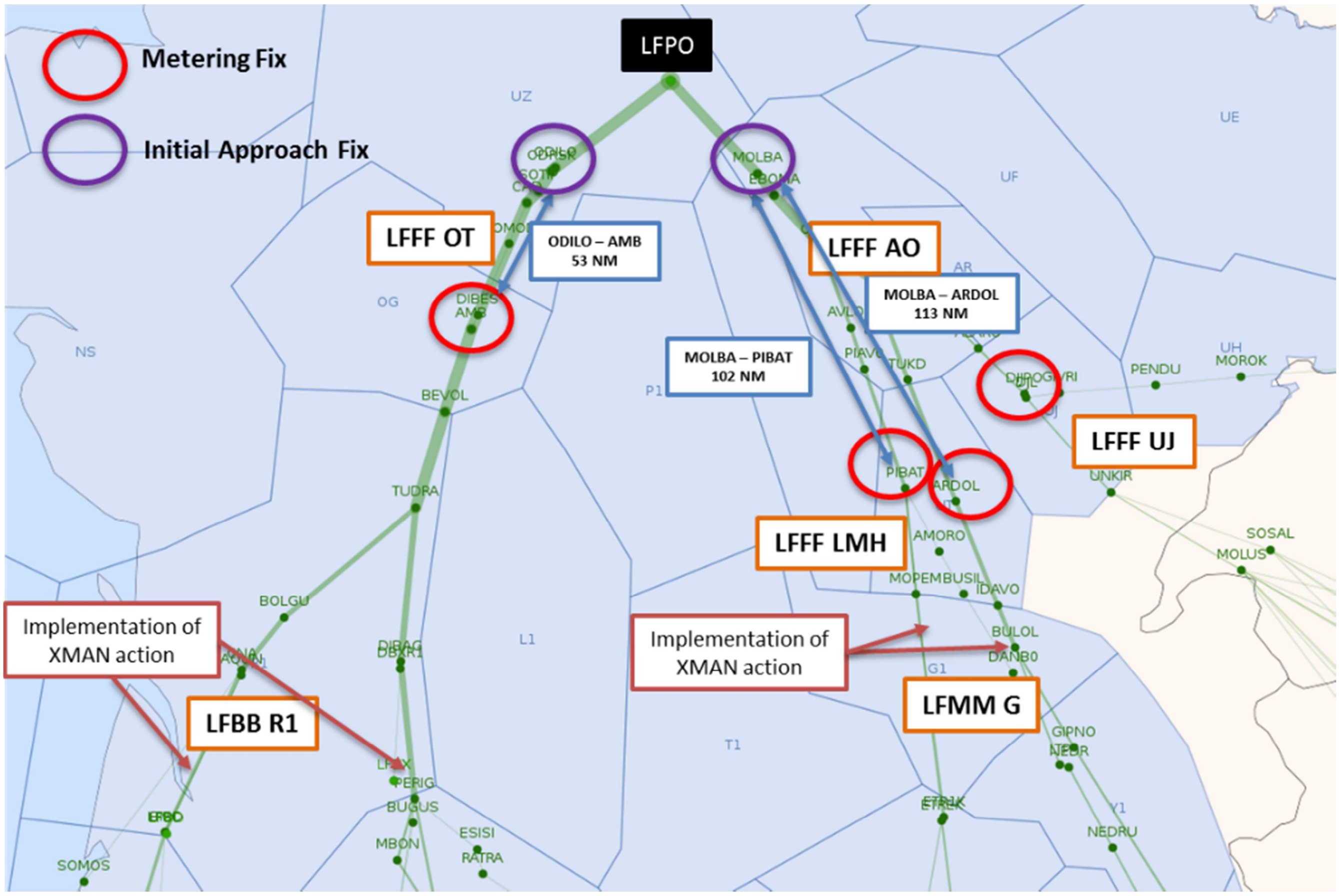

Fig. 6: Map of Paris-Orly arrivals subject to XMAN action

I.3.1.1 Results per KPA

In the results provided in this section:

- The qualitative assessment concerns all the dates when the EXE-VLD-07-001 trial actually took place in 2017;
- If not stated otherwise, the quantitative assessment concerns only the dates with comparable baselines in reference solutions #1 and #2, including
    - Same runway in use (runway 26 in Paris-Orly),
    - No go-around occurring during peak 2,
    - No weather issues (strong winds or CBs enroute or in the vicinity of the airport).

I.3.1.1.1 KPA Safety

Safety KPA was assessed quantitatively by using incident reports by ATC; and qualitatively by using questionnaires in Paris ACC for ATCOs.

Additional feedback was collected from Paris Orly Tower supervisors and Bordeaux ACC head of Operations using interviews.

I.3.1.1.1.1 Quantitative Assessment

Number of Incident Reports:

No incidents related to the xStream trials were reported in Paris ACC, Paris Orly or Bordeaux ACC.

I.3.1.1.1.2 Qualitative Assessment

Questionnaire results related to Safety:

- According to the 16 questionnaires filled by the Paris ACC ATCOs during the trials, 100% of the ATCO assess safety was never compromised during the EXE-VLD-07-001 trials (see Figure 7).

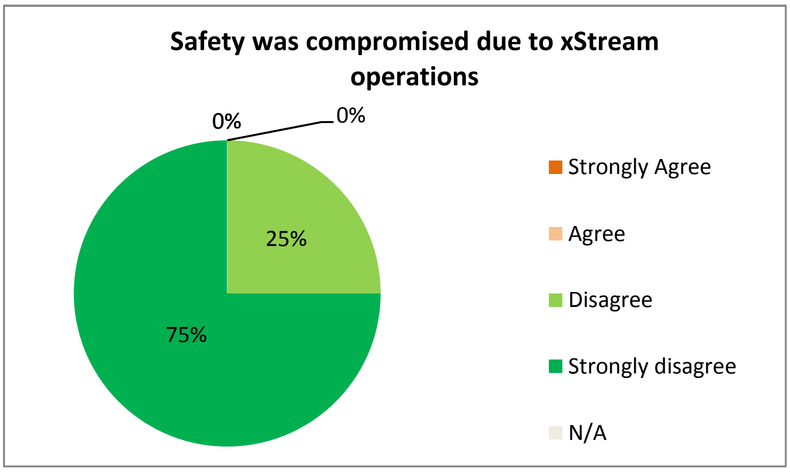

Fig. 7: Paris ACC questionnaire result about safety

Other subjective feedback related to Safety:

- For arrival flights being reduced in Bordeaux ACC sector R, an Operational Instruction had been issued and the concerned ATCOs were briefed of the trial.
- No safety issue was reported by Bordeaux ACC during an oral debriefing with Bordeaux ACC Head of Operations after the 2017 trials.
- No safety issues were reported by Orly Tower supervisors.

According to the process implemented during the trial, Paris ACC ATC sectors that were impacted by the speed reductions were notified of the trials by the issuance of an Operational Instruction.

During the execution of the trials, to maintain a safe management of the traffic for the ATCO, Paris FMP had to inform the impacted ATC sector of any arrivals being reduced beforehand by the upstream ACC.

In case Paris ACC sectors needed to reduce the arrivals at an earlier horizon than usual, as required by the experiment, Paris FMP had to timely notify the measure to the ATCO of the concerned ATC sector.

I.3.1.1.2 KPA Predictability and Punctuality

Predictability and Punctuality KPA was assessed quantitatively by using two performance indicators, i.e. Time difference actual - planned and Landing sequence predictability.

I.3.1.1.2.1 Quantitative Assessment

Landing Sequence Predictability:

CPR and iAMAN scheduler data were used for this analysis. The results listed here were calculated with an in-house DLR software application which was developed especially for xStream performance assessment and calculates the number of sequence jumps in the predicted arrival sequence, compared to the actual arrival sequence, from the mentioned data.

All days between 25th July and 29th September 2017, that were no originally planned trial days were used as reference (21 days, excluding weekends, corresponds to reference #2). Due to data quality (mainly data gaps in the scheduler data), 7 of 21 reference datasets and 4 of 16 trial datasets are useable for analysis.

Within these trial datasets, speed advisories were given on 2 of 4 usable trial datasets.

Comparability checks indicated that the used 14 of 21 reference datasets are usable to serve as baseline against 15 comparable of 16 trial datasets.

The following table shows the measured average number of sequence jumps per flight for LFPO arriving traffic between actual landing sequence and planned arrival sequence at 100NM distance from LFPO (hypothesis: LFPO XMAN extension leads to a smoother and more predictable arrival flow of the traffic closer to the airport).

	Average sequence jumps per flight (standard deviation in brackets)	
	All usable datasets	**Trial days with given speed advisories only**
Reference	0,35 (SD: 0,24)	-
Trial	0,37 (SD: 0,12)	0,27 (SD: 0,06)
Difference	+0,02	-0,08

Table 4: Landing sequence predictability results

When looking at the traffic as a whole, almost no change is visible.

When looking just on those days where speed advisories where actually given, a very slight decrease of the average number of sequence jumps per flight can be seen, indicating a slightly improved predictability of the whole arrival sequence for all LFPO arrivals.

It has to be noted that, due to the mentioned gaps in the scheduler data, these values were calculated with very little sample sizes (7 reference days, 4 trial days, 2 trial days with speed advisories).

Therefore, these results may be unprecise.

I.3.1.1.2.2 Qualitative Assessment

The extension of the AMAN horizon using a new E-AMAN tool for the Orly Tower supervisor and Paris FMP could bring an extended outlook on the predicted arrival sequence earlier than during the baseline. The qualitative feedback from the Tower supervisors and Paris FMP was very positive about the new E-AMAN tool to anticipate the arrival sequence to Orly.

I.3.1.1.3 KPA Environment

Environment KPA was assessed quantitatively by analysing the performance indicators of calculated fuel consumption, based on BADA 3.13.

I.3.1.1.3.1 Quantitative Assessment

Fuel Consumption:

CPR data was used for this analysis.

The results listed below were calculated with an in-house DLR software application which estimates the fuel consumption of aircraft flight trajectories based on BADA version 3.13. The results are therefore specific to the aircraft type.

To get reliable results, a certain number of flights of the same aircraft type must be contained in the datasets to average outliers.

For this reason, the 5 most frequent aircraft types were considered for the analysis, i.e. A319, A320, A321, B738, and AT45.

In total, 53.1% of all flights were performed with one of these aircraft types. The individual shares of these aircraft types are visible in the figure below:

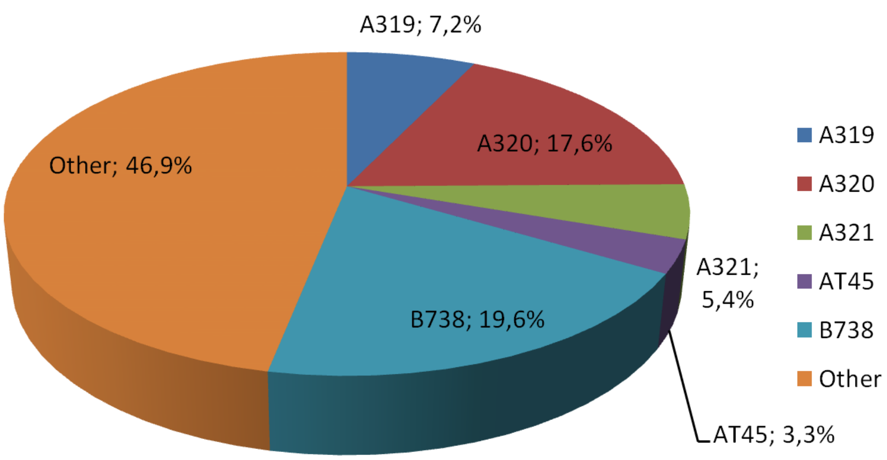

Fig. 8: Average aircraft type shares of the traffic during trial and reference datasets

The observed traffic mix is very diverse, which is the reason why not more aircraft types can be included (all other types, especially those that are available in BADA 3.13, have a share of about 1% or less, which causes a high risk that outliers distort the results).

However, as only every second airplane can be included in this analysis, and because of relatively small sample sizes, the results may be unprecise.

As the results are an estimation based on BADA 3.13 data, which is not or just marginally considering most influencing factors for fuel consumption (actual aircraft weight, weather, engine types, etc.), the actual fuel consumption values (kg) are not meaningful.

Therefore, only the relative difference compared to the baseline datasets is written down below (average relative fuel savings within 100NM).

The hypothesis is that the ORY XMAN horizon extension leads to a reduction of fuel burn for the flights closer to the aerodrome due to more efficient flight profiles, which is directly connected to a reduction of gas emissions.

As result of the fuel calculation for these aircraft types, considering all traffic within all planned trial datasets (16 days) and comparing them to all reference datasets (21 days), the average fuel saved per flight for the leg within a circle with a radius of 100NM around ORY ARP according to the performed analysis is determined **2,99%**.

When only considering all trial and reference datasets which passed comparability checks as described in appendix E, the average fuel saved per flight for the leg within a circle with a radius of 100NM around ORY ARP according to the performed analysis equals **1,32%**.

When only comparing all days where speed advisories were given (10 datasets) and comparing them to datasets without speed advisories within the whole period with a comparable traffic throughput (22 datasets), the average fuel saved per flight for the leg within a circle with a radius of 100NM around ORY ARP according to the performed analysis equals **4,75%**.

When additionally considering the results of the comparability checks as described in appendix E, the average fuel saved per flight for the leg with a radius of 100NM around ORY ARP according to the performed analysis equals **4,49%**.

Summarized, when averaging over the whole trial period and considering the traffic as a whole, a slight improvement regarding calculated fuel consumption is observed.

A decrease of fuel consumption was also clearly determined when focussing on the runs where speed advisories were actually given.

I.3.1.1.3.2 Qualitative Assessment

No qualitative assessment was performed regarding environment.

I.3.1.1.4 KPA Cost Efficiency (not required by DEMO objectives but covered)

Cost efficiency assessment was made:

- Quantitatively: by calculating the additional ASMA (Arrival Sequencing and Metering Area) time in Orly TMA and Paris ACC per flight during the reference scenarios and EXE-VLD-07-001 compared to unimpeded ASMA time and by calculating average number of holding patterns per hour. Both indicators are directly related to cost efficiency as they a measure of airborne delay a flight experiences.
- Qualitatively: only qualitative feedback about the usage of ATFCM regulation rates has been received from operational staff. (Orly Tower supervisors and Paris FMP)

I.3.1.1.4.1 Quantitative Assessment

	EXE-VLD-07-001	Reference	Reference

	(2017 Runway works with xStream)	scenario 2 (2017 Runway works without xStream)	scenario 1 (2016 Runway works without xStream)
Total additional ASMA per flight (mins)	2,80	3,73	4,43
Additional ASMA in Orly TMA per flight (mins)	1,78	2,77	3,16
Additional ASMA in Paris ACC per flight (mins)	1,02	0,96	1,27
Holding pattern per hour	0,04	3,10	1,54

Table 5: ASMA data per flight and holding pattern per hour during EXE-VLD-07-001 and comparison with reference scenarios

Additional ASMA Time:

The trials showed a reduction of additional ASMA time in Paris ACC + Orly TMA (see table above)

- By 60s per flight compared to reference scenario #2,
- By 90s per flight compared to reference scenario #1.

The trials also showed a rebalancing of additional ASMA time between Orly TMA & Paris ACC (see table above):

- Orly TMA ASMA per flight is reduced from 71% of total additional ASMA time (scenario 1) & 74% of total additional ASMA time (scenario 2) to 64% of total additional ASMA time during EXE-VLD-07-001
- Paris ACC ASMA per flight is increased from 29% of total additional ASMA time (scenario 1) & 26% of total additional ASMA time (scenario 2) to 36% of total additional ASMA time during EXE-VLD-01-001

Number of holding patterns flown in TMA:

The trials showed a reduction of holding patterns per hour by almost 100% during the EXE-VLD-07-001 exercises compared to reference scenarios #2 and #1 (see table above).

I.3.1.1.4.2 Qualitative Assessment

No other qualitative assessment was performed regarding cost efficiency.

I.3.1.1.5 KPA Capacity

I.3.1.1.5.1 Quantitative Assessment

Runway Throughput:

	EXE-VLD-07-001 (2017 Runway works	Reference scenario 2 (2017 Runway	Reference scenario 1 (2017 Runway

	with xStream)	works without xStream)	works without xStream)
Total movements per hour	41,4	40,2	41,0
Average landings per hour	23,0	23,0	23,4
Average departures per hour	18,4	17,2	17,6

Table 6: Runway throughput data during Paris-Orly peak 2 arrivals (11h00 LT to 13h30 LT)

According to runway throughput analysis depicted in Table 6:, during EXE-VLD-07-001:

- Average number of landing per hour,
- Average departures per hour,
- Total movements per hour,

was very similar compared to reference scenarios #1 and #2.

No decrease due to xStream actions was observed.

Flight Path Diversity:

CPR data was used for this analysis.

The results listed here were calculated with an in-house DLR software application (EWMS) which is capable of calculating various performance indicators and that was used here to analyse the flight path diversity within an airspace of 100NM radius around ORY for the peak time period.

The Flight path diversity indicator has a value from 0 (zero diversity) to 1 (max diversity) and is one means to quantify traffic complexity, based on flight trails. It can be handled like a percentage value.

The following table shows the results for ORY arriving traffic (hypothesis: xStream tries to absorb delay early in upstream sectors rather than later in the TMA, therefore leads to less vectoring and other path stretching manoeuvres in the approach sectors).

Therefore, this indicator should show a slight decrease.

In total, two different dataset compositions were analysed:

- All planned trial days (16 days, excluding weekends and days of trial abortion) are compared against all non-trial days between 25th July and 30th September 2017 (21 days, excluding weekends).
- Is a subset of composition 1) containing most comparable datasets following the comparability checks described in appendix E (14 trial days, 10 reference days).

A further differentiation is not meaningful as speed advisories were given at the majority of trial days.

		Average flight path density (value from 0 to 1) / Standard deviation (SD)
Composition 1)	**Reference**	0,1938
	Trials	0,1953

Composition 2)	**Reference**	0,1905
	Trials	0,1963

Table 1: Flight path diversity results for UJ Sector

The expected behaviour cannot be observed. Very small changes in this indicator can be neglected, so no difference between trials and reference could be determined.

I.3.1.1.5.2 Qualitative Assessment

Thanks to the collaborative use of iAMAN by both Paris FMP & Orly sequencer / Tower supervisor, the arrival flows could be slowed down upstream, sometimes 250 NM out, allowing the ATFCM regulation rate to remain at a higher rate than expected, while guaranteeing streamlined & reduced arrival flows to the Paris Orly IAF feeding the TMA.

This was done thanks to the use of the Extended AMAN process and the slowdown of Orly arrivals, thanks to Paris FMP expertise and the collaboration of upstream sectors.

ATCO workload:

Complexity & workload in Orly TMA could also be reduced thanks to Extended AMAN.

When delays were building up on the arrival flows, Paris FMP was able to reduce the flights in the upstream sectors based on iAMAN output to avoid absorbing all the AMAN delay in Paris terminal sectors and in Orly TMA. Workload could therefore be reduced in Orly TMA and Paris ACC E-TMA to be transferred to Bordeaux ACC.

ATFCM delays:

For instance, on one day during EXE-VLD-07-001, Orly Tower supervisor had an ATFCM regulation applied for LFPOARR2 Traffic Volume at the usual rate of 20 arrivals per hour.

After assessing the situation, Paris FMP and Orly Tower supervisors & sequencer jointly decided to raise the regulation rate to 23/h, while carefully updating the iAMAN parameters to match the planned runway arrival rates and reducing the speed of arrival flows inbound Orly.

Eventually, 24 arrivals could have landed in one hour.

iAMAN & Extended AMAN process was also used two times in case of bunching of the LFPOARR2 arrival ATFCM regulation. An example is described as follows:

With a late 20 mins bunching observed by Paris FMP & Tower supervisors, it was possible to absorb this 20 mins bunch of arrivals without the extension of the ATFCM regulation or without using holding patterns, but only by using anticipated speed advisories with the upstream sectors.

In Fig. 9: the CHMI window is showing an ATFCM regulation of 28 arrivals per hour has been set on LFPOARR2 TV. During this morning, a bunching appeared during a 20 minutes' step (between 10H40 UTC and 11H00 UTC) of 16 flights, instead of 9.

To cope with this bunching, 8 flights were requested to slow down in Paris ACC LMH sector and in Bordeaux ACC R1 sector.

These actions allowed the bunching to be absorbed by the ATC without using holding patterns, which allowed extending the ATFCM regulation which would otherwise have created additional grounds delays for Orly arrivals.

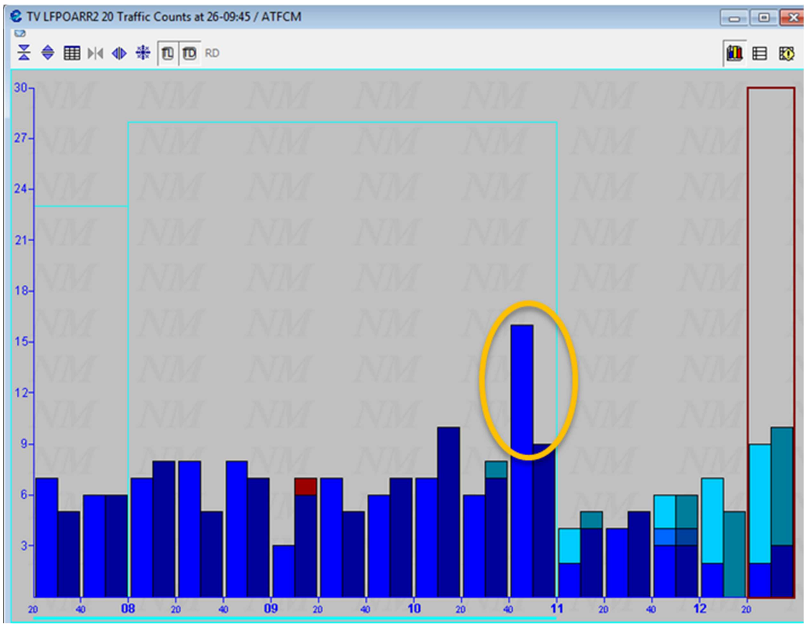

Fig. 9: CHMI view of LFPOARR2 regulation bunching absorbed using early speed advisories

16 questionnaires were filled by Paris ACC ATCOs. Two questionnaires were filled by Bordeaux ACC ATCOs.

Questionnaire results related to TMA capacity:

The figure below shows questionnaire results related to traffic complexity ("Please state to which extent you agree or disagree: xStream improvements increased traffic complexity"), which is directly related to ATC capacity.

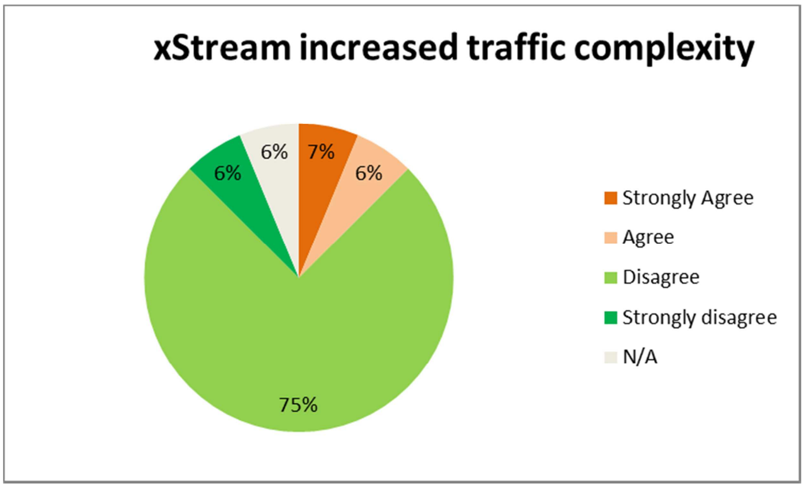

Fig. 10: Paris ACC questionnaire results about traffic complexity

81% of Paris ACC ATCOs assessed traffic complexity was not increased during EXE-VLD-07-01.

Only 13% of Paris ACC ATCOs estimated traffic complexity was increased, this was according to them due to

- For Paris OT sector: the difficulty of sequencing jet aircraft, being already reduced upstream, with turboprop aircraft to the Orly IAF.

- For Paris LMH sector: slowing down aircraft while still in enroute phase in an enroute sector sometimes brought increased workload to detect conflicts with overflights catching up arrivals being slowed down due to the trial.

Concerning Bordeaux ATCOs, only 2 questionnaires were filled, yet stating there was no increase in traffic complexity for the upstream sector. This was confirmed by Bordeaux ACC head of Operations.

Qualitative feedback related to ATCO workload:

Based on post-trial interviews with a dozen of Orly Tower supervisors and Approach ATCOs, a very positive feedback has been received during the experiment, with workload, complexity, pressure being mitigated in Paris-Orly TMA.

This could allow Orly ATCs to integrate departures more easily according to the arrival flows.

On two occasions, Bordeaux ACC ATCO workload has been reported to be increased when:

- Implementing the measure in case of severe weather conditions (i.e. CBs),
- The sector was combined with another sector nearby.

A few other times, speed reductions being requested were not in the proper sequence order in Bordeaux ACC so ATCO could not give the speed reduction. Indeed, according to the LOA between Bordeaux ACC sector R and Paris ACC sector OT, Paris-Orly arrivals are supposed to be delivered by R sector descending to FL280, 10 NM in trail.

If the arrival sequence shown on E-AMAN doesn't match the actual arrival sequence shown on the ATCO's radar display, this can lead to confusion.

This may have implied additional coordination with Paris FMP or with Paris OT sector.

Questionnaire results related to ATCO situation awareness:

The figure below shows questionnaire results related to ATCO situation awareness ("Please state to which extent you agree or disagree: xStream improvements negatively impacted the traffic situation awareness"), which is also directly related to ATC capacity.

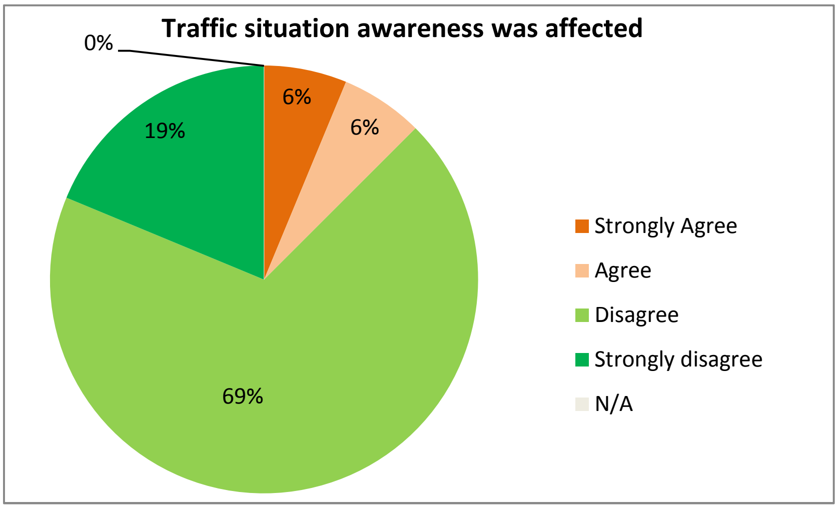

Fig. 11: Paris ACC questionnaire results about situational awareness

According to Paris ACC questionnaire results, situational awareness was not impacted by EXE-VLD-07-001 for 88% of the ATCOs.

8% agreed their situational awareness was impacted because Orly arrivals were not delivered as usual by Bordeaux R1 sector, when they were not complying with the LOA, although adherence to the LOA should be mandatory.

Other subjective feedback related to ATCO situation awareness:

During post trial interviews, Paris Orly Tower supervisors & ATCOs assessed they were more aware of the flights reduced upstream and E-AMAN helped them improve their situation awareness.

Other subjective feedback related to Enroute capacity:

According to Paris FMP feedback:

- Capacity was not degraded in Paris en-route sector LMH
- No ATFCM regulation had to be implemented to cope with XMAN requests

According Bordeaux FMP feedback,

- Capacity was not degraded in Bordeaux en-route sector R1
- No ATFCM regulation had to be implemented to cope with XMAN requests

I.3.1.2 Results impacting regulation and standardisation initiatives

Results impacting regulatory and standardisation activities should be analysed to present the needs for Regulation and/or Standardisation to support the following development phase (V4).

During planning EXE-VLD-07-001, a reduction of Mach 0.04 was decided as the standard Mach number reduction to be applied for Orly arrivals, beyond 200 NM.

This reduction was accepted by all the flight crews operating flights to Orly, from medium-bodies (B737 or A320 series) to wide-bodies (B777 series or A330/340 series).

This trial supports this magnitude of Mach number reduction for XMAN operations.

Furthermore, turboprop aircraft were shown in the Extended AMAN tool, however, speed reductions were not given beyond 200 NM since their position in the arrival sequence can be very different when reaching the regular AMAN.

Turboprop performance doesn't allow the same magnitude of speed reduction depending on aircraft types.

Runway configuration & rates, and arrival sequence by runway or Metering Fix should also be made available in the arrival sequence service from E-AMAN to be available for use by enroute ACC.

I.3.2 Analysis of Exercises Results per Demonstration objective

This section provides, per demonstration objective, a consolidated analysis of the demonstration exercise results.

It provides a general analysis of the results, including rationale of the results, potential deviations with respect to the expected performance benefits, possible reasons and relationship between the results and the appropriate assumptions.

I.3.2.1 OBJ-VLD-01-001 Results

The objective "OBJ-VLD-01-001: No negative impact on safe management of traffic for ATCO" was to show that xStream operational improvements are respecting the current level of safety in air traffic management. The corresponding success criterion is fulfilled when the safe management of traffic by ATC is not compromised and new procedures do not cause critical incidents.

No safety occurrences were reported in Paris ACC, Paris Orly or in Bordeaux ACC.

Qualitative analysis & feedback from operational staff confirms that the safe management of traffic was never compromised in Paris ACC, Paris Orly or in Bordeaux ACC.

This objective can be considered fulfilled.

I.3.2.2 OBJ-VLD-02-001 Results

This objective "OBJ-VLD-02-001: Improve flow prediction in TMA and terminal sectors" was to show that xStream operational improvements provide a better predictability and punctuality of air traffic in TMA / terminal sectors.

The corresponding success criterion is fulfilled when differences between planned / predicted and actual traffic flow at prominent points or at the runway are reduced.

According to performed quantitative analysis, no visible change has been recorded.

However According to the qualitative feedback from Orly Tower supervisor and Paris FMP, the prediction of the arrival sequence at the runway was improved with the use of iAMAN fed by NM data & local TP parameters, which was reliable enough to be for Extended AMAN to Orly airport.

This objective can be considered fulfilled.

I.3.2.3 OBJ-VLD-03-001 Results

This objective "OBJ-VLD-03-001: Apply ATC procedures which allow reduction of fuel burn" was to show that xStream operational improvements provide benefits in terms of environmental sustainability of air traffic.

The corresponding success criterion is fulfilled when fuel efficiency of air traffic is increased while emissions (and noise pollution) are reduced.

Fuel consumption analysis shows a clear decrease in fuel consumption during EXE-VLD-07-001.

This objective can be considered fulfilled.

I.3.2.4 OBJ-VLD-04-001 Results

This objective "OBJ-VLD-04-001: xStream operational improvements increase cost efficiency from more efficient processes for AU" was to show that xStream operational improvements increase cost efficiency from more efficient processes for airspace user.

The corresponding success criterion is fulfilled when flight efficiency is increased and flight management / flight coordination costs are reduced.

This objective was not required by the demonstration plan but is nevertheless covered by the assessment.

During EXE-VLD-07-001, it was demonstrated that all the arrivals to Paris-Orly saw their additional ASMA time reduced by 60s to 90s (depending on baseline scenario), while only an average of 10 flights were receiving XMAN action by reducing by M0.04 around 40 to 50 minutes before their ELDT. This also allowed the drastic reduction of holding patterns during EXE-VLD-07-001.

Moreover, on one occasion, the Orly arrival ATFCM regulation rate could be increased, saving hundreds of minutes of ATFCM delays for the AU.

On another occasion, a bunching during an Orly arrival ATFCM regulation rate could be absorbed by implementing XMAN action in upstream ACC, rather than extending the ATFCM regulation that would have generated additional ATFCM delays for the AU.

This objective can be considered fulfilled.

I.3.2.5 OBJ-VLD-04-002 Results

This objective "OBJ-VLD-04-002: Increased cost-efficiency from more efficient processes for ANSPs" was to show that xStream operational improvements are feasible while maintaining current level of ANSP cost efficiency.

The corresponding success criterion is fulfilled when ANSP costs are maintained or reduced.

This objective was not required by the demonstration plan but is nevertheless covered by the assessment.

During EXE-VLD-07-001 trials, neither extra working hours nor extra staff was needed to apply the Extended AMAN concept in Paris ACC, Paris Orly or Bordeaux ACC.

This objective can be considered fulfilled.

I.3.2.6 OBJ-VLD-05-001 Results

This objective "OBJ-VLD-05-001: Opening capacity improvements by reducing workload and complexity in E-TMA" was to show that ATC capacity usage in TMA is optimized by xStream operational improvements.

The corresponding success criterion is fulfilled when Traffic load, ATC workload or complexity in terminal sectors is reduced.

More than 80% of Paris ATCOs assessed the Paris-Orly Extended AMAN trials did not increase traffic complexity. Moreover, 88% of the ATCOs estimated their situation awareness was not affected.

Orly Tower supervisor feedback in terms of complexity decrease and workload reduction in Paris-Orly TMA during EXE-VLD-07-001 is very positive.

This objective can be considered fulfilled.

I.3.2.7 OBJ-VLD-05-002 Results

This objective "OBJ-VLD-05-002: Assess impacts on en-route capacity" was to show that available enroute sector capacity allows the application of xStream operational improvements.

The corresponding success criterion is fulfilled when Traffic load, ATC workload or complexity in enroute sectors do not exceed available capacity.

According to the interview of Bordeaux ACC operations managing staff, speed advisories transmitted by Paris FMP to upstream sectors could be implemented without impacting the en-route capacity.

For Paris ACC LMH sector, speed advisories could be implemented without degrading the sector's capacity according to the ATCO & FMP feedback.

Only 1 case was reported when the implementation was difficult due to stormy weather and another case due to sector configuration that was not optimal to act on the arrival flows. Sector capacities in Bordeaux ACC were not impacted nor lowered by EXE-VLD-07-001 trials.

This objective can be considered fulfilled.

I.3.3 Unexpected Behaviours/Results

The following main unexpected behaviours were reported during the trials:

- Some difficulty was occasionally reported by Paris ACC ATCO when sequencing jet aircraft, being already reduced upstream, with turboprop aircraft to the Orly IAF. This was a change in the current working methods ATC had to cope with,
- Another difficulty was reported on a few occasions by Paris ACC ATCO when reducing jet aircraft still in enroute phase and the possibility of conflicts with other overflights,
- Another reported difficulty was the inability to comply with the LOA between Bordeaux ACC sector R and Paris ACC sector OT to deliver Paris Orly arrivals in the prescribed way (e.g. 10 NM in trials and at compatible speeds) if speed reductions were applied inside Bordeaux ACC sector R
- XMAN actions provided by Bordeaux ACC R sector may have been difficult to comply with in a few cases (due to ATC workload inherent to the sector or weather issues)

- Integration of pop-up flights inside E-AMAN horizon: when flights in the predicted sequence are departing very close to the horizon, it is very difficult for FMP operator to assess the situation and decide whether to reduce a flight (too much variability on the sequence due to unpredictability of take-off). Solution was to wait that all flights are airborne to pick-up the right candidates. N.B: this effect has already been shown in previous E-AMAN work.

I.3.4 Confidence in the Demonstration Results

I.3.4.1 Level of significance/limitations of Demonstration Exercise Results

Quantitative assessments:

The quantitative assessments were made on solution and reference datasets without weather issues, with comparable regulation rate, comparable traffic demand during peak 2, with the same runway in use.

EXE-VLD-07-001 quantitative analysis contains 10 days of trials, including 95 flights receiving XMAN action in upstream ACCs. (44 in Bordeaux ACC sector R and 51 in Paris ACC sector LMH).

Reference solution #2 quantitative analysis contains 16 days during peak 2 comparable to EXE-VLD-07-001.

Reference solution #1 quantitative analysis contains 35 days during peak 2 comparable to EXE-VLD-07-001.

Peak 2 being one of the busiest arrival peaks in Paris-Orly, if not the busiest, EXE-VLD-07-001 and reference solutions measurements and results are very significant, with the involvement of all the operational staff concerned by the arrival peak: ATCOs in Paris ACC, Orly, Bordeaux ACC, FMP in Paris ACC and Tower supervisor in Orly.

Qualitative assessments:

The qualitative assessments were made as follows:

Bordeaux ACC ATCOs:

- 2 questionnaires were filled by LFBB ATCOs implementing XMAN actions

Paris ACC ATCOs:

- 8 questionnaires were filled by LFFF OT ATCOs receiving flights reduced upstream by Bordeaux ACC
- 8 questionnaires were filled by LFFF LMH ATCOs implementing XMAN actions
- Additional post trial interviews were conducted with the concerned ATCOs.

Paris ACC FMPs:

- 12 questionnaires were filled by LFFF FMP transmitting speed reductions to Bordeaux ACC R sector and Paris ACC LMH sectors
- Additional post trial interviews were conducted with 24 FMPs in Paris.

I.3.4.2 Quality of Demonstration Exercise Results

This section describes all issues concerning the quality of the results achieved in the Demonstration Exercise #01. In that regard quality could refer to both the accuracy of results and the confidence in the results, which might be influenced by decisions, constraints, and assumptions made at exercise level.

For assessment & benchmarking matters, only “comparable” peaks have been considered, with the following parameters being taken into account:

- Full and equivalent data available to be analyzed,
- No weather issues,
- No technical issues,
- Same runway configuration,
- Same arrival regulation rate for LFPOARR2 TV
- Same total number of movements during peak 2
- Or other issues degrading the performance, in order to avoid any side effect.

Comparison of traffic load during the targeted peak 2 and departure/arrival balance show that solution scenario is comparable to reference scenarios:

	EXE-VLD-07-001	Reference scenario #2 (2017)	Reference scenario #1 (2016)
Average total number of movements	104	101	102
Average regulation rate for LFPOARR2 TV	25,4	25,3	25,8
Average movements per hour	41,4	40,2	41,0
Average number of arrivals per hour	23,0	23,0	23,4
Average number of departures per hour	18,4	17,2	17,6

Table 7: Comparison between EXE-VLD-07-001, reference scenario #1 and reference scenario #2

Each scenario (reference and solution) contains at least 10 days analysed, which represents a total of 100 flights per peak that have been proven statistically sufficient.

I.3.4.3 Significance of Demonstration Exercises Results

Significance of the results refers to statistical and operational significance. Statistical significance will be based on the number of independent variables of the different Demonstration Exercise and the number of exercise runs carried out. Operational significance concerns operational realism of the different Demonstration Exercises which depends on a number of factors which are very much dependent on the chosen environment.

The EXE-VLD-07-001 analysis outlines the need of applying the Extended AMAN concept, especially when the runway capacity is severely degraded compared to the traffic demand.

The 2017 trials ran during the highest arrival peak in Paris-Orly airport, second airport in France in terms of movements, when facing strong capacity constraints at the airport, in this period during runway works.

These demonstration exercises results from 2017 trial period were compared with 2016 performance during the same arrival peak, with similar traffic loads, similar ATFCM regulation rates, and similar weather conditions.

It was proven that the concept already shows clear operational benefits in terms of flight efficiency, cost efficiency, capacity, even with only 80% of the arrival flows eligible to a speed reduction beyond 200 NM.

I.4 Conclusions

Although some ACCs (Marseille, Brest, MUAC) close to the 200 NM horizon were not part of the trial, the trial showed significant benefits in terms of

- Flight & cost efficiency: significant reduction of additional ASMA delay, fuel consumption and holding patterns for all arrivals during the trial period were measured with no extra cost supported by the ANSP
- Capacity: Reduction of ATCO workload in TMA with no increase of ATC sector complexity in E-TMA and in the upstream ACC, while maintaining a continuous and high runway feed
- Airspace Users feedback: No specific remarks. Air France supports this procedure and recognizes its benefits as described in the Demo Report.

These trials should be transformed to daily operations, including the development of an electronic process to transmit speed advisories to upstream ACCs instead of phone coordination.

Moreover, it would be even more beneficial to include more ACCs in the future, such as Marseille ACC and Brest ACC.

I.5 Recommendations

I.5.1 Recommendations for industrialization and deployment

This section contains recommendations for industrialization and deployment phases:

- Electronic coordination of speed advisories between the E-AMAN tool and the upstream ACCs CWP allows better implementation of XMAN actions;
- Participation of neighboring ACCs handling the major arrivals flows to the airport in the Extended AMAN process is crucial.
- Provide a comprehensive briefing and cross-training of Tower Supervisors, Flow Managers, Approach & upstream ACC ATCOs to provide a global view of the concept to all the operational staff;
- The compliance with the Letter of Agreements between upstream ACC, Extended TMA and TMA should have priority to XMAN actions to avoid any confusion between the operational staff;
- Turboprops and flights in climbing phase or close to the horizon should be considered separately in the arrival strategy;
- Obtain the best accuracy available of ELDT/ETAs in order to have the most realistic sequence and take the most appropriate actions;
- Installing an air situation display next to E-AMAN may also help the Flow Manager in assessing the situation, depending on the LOA with upstream sectors and the local conditions;
- Horizon and effectiveness of the concept can depend on the amount of pop-up flights and mix of traffic (between turboprops/jets); therefore the application of this concept should be (re-)customized to local traffic conditions upon implementation as well as from time to time;

I.5.2 Recommendations on regulation and standardisation initiatives

It is recommended to:

- Standardize the XML format for the exchange of requests with upstream ACCs (speed advisories, TTL, STA, etc.).
- Provide an automatic way of determining the status of a request (has it been implemented or not) with the XMAN Status.
- Provide a communication tool between the XMAN provider and the upstream ACCs to coordinate & plan the availability and unavailability of XMAN service rendered by the enroute ACCs.

=== End of Appendix I Demonstration Exercise EXE-VLD-07-001 Report ===