Appendix L Demonstration Exercise EXE-VLD-08-001 (Zürich Extended Arrival Management) Report

L.1 Summary of the Demonstration Exercise EXE-VLD-08-001 Plan

L.1.1 Exercise description and scope

The scope of this exercise is to extend Zurich arrival management horizon and use arrival management techniques for the calculation, updating and passing of arrival constraints to airborne aircraft such as AMAN allocated time, time-to-lose/gain or speed advisory from the Zurich arrival management system to upstream control units.

The main objective is to compute an entry sequence into the Zurich extended-terminal sequencing area, transmit arrival constraints to upstream centres in order to smooth traffic entries and enhance the use of the available capacity in the terminal area. The expected improvements are the following:

- Optimization of global arrival management for Zurich (in particular for the peak waves 3 and 4, i.e. 10:30-12:15 and 15:20-16:45 LT),
- Improvement of sector load predictability, particularly in Zurich terminal airspace & available ARR capacity predictability,
- Improvement of environmental efficiency.

Current Zurich AMAN horizon is approximately 80 NM (radar coverage). The main objective of EXE-VLD-08-001 is to extend arrival management horizon to a radius of 200 NM. The exercise was therefore closely linked with skyguide internal Extended-AMAN implementation project in order to benefit from skyguide's AMAN provider, HARRIS, newest version of AMAN system.

Also a close link was maintained with FABEC XMAN project in order to keep synergies between the projects and ensure an efficient and seamless process of improvement for the arrival management at Zurich.

The exercise addressed flights for all timeframes with a 200 NM horizon, coordinating with upstream DSNA Reims ACC. Two main flows were considered:

- Brest ACC → Reims ACC → ZRH ACC + ARR
- Maastricht ACC → Reims ACC → ZRH ACC + ARR

The coordination was performed with flights entering Reims ACC at approximately waypoints RESMI-TEPRI for flights coming from Brest ACC and at DIK for flights coming from MUAC ACC; which represents approximately 200 NM from Zurich (see Figure 1).

Figure 1: EXE-VLD-08-001 Extended horizon (orange line) in comparison with the baseline horizon (red line) as well as considered incoming flows

The extension of the AMAN was tackled with the newest version of AMAN (also referred as OSYRIS), which has an ETFMS connection and is therefore capable to retrieve flight data from the Network Manager.

The E-AMAN was installed in the TEST centre with all the connectors to OPS systems to retrieve the live operational inputs; such as FPL, Tracks and Weather data. The E-AMAN system was working in parallel of the current AMAN system; called "CALM". Within the Zurich radar coverage area, CALM was solely used.

The Extended arrival sequence was provided on the TEST PENS network and was retrieved automatically by Reims system at regular intervals (see Figure 2).

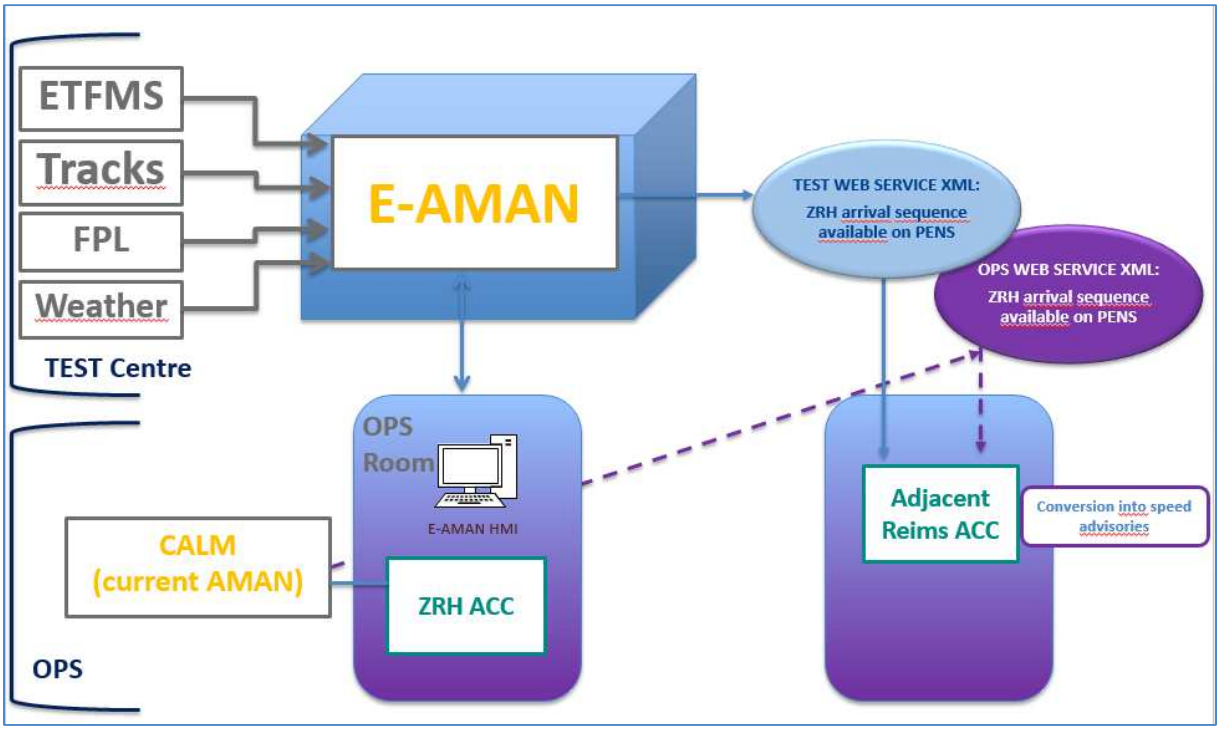


Figure 2: EXE-VLD-08-001 Technical Infrastructure

During the Trials, an operator had to input all the CALM parameters into the E-AMAN to reproduce the exact situation into the E-AMAN (cf. Figure 3). The manual interactions with the E-AMAN interface were the following:

- Runway & route selection,
- Constraints: separation, runway configuration, runway blocking (gaps),
- Slot creation, sequence change,
- Holding capacity.

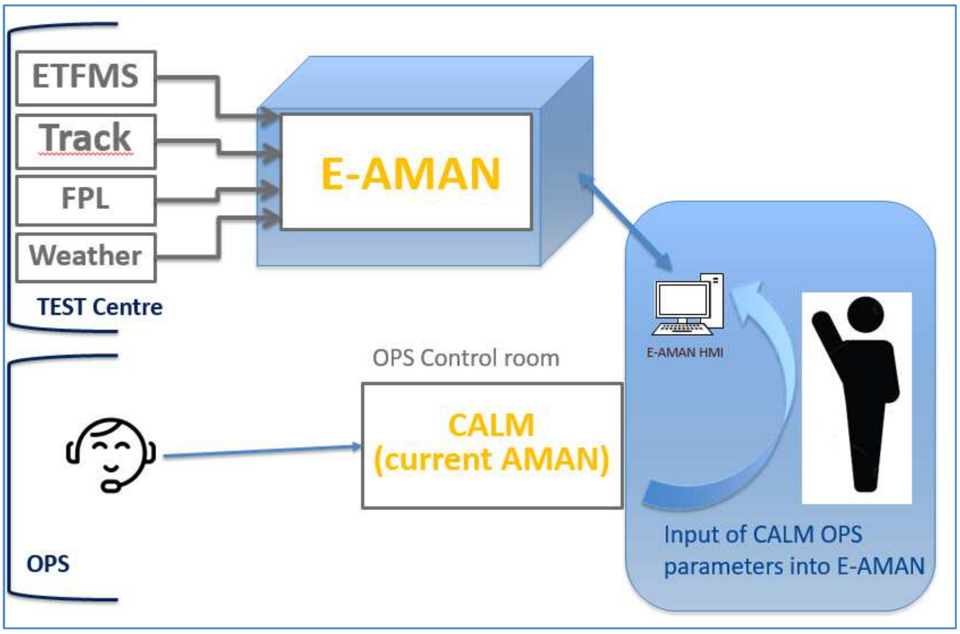


Figure 3: EXE-VLD-08-001 Execution of live trials

The operational procedure defined was the following:

1. E-AMAN gets the full operational situation with ETFMS flight data to cover the 200 NM horizon.
2. E-AMAN computes Zurich arrival sequence (with Time-To-Lose/Time-To-Gain & Requested Time Over) and make it available on the TEST PENS network.
3. Sequence is retrieved by Reims.
4. Speed advisory displayed by 4ME (Reims system) based on the E-AMAN delay.
5. Speed instructions are indicated on the corresponding 5H / 5E / KD / 2F Reims sectors.
6. Reims sector instructs speed reduction when possible.

It was agreed to keep the procedure simple in order to reach best feasibility level; therefore it was limited to one action per flight; no revision of speeds were possible.

Table 1defines the speed reductions based on the Entry level in Reims Upper Area, the delay value provided at Reims Exit Coordination Point BLM, and the corresponding Mach and knots advisories.

EFL in REIMS UAC	E-AMAN Delay @ BLM	Mach Advisory	Speed Advisory
EFL > 315	D>5min	-M0.04	250Kts
EFL < 315	D>5min	Nil	250Kts

Table 1: EXE-VLD-08-001 Speed reduction table

L.1.2 Summary of Demonstration Exercise EXE-VLD-08-001 Demonstration Objectives and success criteria

The objectives and success criteria for EXE-VLD-08-001 are provided in the xStream DEMOR main document in chapter 3.4 "Summary of the xStream Demonstration Plan".

L.1.3 Summary of Demonstration Exercise EXE-VLD-08-001 Demonstration scenarios

Solution scenario

The Solution scenario, also referred as the Trial period, is the trials' execution dates from 16 September until 27 September 2019 from 08:00 until 17:00 LT, excluding the weekend days 21 and 22 September 2019.

The Solution scenario operates in parallel the new E-AMAN system, for the transmission of the extended arrival sequence to Reims & Reims' actions; and the current AMAN system (known as "CALM"), which takes over the arrival management once the flights enter the Zurich radar coverage area.

Reference scenario

The Reference scenario, also referred as the Baseline period, is the current operations from 2nd September until the 13 September 2019 from 08:00 until 17:00 LT, excluding as well the weekend days 7 and 8 September 2019.

The Reference scenario operates solely the current Zurich AMAN system ("CALM").

L.1.4 Summary of Demonstration Exercise EXE-VLD-08-001 Demonstration Assumptions

The assumptions concerning EXE-VLD-08-001 are provided in the xStream DEMOR main document, in chapter 3.4 "Summary of the xStream Demonstration Plan".

L.2 Deviation from the planned activities

The trials were executed all the planned days; i.e. daily from 16 until 27 September (21 and 22 September excluded), from 08:00 until 17:00 LT.

Some local situations (weather, or local restrictions due to Zurich RWY concept) mitigated the expected results, but those conditions serve the analysis and will be of relevance for the exercise conclusion and recommendations. An attempt is also made to compensate these effects by excluding days with severe weather, strong winds, totally incomparable traffic constellation etc. by applying the comparability checks described in Appendix E. However, due to the relatively small sample size of 10 trial days as well as 10 baseline days in total, this was limited to extract the 6 most comparable trial and baseline datasets. A full list of this data subset can be found below.

Date	B / S	Most Comparable
02.09.2019	B	X
03.09.2019	B	
04.09.2019	B	X
05.09.2019	B	
06.09.2019	B	X
09.09.2019	B	X
10.09.2019	B	
11.09.2019	B	
12.09.2019	B	X
13.09.2019	B	X
16.09.2019	S	
17.09.2019	S	X
18.09.2019	S	X
19.09.2019	S	X
20.09.2019	S	X
23.09.2019	S	
24.09.2019	S	
25.09.2019	S	
26.09.2019	S	X
27.09.2019	S	X

Table 2: Subset of most comparable datasets to compensate weather disturbances etc.

Further, it was foreseen to use a tailor-made questionnaire for qualitative assessment. Unfortunately, no questionnaire was answered and returned by the controllers, which is why the qualitative assessment is restricted to feedback received in general.

L.3 Demonstration Exercise EXE-VLD-08-001 Results

L.3.1 Summary of Demonstration Exercise EXE-VLD-08-001 Demonstration Results

See DEMOR main document chapter 4.

1. Results per KPA

a. KPA Safety

i. Quantitative Assessment

Number of Incident Reports

None incident were caused/reported due to EXE-VLD-08-001 implementation.

ii. Qualitative Assessment

Subjective feedback related to Safety

No safety concerns were raised, neither by Reims ACC nor by Zurich ACC personnel.

b. KPA Predictability and Punctuality

This assessment was based on a detailed analysis of the CALM log files for baseline and trial days. The estimated landing time as well as the planned landing sequence, which were valid at the time when a flight was entering the TMA ("entry time") was compared with the actual landing time resp. actual landing sequence. This was additionally done for 15min before entry time, 10min before entry time, 5 min before entry time and 5 min after entry time to better cover the CALM horizon and the TMA itself (otherwise only the situation at the TMA boundary would be assessed).

However, not in every case a flight was contained in the current AMAN sequence at the required time (it was instead contained in the "list of temporary removed flights" in the CALM log file). As a consequence, the predictability results could only be calculated for about 80%-90% of the arriving flights. Details are provided in the figures below.

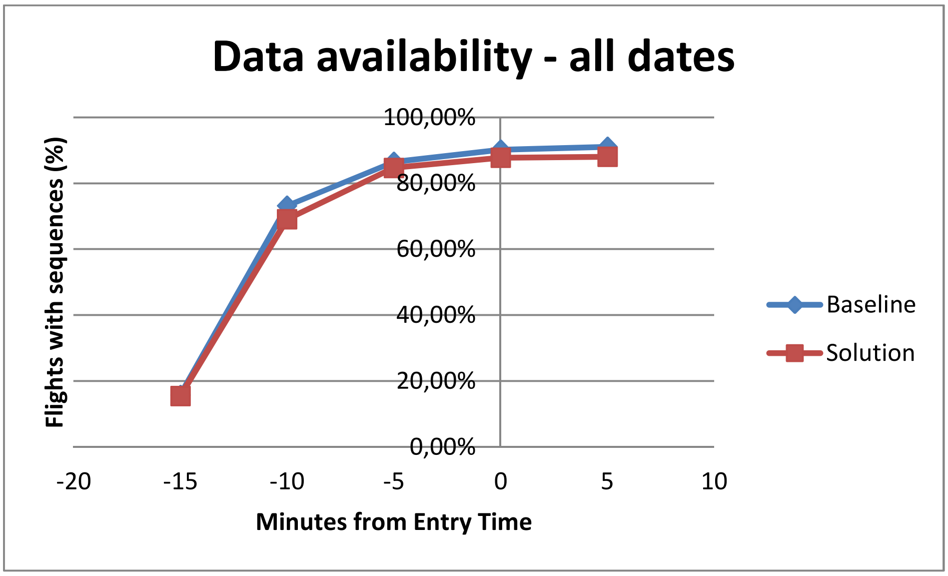


Figure 4: Data availability - All dates

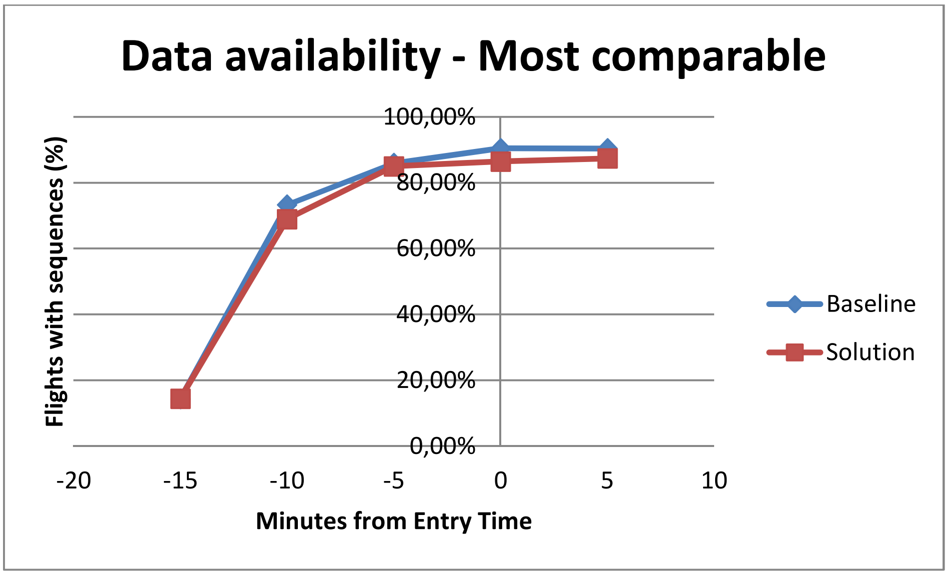


Figure 5: Data availability - Most comparable dates

The significant drop in data availability at 15 min before entry time is caused by the 80NM-AMAN horizon of CALM. As a consequence, the results at 15 min before entry time are very unreliable and only included for completeness.

i. Quantitative Assessment

Time difference actual - planned

As the CALM logs regularly contain ETOs for the planned landing runway and just now and then for intermediate waypoints, reliable results can only be calculated as an ELT-ATA comparison. ELT means here the estimated landing time according to the current CALM predicted sequence and arrival flow. Results are visible in the figure below.

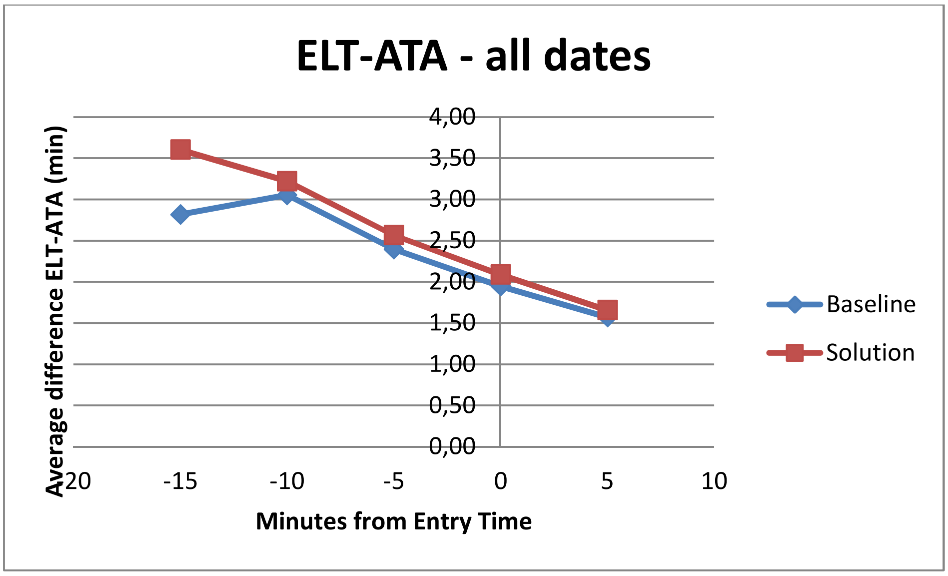


Figure 6: Time difference ELT-ATA, all dates

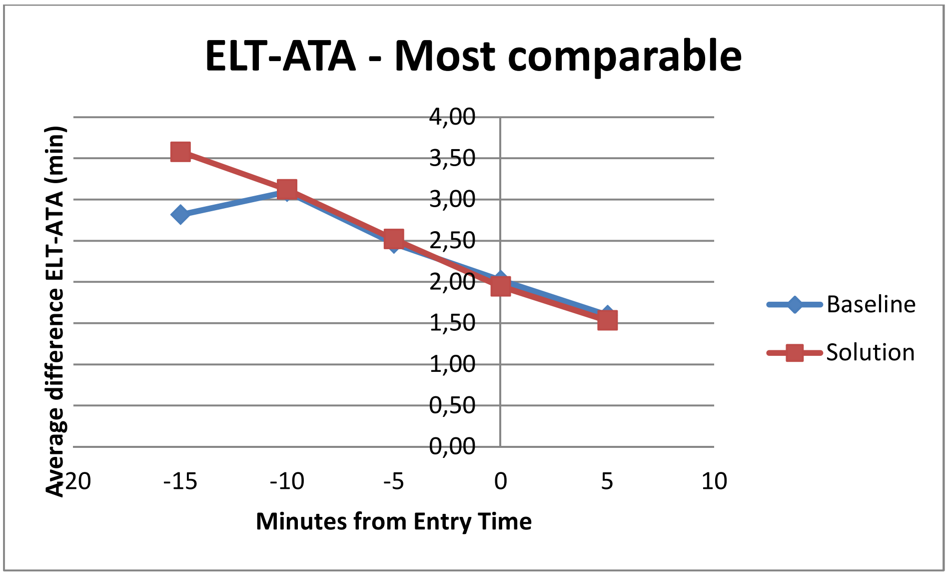
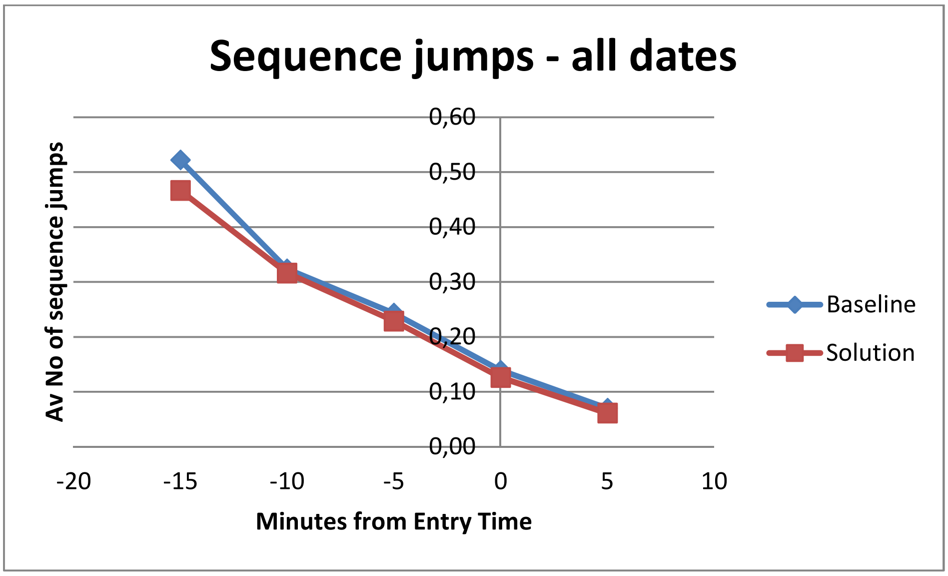
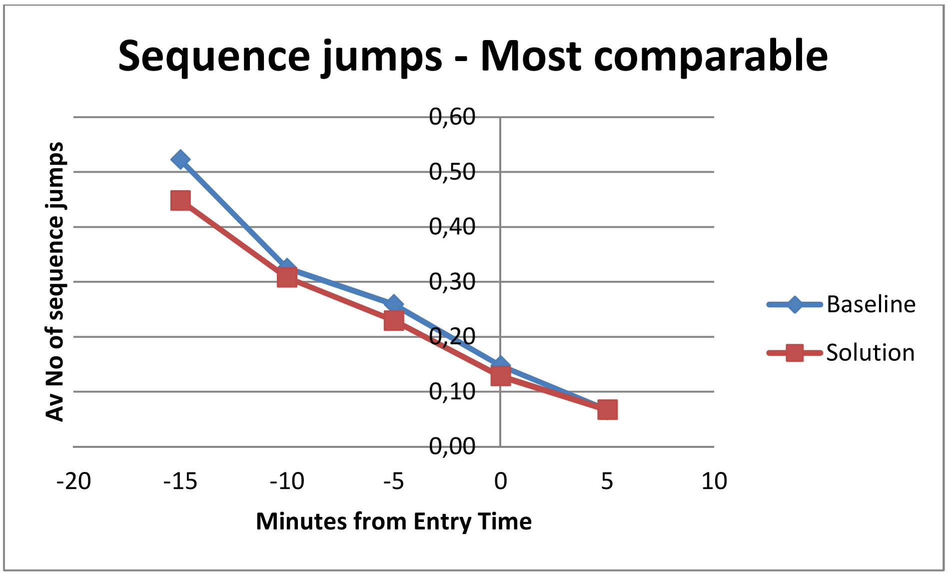


Figure 7: Time difference ELT-ATA, most comparable dates

It can be seen that the difference is very small for all dates (9 sec on average) and not measureable for the most comparable dates. In total, these results should be considered to indicate no change.

This indicator is a measure for sequence stability and counts the average number of sequence jumps per flight. More detected sequence jumps means a less stable approach sequence. Results are visible in the figure below.





Both figures indicate a very slightly decrease in the average number of sequence jumps (0,01 to 0,02 less sequence jumps per flight on average). This is a positive result and may be real, but due to the low magnitude (which may well correlate with the low flight participation) and small sample size the benefit should be confirmed again by separate investigations. Operationally, the measured difference will not be recognized by controllers or pilots as it is too small.

ii. Qualitative Assessment

Not foreseen

c. KPA Environment

i. Quantitative Assessment

Fuel Consumption

Track data provided by skyguide 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 mitigate outliers.

For this reason, the 10 most frequent aircraft types that are contained in BADA version 3.13 were considered for the analysis, i.e. A319, A320, A321, A333, A343, B737, B738, B77W, E190 and CRJ9. In total, 70.83% of all flights were performed with one of these aircraft types. The shares of these aircraft types are visible in Figure 8.

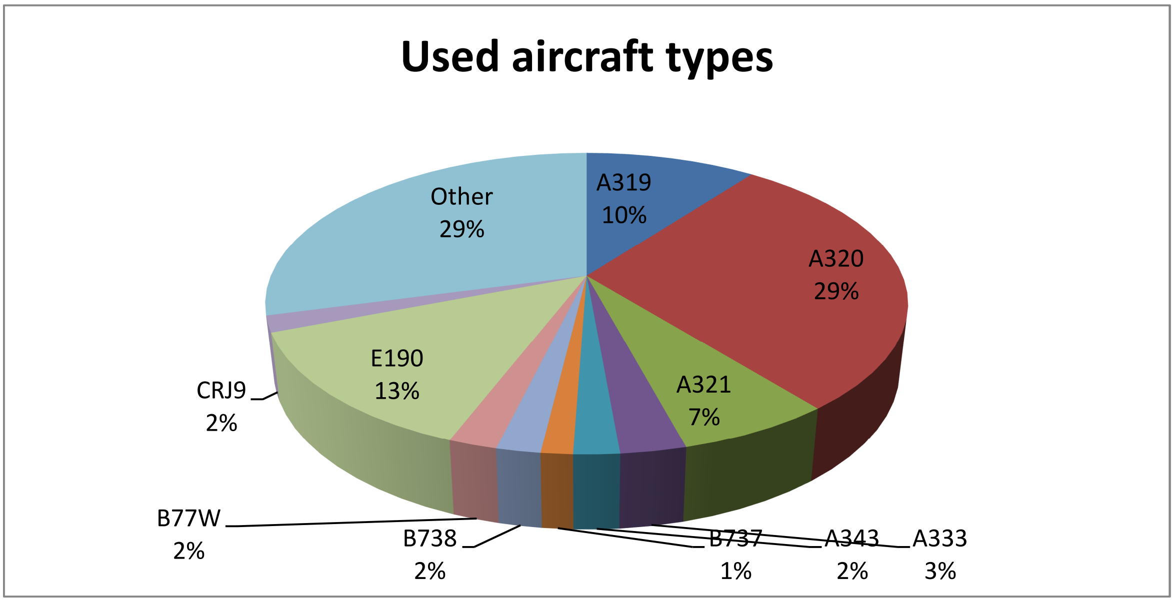


Figure 8: Average aircraft type shares of the air traffic during trial and reference datasets

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 a circle of 30NM around LSZH ARP).

The hypothesis is that E-AMAN leads to a reduction of fuel burn in Zurich TMA, 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 (10 days) and comparing them to all reference datasets (10 days), the average fuel saved per flight within a circle of 30NM around LSZH ARP according to the performed analysis equals **0,68%**.

When only considering the most comparable dates according to the described subset, the average fuel saved per flight within a circle of 30NM around LSZH ARP according to the performed analysis equals **1,04%**.

This is basically a positive result, but it has to be noted that this is based on an estimation with BADA 3.13, which is why the observed change is very close to or below the accuracy of this assessment method. The conclusion is that this result most probably either means 'no change', but a very small improvement is not excluded.

Time per Level

Track data provided by skyguide was used for this analysis.

The purpose of E-AMAN is to absorb delay during enroute flight rather than inside the TMA in low altitudes. Unfortunately the track data are not covering the complete CALM horizon a complete analysis cannot be made. Flights entered the coverage area at levels between FL120 and FL200, which is why only the analysis of radar plots below FL120 is meaningful. However, at least a slight decrease should be visible.

For this analysis one level was considered to actually be a level band between -500< and +500≤. The results of this assessment are visible in the figure below.

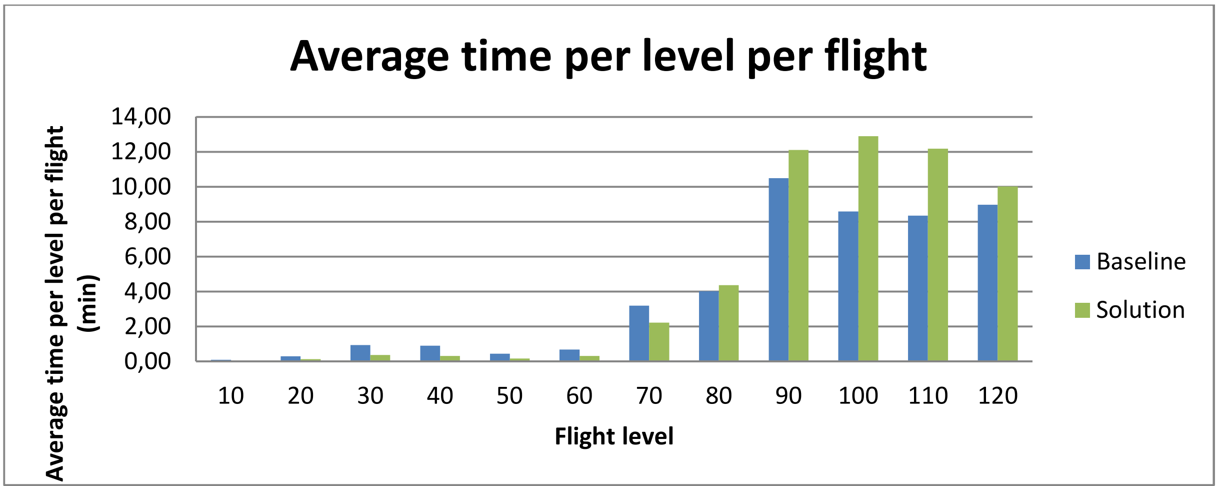


Figure 9: Average time per level per flight - all dates

A very slight decrease of the time spent per level below FL80 is visible, but on the other hand a significant increase above FL90 was observed. The reason for this is still subject to discussion and investigation and cannot yet be answered. However, it is doubted that this was actually caused by E-AMAN.

The same conclusions are also valid for most comparable dates, there are only small differences.

ii. Qualitative Assessment

Not foreseen

d. KPA Cost Efficiency

In order to assess cost efficiency, the number of track miles for SWISS flights within a radius of 200 NM around Zurich Airport is analysed. It is investigated how many track miles can be saved by so-called E-AMAN flights, which receive a speed reduction by Reims Control, to comparable baseline flights. The time until landing within the 200 NM range is also considered. Due to the early control and deceleration of the aircraft, it is expected that the number of track miles will decrease, but the time until landing will remain stable with given traffic volume.

i. Quantitative Assessment

Air Transport Distance Efficiency

The following graph shows the average track miles flown each day for all flights within a 200 NM circle around Zurich Airport coming from Reims Control via BLM. In addition, the average values for the two time periods before the trial (left) and during the trial (right) are shown in dark grey.

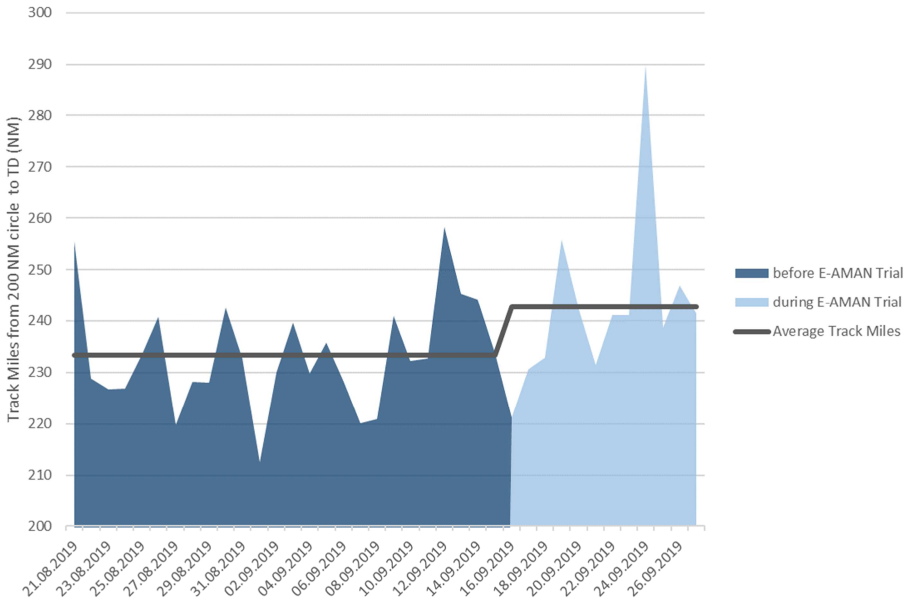


Figure 10: Distance flown from a 200NM circle around the airport to touchdown before and during the E-AMAN trial

The left average value shows that in the time before the trial an average of 233 NM track miles are flown around the airport within 200 NM until landing. The right average shows that the average number of track miles during the trial is more than 4 % at 243 NM.

This fact can be an indication that during the two-week trial the runway concept often had to be changed due to weather conditions, resulting in a lower landing capacity and more track miles. Another reason could be a generally higher traffic volume during the trial phase. It is also possible that during the trial additional take-offs took place on runway 16 (e.g. due to high T/O weight, high tailwind etc.), which reduces the landing capacity for runway 14 and leads to longer approaches due to the dependent take-off and landing concept in Zurich.

For these reasons, it is very difficult in this context to compare flights before and during the trial. Therefore, E-AMAN flights are only compared to flights that took place during the trial. In particular, the number of E-AMAN flights is relatively low, as only SWISS flights are taken into account for the evaluation. In addition, it was found that during the trial nearly only flights with a landing time between 7-10 UTC were slowed down (due to the high Time to Lose Threshold defined for the trial). Therefore, the baseline scenario is also limited to flights with a landing time between 7-10 UTC. Furthermore, flights with a departure airport within the 200 NM range are excluded from the statistics, as these flights influence the average number of track miles downwards.

The following chart shows the average number of track miles flown within 200 NM around Zurich Airport per day. The track miles of the reduced E-AMAN flights are shown in light blue and the comparable baseline flights in dark blue.

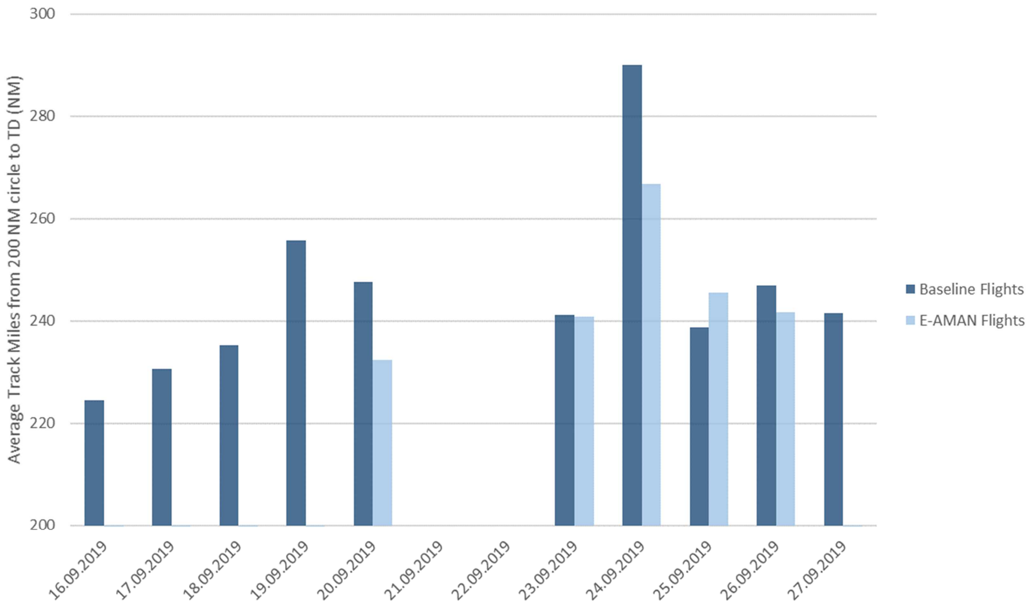


Figure 11: Average distance flown per day from a 200NM circle around the airport to touchdown

The chart shows that there are days on which not a single SWISS flight has received a speed reduction, i.e. no E-AMAN flight has taken place. Of the 10 weekdays on which the trial took place, between three and six flights were slowed down on each of the five days with speed reductions.

The decelerated E-AMAN flights have a lower average on four days and a higher average on one day compared to the baseline flights. Basically, there is no significant difference between the number of track miles of the E-AMAN flights and the baseline flights. One explanation why the E-AMAN flights did not fly significantly fewer track miles could be that during the trial it was not the E-AMAN approach sequence that was used, but skyguide's existing AMAN approach sequence. This means that E-AMAN flights were rearranged into the approach sequence at BLM when they were transferred to Swiss Radar and could not expect a shortened approach. If in a next trial the E-AMAN sequence were extended to all approaches and applied effectively, a significant reduction of the track miles would be possible and one could benefit from the E-AMAN concept.

Air Transport Time Efficiency

The following graph analyses the average flight time for SWISS flights in minutes from entering the 200 NM circle around the airport to touchdown (analogous to the previous graph with track miles).

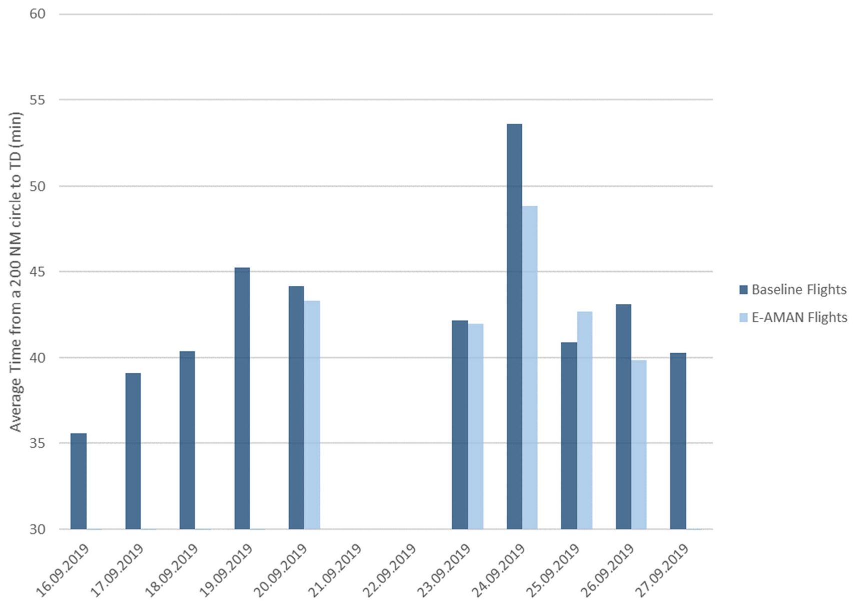


Figure 12: Average time spent in air per day from a 200NM circle around the airport to touchdown

The graph clearly shows that the difference in the minutes flown are generally correlated with the track miles flown. On days when the E-AMAN flights flew significantly less miles than the baseline flights (20, 23, 24 and 26 October 2019), the flights also spent less time in the air. Vice versa, more miles flown during the trial (25 October 2019) also means a longer flight time until landing.

After a successful E-AMAN implementation, it can be expected that the flight time until landing will remain constant (landing capacity will not be increased by E-AMAN), but due to early sequence control and aircraft deceleration, fewer track miles will have to be flown.

In summary, despite the small number of flights during the short trial, the E-AMAN concept is very promising. During the trial, the communication between skyguide, Reims Control and the pilots was already functioning via all interfaces. Future steps will now involve evaluating a larger number of E-AMAN flights, calculating the Time to Lose more reliably and time-stable and defining a suitable threshold for speed reduction. This will make it possible to demonstrate a clear and significant added value in future trials. Especially if the approach sequence is shared with the AU in the future, there is great additional potential for AU to proactively control the operational processes.

ii. Qualitative Assessment

Not foreseen

e. KPA Capacity

i. Quantitative Assessment

Traffic Density (TMA)

Track data provided by skyguide was used for this analysis. Traffic Density here means aircraft per airspace volume, similar to physical density (parts per volume). This value is calculated here for the TMA Zurich as a function of time. As a simple indicator, the average as well as the maximum peak was determined. Results for all dates are visible in the figure below.

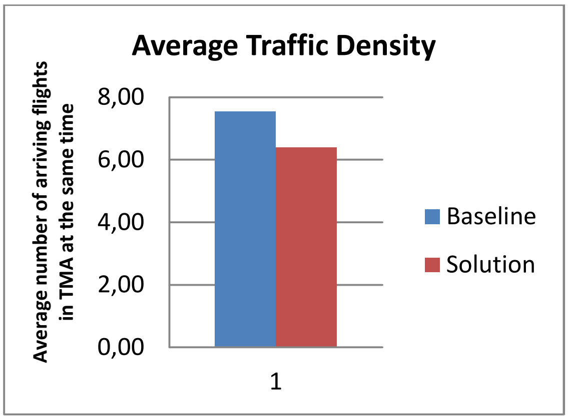


Figure 13: Traffic Density - Average

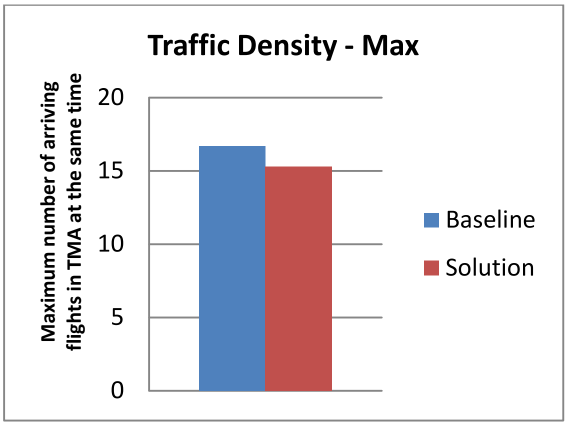


Figure 14: Traffic Density - Maximum

According to this indicator, the average traffic density as well as maximum peak density decreased, which points towards less congestion in the TMA during trial periods.

Flight Path Diversity

Radar track data provided by skyguide 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 to analyse the flight path diversity in a 30NM circle around Zurich ARP.

The flight path diversity indicator has a value from 0 (zero diversity) to 1 (max diversity) and is a mean to quantify traffic complexity, based on flight trails.

The following table shows the results for traffic arriving at Zurich airport (hypothesis: E-AMAN leads to less bunching and less vectoring and other path stretching manoeuvres inside the TMA. Therefore, this indicator should show a slight decrease).

		Average flight path density (value from 0 to 1) / Standard deviation (SD)
All dates	**Baseline**	0,8799 (SD: 0,0355)
	Solution	0,8448 (SD: 0,0528)
Most comparable dates	**Baseline**	0,8768 (SD: 0,0306)
	Solution	0,8578 (SD: 0,0543)

Table 3: Flight path diversity indicator

The expected decrease can be observed, indicating a slightly lower traffic complexity.

Total ATFCM Delay

For this assessment all LSZHARR regulations were analysed. Unfortunately, various regulations caused by weather were activated, which made it difficult to determine any benefit. Therefore, only the "most comparable" dates are considered in the following, as weather delays are filtered out to a certain extend (but not completely due to a required minimum sample size).

Using "Most comparable dates"	Nb LSZHARR regulations	Delays due to WX	Other delays
Trials	11 (incl. 5 for WX reason)	5440	1914
Baseline	9 (no WX reason)	0	1737

Table 4: ATFCM delay for most comparable dates

The Trials did not demonstrate real gain regarding ATFCM delays, but due to the trial configuration and limitations (only ¼ of arrival flows considered, E-AMAN used for coordination with Reims; current AMAN taking over the flights once in ZRH; short and weather-impacted Trials period), it was hardly possible to expect a reduction in ATFCM delay.

During the Trials' period, Zurich area was significantly affected by weather restrictions compared to the Baseline period. 60% of the total ATFCM delay during the Trials period were due to weather reasons regulations; whereas only 28% in the Baseline period.

ii. Qualitative Assessment

Subjective feedback related to Capacity

According to the feedback from TMA and upstream enroute air traffic controllers, an assessment was difficult to make as only ~25% of the arrivals (only those passing through Reims ACC airspace) were considered in the trials for implementing speed reductions. Therefore it was not really valuable to assess capacity and ATCO workload in this configuration. In any case, no feedback was received that workload was significantly increased, neither situation awareness decreased or capacity increased. Actually, no significant change was perceived compared to normal operations. The one-shot-procedure for issuing speed advisories in enroute airspace has given satisfaction as it did not increase overall RT load. A very slight increase in terms of ATCO workload in enroute airspace was reported, but it is expected that this will not be the case in the future anymore as trust in the system builds up and further optimization regarding the procedure and its steps is expected. Situation awareness was guaranteed by the fact that all sectors concerned by a particular flight were updated with the advisories and related actions taken.

Two times the ATCOs witnessed that flights coming Reims (Trials flights) were overtaken by flights coming from East (non-Trial flights). This confirms the fact that the trials' configuration (only arrivals approaching via Reims ACC were considered) was not optimal.

2. Results impacting regulation and standardisation initiatives

The EXE-VLD-08-001 experienced a reduction of Mach 0.04 to be applied for Zurich arrivals beyond 200 NM.

This reduction was accepted by all the flight crews operating flights with majority of aircraft types (medium to heavy).

This trial supports this magnitude of Mach number reduction for E-AMAN operations. However all aircraft types should be studied for a further standardisation of the speed reduction magnitude implementation.

Secondly, the arrival sequence by metering fix, as well as the upstream reduced flights, should be made available to En-Route ACCs for a better situation awareness and arrival management.

L.3.2 Analysis of Exercises Results per Demonstration objective

1. EXE-VLD-08-001 OBJ-VLD-01-001 Results

This objective 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.

This objective was covered by a quantitative assessment ('number of incident reports').

As no incidents were reported during the trials the objective can be considered as fulfilled.

2. EXE-VLD-08-001 OBJ-VLD-02-001 Results

This objective 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.

Time difference actual-planned indicates no change. Landing sequence predictability indicated a no change to very slight improvement.

Therefore, this objective is considered partially fulfilled.

3. EXE-VLD-08-001 OBJ-VLD-03-001 Results

This objective 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.

Estimated fuel consumption based on BADA 3.13 does not show a significant change. But a slight improvement is not excluded (accuracy of the method).

Time per level indicates a very slight improvement FL80 (less time spent in those levels).

The objective can therefore be considered as partially fulfilled.

4. EXE-VLD-08-001 OBJ-VLD-04-001 Results

This objective 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.

An improvement of flight efficiency could not clearly be determined but is not excluded. However, E-AMAN is judged to offer a great potential for the airspace user.

The objective can be considered as partly fulfilled.

5. EXE-VLD-08-001 OBJ-VLD-05-001 Results

This objective 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.

Quantitative assessment indicates a reduction of traffic density and traffic complexity in the TMA.

The objective can be considered fulfilled.

6. EXE-VLD-08-001 OBJ-VLD-05-002 Results

This objective 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.

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

According to qualitative feedback, E-AMAN does not increase workload or decrease situation awareness.

The objective can be considered fulfilled.

7. EXE-VLD-08-001 OBJ-VLD-05-003 Results

This objective was to show that xStream operational improvements lead to a reduction of ATFCM measures.

The corresponding success criterion is fulfilled when flight delay caused by ATFCM is reduced.

A reduction of ATFCM delay could not be determined as various regulations (mainly due to weather issues) were activated, making a meaningful assessment hard to impossible.

The objective must therefore be considered as not fulfilled.

L.3.3 Unexpected Behaviours/Results

As already described previously, Zurich area was significantly affected by weather restrictions during the Trials' period, which impacted the comparison of the measures with the baseline period and therefore limit the benefit assessment of the trials.

L.3.4 Confidence in the Demonstration Results

1. Level of significance/limitations of Demonstration Exercise Results

Due to the low sample size (10 trial days and 10 reference days) the level of significance must be considered as low.

The exercise suffered from the following limitations:

- Only flights approaching via Reims ACC took part in the trial, which leads to a very limited measureable benefit. It can be expected that the real advantages of E-AMAN are higher than described in this report.
- The available data (especially radar track data) was limited to the area controlled by Zurich ACC for confidentiality issues. For an optimum assessment, at least the baseline AMAN horizon (in this case 80NM around Zurich airport) should be covered.
- Trials were performed in only two weeks. ATCOs usually need some time to get fully acquainted with the new working method, which is why it can be expected that speed reductions were given hesitantly, especially in the first week of the trials. This correlates with assessment results. As a consequence, it can again be expected that the benefits of E-AMAN are actually higher than described in this report.

2. Quality of Demonstration Exercise Results

The source of data for both the Trial and Baseline periods are the NM EFTMS, skyguide track radar and SWISS flight data. Those sources are reliable and therefore the data quality can be assessed accurate. DLR analysis tools are also proven to be reliable as most of them were and are regularly used for all kinds of simulated or live air traffic validations, and therefore full confidence can be given into the results.

For specific KPAs assessment, only “comparable” dates have been considered in order to avoid side effect or jeopardization of the performance, 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,
- Approximately same total number of movements.

More detail can be found in Appendix E.

3. Significance of Demonstration Exercises Results

The results reach the significance level to complete and assess the Demonstration objective and support directions and recommendations for the E-AMAN implementation at Zurich. However the Trial duration (only ten days), configuration (only 25% of incoming flows considered) and E-AMAN system maturity do not yet permit to provide a full view on the expected benefits when a fully operational E-AMAN is implemented, but still highlights the need of applying an Extended AMAN concept.

L.4 Conclusions

The step from AMAN to cross border E-AMAN brings great ecological and economic added value to all stakeholders. In addition to the reduction in fuel consumption/costs and thus CO2 emissions, E-AMAN leads to an overall reduction in the workload for ATCOs and a noise reduction in the vicinity of the airport.

The trial has shown that the interface between skyguide and Reims Control with information on which aircrafts should be slowed down is working well and that a user-friendly HMI is available for Reims ATCOs.

It should be noted that during the trial both current AMAN and E-AMAN systems were working in parallel, thus the existing AMAN sequence was effectively applied, and the calculated E-AMAN sequence was only shared with Reims Control. Furthermore the remaining adjacent airspaces did not participate in the trial. Only one-fourth of the arrival flows were considered in the Trials and this represented a significant limitation for the benefits assessment, as this occasionally lead to an aircraft being slowed down early and later having to fly additional miles based on the applied AMAN sequence.

Concerning the early deceleration of flights, it is important to note that this leads to an earlier TOD. However, early descent to lower altitudes is not always possible due to the sectors below. In any case it makes sense to give a speed reduction during the cruise as soon as possible and not only in the descent, because airplanes cannot fly the necessary descent profile with simultaneous speed reduction. This would take away the ecological added value.

Regarding the threshold from with which an aircraft is slowed down, 5min were chosen for the trial in order to ensure the stability of the sequence (and avoid volatility of delays due to the extended horizon). However, this threshold is too high to take advantage of the maximum possible added value of E-AMAN. Airplanes can usually reduce a maximum of 3-4 minutes with the applied speed schedule of -M0.04 or 250kts, which is why a lower threshold is worthwhile.

The decision was made to convert the calculated TTL into a Mach/Speed instruction and not to use a TTO over a WPT to communicate to the pilots. This makes the behaviour of the pilots more predictable for the ATCOs. However, if the airspace allows, a TTO instead of a Mach/Speed instruction would be advantageous, because pilots could fly within the best possible flight envelope.

Finally, it has to be mentioned that some flights were observed with a time-unstable TTL. To give an example a flight with a TTL of 6min was slowed down and shortly thereafter the TTL was displayed with only 1min. Under these circumstances the leading aircraft delays the following aircraft with a TTL < 5min and is slowed down, although no 6min delay is expected at the airport in ZRH. This is the reason why a correct and time-stable TTL is essential for a successful E-AMAN. The TTL is the basis for slowing down aircrafts early and to bring them to the airport at the desired time.

In summary, despite the small number of flights during the short trial, the E-AMAN concept is very promising. During the trial, the communication between skyguide, Reims Control and the pilots was already functioning via all interfaces. Future steps will now involve evaluating a larger number of E-AMAN flights, calculating the Time to Lose more reliably and time-stable and defining a suitable threshold for speed reduction. This will make it possible to demonstrate a clear and significant added value in future trials. Especially if the approach sequence is shared with the AU in the future, there is great additional potential for AU to proactively control the operational processes.

L.5 Recommendations

As E-AMAN brings great ecological and economic added value to all stakeholders, the further development and execution of further trials is of great benefit. In order to fully develop the potential, it will be important in the future to extend the E-AMAN to all adjacent ATC sectors and have a symmetric extended horizon, and to apply the E-AMAN sequence operationally instead of the local AMAN sequence.

Due to the fact that aircraft can only lose about 3-4min on the last 200NM, the current threshold of 5min is too high and has to be investigated further in future. A correct and time-stable TTL is essential for a successful E-AMAN with a useful threshold.

If the capacity in the airspace allows, communicating a TTO over a certain WPT instead of a Mach/Speed instruction would be preferable. This would enable pilots to control the aircraft optimally within the flight envelope.

Within the framework of SESAR, it would also be a great added value in the future if AU would then be able to view the sequence calculated by the E-AMAN. This would enable them to optimally match the flight operation to the calculated sequence and steer flight operations with predictive planning.

Improving and optimizing the E-AMAN system is of the utmost importance for a successful E-AMAN. It is essential that the TTL calculation software is accurate and stable over time. The expected delay calculated by the software must correspond to the actual traffic situation at the airport in ZRH. Otherwise all following steering measures are useless and will not lead to an improvement of the approach control over several ANSPs.

On the ATC en route side, it would be very beneficial to implement a "feedback loop" in order for the En Route ACCs (intermediary ACCs and destination En-Route ACC) to have the knowledge of the previously reduced flights to comply with the E-AMAN computed sequence.

L.5.1 Recommendations for industrialization and deployment

The recommendations from the EXE-VLD-08-001 for future industrialization and deployment phases would be the following:

- Involvement of all the neighboring ACCs in order to ensure the whole arrival flow is taken in account and therefore ensure efficiency of the E-AMAN measures;
- Automatic/electronic coordination of speed advisories between the E-AMAN system and the upstream ACCs; ideally with a speed reduction display on the ATCO radar screen;
- Automatic/electronic feedback from upstream ACCs E-AMAN measures requests implementation (if the speed reductions have been instructed or not);
- ETFMS flight data accuracy in order to have most accurate Estimated Time Over the metering fixes, therefore the most accurate estimated landing sequence and consequent speed reductions requests.
- Benefit from a harmonized tool, e.g. XMAN portal developed in the FABEC XMAN project to coordinate with upstream ACCs.

L.5.2 Recommendations on regulation and standardisation initiatives

The main recommendation for standardization initiatives would be to provide a standardisation of the E-AMAN sequence format exchange.