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RESET

Reduced Separation Minima

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WP4 Final Report and annex with refined DOD examples

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Executive summary

RESET project (REduced SEparaTion minima) aims to identify what reductions in separation minima are safe and feasible and can contribute towards enabling a "factor of 2" (x2) traffic growth over Europe from 2005 to 2020. RESET WP4 is focused on the Future Scenario Definition. The scope of this deliverable (D4.4) is to refine the future operational concept based on the feedback of the assessment activities developed in WP7, Safety and Human Factors Case, and WP8, Efficiency and Economy Assessment.

The RESET operational concept has been created in two different phases. During the first one, a high level operational concept was developed for TMA and airport. They were described using knowledge from several disciplines and they were afterwards evaluated on terms of safety, human factors, efficiency and economy. During the second phase the feedback received from these assessments was used to further improve and refine the operational concepts, with particular attention to identifying the main technology requirements that are in need of further development in order to enable a factor two increase of air traffic.

This document summarizes the work performed during this second phase. It should be used as a kind of guidelines to understand what changes have been introduced into the two initial operational descriptions and also why. These two initial TMA and Airport operational descriptions, including the Lateral separation between STARs and SIDs, Time Based separation and Taxi Into Position and Hold operational scenarios, have been included as annexes for readability reasons. New contributions to the initial versions have been identified by appearing in brown colour throughout the documents.

Economy and efficiency assessments did not provide any input to the DODs since most part of the results are limited to local level. However, the expected benefits that the operational scenarios will bring out were confirmed. Therefore, both the preliminary safety and human factors cases were mainly feeding back the initial DODs in terms of the description of roles and responsibilities of the involved actors and of the technological enablers involved in the operation. In TBS it should be also highlighted the role of the Human in the Loop as one of the main feeders of this operational scenario mainly in terms of the ATC support tool developed in the scope of RESET

When the findings of the assessments could not feed directly the DODs, as further research was needed, it has been also highlighted in order to make easier the continuation of RESET activities in future projects.

1 Introduction

The RESET (REduced SEparaTion minima) project started to run on the 30th of October 2006 under the contract N° TREN/06/FP6AE/S07.62916/037146. The RESET aim is to identify what reductions in separation minima could be realised to meet the following challenging goal: "Where feasible, reduce SM so that they contribute towards enabling a safe factor of 2 traffic growth over Europe". Three potential separation standard modifications were selected for detailed safety, human factors, efficiency and economic assessments:

- Lateral separation between SIDs and STARs operational scenario, described in the TMA DOD;
- Time-based separation operational scenario, described in the TMA DOD;
- Line-up and Wait in All visibility conditions operational scenario, previously referred as Taxi-Into Position and Hold scenario in WP4.3 and described in the Airport DOD.

This document is the contractual deliverable D4.4 including the following three parts:

- This document, which purpose and scope is further explained in the next sections;
- Annex II, refined RESET TMA DOD based on D4.3.1, v4.0, 01/08/2008;
- Annex III, refined RESET Airport DOD based on D4.3.2, v1.1, 01/08/2008.

1.1 Purpose of the document

The purpose of this document is to refine the Detailed Operational Descriptions delivered in WP4.3 "Develop a high level DOD which covers the WP4.2 identified gaps", according to the methodology detailed in this document. The DODs that have been further refined are:

- TMA DOD, which includes two operational scenario descriptions:
    - Lateral separation between SIDs and STARs (T1-TMA);
    - Time Based Separation (TBS);
- Airport DOD, including the V4LUW operational scenario, previously referred to as TIPH concept in D4.3.2 (see [16]).

Any reference in the DODs to a non validated scenario has been removed in order to avoid potential confusions when reading the documents.

Prior to starting the refinement of the operational concept in order to accommodate the factor two traffic of WP1 "Development of goal settings", the first need is adequate communication between the operational experts and concept designers on one side, and the experts in safety, HF, capacity and economy assessments on the other side. This should lead to a proper understanding of the persons involved what exactly are the current shortcomings, and what are the potential hazard mitigating measures and HF improvements.

Subsequently it is a role of operational concept experts, rather than safety capacity experts, to use expert-judgement type of process in order to identify the options, and subsequently select the preferred ones. Finally, the DODs are refined in line with the preferred options. The technology development that is needed in order to implement these operational concepts is also stressed through this document.

1.2 Intended audience

The audience for this document is the European Commission who co-financed the RESET project, the SESAR community at large, and more particularly the SESAR JU who will find an example of how to refine the SESAR operational concept for the execution phase in terminal airspace and airport.

This document also intends to serve the ATM validation community and, in particular, those who will be engaged in the concept refinement in SESAR.

1.3 Structure of the document

Section 2 of this document provides the scope of this document.

Section 3 provides a description of how the TMA DOD has been refined considering the different WPs input.

Section 4 provides a description of how the Airport DOD has been refined considering the different WPs input.

Section 5 summarizes the main conclusions.

Section **¡Error! No se encuentra el origen de la referencia.** lists the different references used to develop this document.

Annex I summarizes in a table the A-SGMCS level 3 and 4 technological requirements proposed by EMMA2.

Annex II provides D4.3.1, RESET TMA DOD, refined.

Annex III provides D4.3.2, RESET Airport DOD, refined.

1.4 Background and context

RESET was tasked to align its work with that of SESAR during the OSED gap analysis in WP4.2 "Identify gaps in the WP4.1 collected OSEDs". It was at this point when the SESAR Operational Description was being finalized. So RESET had to make a strategic decision, whether to continue with the OSED format based upon previous or current FP6 projects, or take on the DOD format being developed by Episode 3 that used the SESAR Operational Descriptions as its base. Making this change not only involved changing the layout of the document to be delivered in WP4.3, but also the contents so that it would include all the operational changes foreseen by SESAR and add operational details related to the changes in separation minima that are being investigated by RESET. It was decided that changing to the DOD format and content would not only comply with the directive to align with SESAR, but would also reflect a closer approximation to what would be the operational environment in the year 2020. It was for that reason that the initial four OSEDs (time-based separation, en-route, TMA and Airport) were replaced with two DODs (TMA and Airport).

Time Based Separations are off-nominal procedures that maintain, and possibly increase, capacity during challenging head-wind conditions by reducing the spacing that needs to be set up for a significant proportion of the arrival pairs while turning on to the localiser. This procedure begins in the TMA flight phase and is carried over into the final approach and landing. It was therefore decided that since the operation is off-nominal and begins in the TMA phase, the description for TBS operations should be placed inside the off nominal operations section of the TMA DOD.

All the changes that WP4.3 has introduced in the DODs coming from Episode 3 can be easily tracked along this document as they appeared in dark blue. Afterwards, refinement of DODs with the results coming from the different assessments performed in RESET can be tracked as they are brown-coloured.

2 Scope

2.1 Objectives

The aim of this work package is to review, update and mature the two Detailed Operational Descriptions (DODs) delivered in WP4.3. Furthermore, emphasis on technology pull will be performed; i.e. to identify which technological developments are in need of further development.

2.2 Links with other activities

RESET WP4 has kept a close relationship with Episode 3 (EP3), project of the 6th Framework Programme of the European Commission, whose aim was to build on the output of the SESAR definition phase work programme (2006-2008) and undertake initial validation activities of its 2020 concept (SESAR D3). The project targets were:

- To provide detail on key concept elements in SESAR;
- To undertake initial operability studies and assess the performance of those key concepts;
- To perform an initial impact assessment of the supporting technical needs;
- To analyse the available tools and gaps for SESAR concept validation;
- To report on the validation methodology used in assessing the concept.

EP3 detailed the concept envisaged for the 2020 timeframe through the development of Detailed Operational Descriptions (DODs) following the format based on the ED-78A standard. The OSED format was considered inappropriate as there was a need to take a higher level view to support an integrated description of the concept.

As it would be further explained in next section, the life cycle of the DODs is iterative. The Initial and Interim EP3 DODs were prepared as a starting point for the project with the objective of incrementally building the Final DODs. Additional detail on the concept beyond the structuring of available concept information was achieved through the review process of the DODs, the results from the EP3 exercises and the EP3 discussion forum. Although the overall balance of the concept detailing was generally aligned with the research priorities of the project (Short/Medium Term Network Planning and ATC Execution), detail was added across all areas.

The RESET project has used the EP3 E1 (Runway Management) DOD and the EP3 E5 (Arrival and Departure) DOD to study the SESAR concept elements relevant to their study.

Also, within RESET project, close coordination has been kept with WP7 “Preliminary safety and human factors assessment” and WP8 “Preliminary efficiency and economy assessment” which were providing feedback to the TMA and Airport DODs.

2.3 Methodology

The life cycle of the DODs is iterative, as illustrated in the figure below and the main aim of WP4.4 is to close this cycle started in WP4.3.

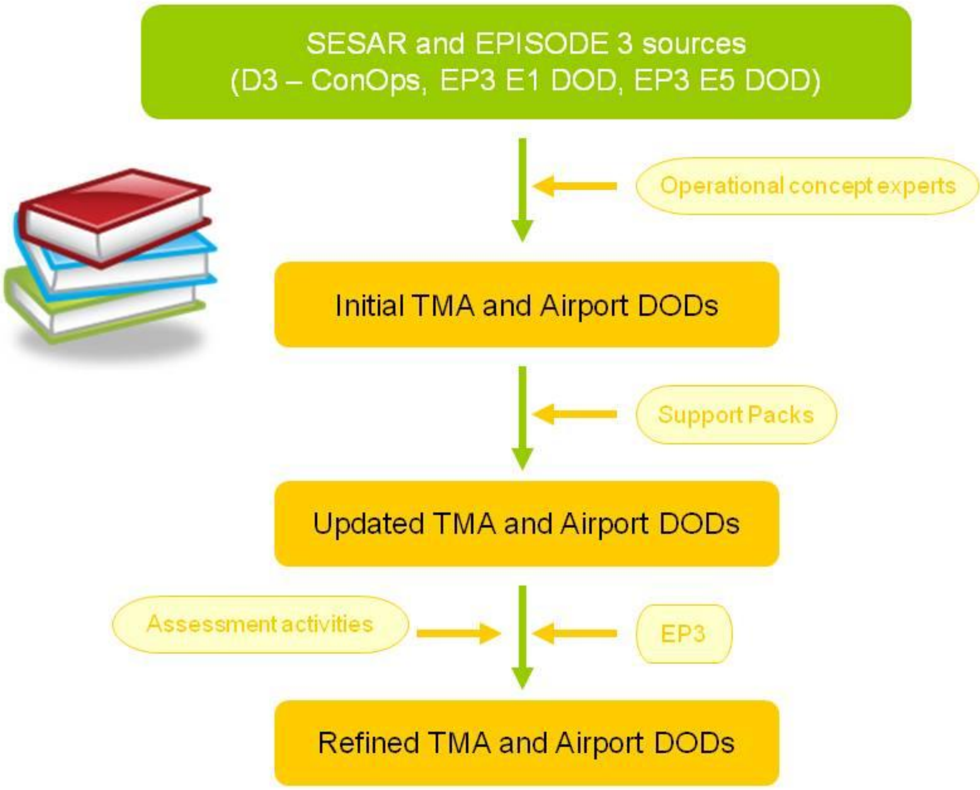

Figure 1: DODs methodology

The baseline DODs to start WP4.4 activities are the ones produced in WP4.3: D4.3.1 dealing with TMA and D4.3.2 with airport. Some aspects of the concept were still unknown or unclear when these documents were delivered: a number of options existed to be assessed during the further validation process.

Before starting with the different assessments undertaken in WPs 7 and 8, the initial DODs were further detailed especially in those areas identified and required by the validation experts. This work was undertaken by the Project Coordinator in RESET which developed three different support packs, one per concept addressed in the project: T1-TMA, TBS (included also in the TMA DOD) and Line Up and Wait in All Visibility Conditions (V4LUW) which was previously referred to as Taxi-Into Position and Hold (TIPH). Therefore the fist step concerning the refinement of the initial DODs was to integrate this input to update the three concepts of operations previous any validation activity.

The integration of these support packs filtered information in RESET DODs mainly provides further details in actors' roles, and communication and transfer of responsibilities among them. Besides, the list of additional enablers needed to implement the different operational scenarios was increased. However, the main contribution from them is the addition of a Hierarchical Task Analysis, which provides a fully detailed view of the new concepts.

The adoption of the DOD format and content comply not only with the directive to align with SESAR, but also reflect a closer approximation to what would be the operational environment in the year 2020. However, due to its lack of maturity, the SESAR Operational Description does not include the same level of detail as the OSEDs what has required that RESET WP4 include these details within the DODs in order to be able to validate the different scenarios.

EP3 has fed again the updated DODs at this stage: the initial RESET DODs were based in the initial and interim EP3 DODs which were further detailed and refined into the final EP3 DODs. In order to be consistent with the results of this project, updated RESET DODs and final EP3 DODs have been aligned to avoid confusion to the reader when comparing both documents.

Preliminary safety, human factors, efficiency and economy assessment were performed to evaluate the novel separation minima criteria. Finally, results from each validation exercise were fed into the refined DODs which reflect the most mature understanding of the SESAR ConOps achieved by RESET.

3 Refinement of the TMA DOD

This section should be understood as a guidance to understand how the RESET TMA DOD was refined based on the validation activities results.

3.1 Lateral separation between SIDs and STARs operational scenario

3.1.1 Technological developments

3.1.1.1 MONA

Technological research in this section is mainly based on the work performed by EUROCONTROL in FASTI (First ATC System Tools Implementation) projects that address the operational requirements for MONitoring Aids (MONA).

The purpose of MONA is to assist the controller in the routine monitoring of the traffic situation, warning the controller when aircraft deviate from their planned route or clearances, reminding the controller of actions that need to be performed and keeping the trajectories updated with the progress of the flights. Looking at these objectives it is clear that MONA will support the implementation of T1 TMA operational scenario.

The requirements for MONA cover three distinct functions:

- The detection and notification to the controller of deviances of the aircraft from their clearances;
- The provision of reminders to the controller of routine actions to be performed;
- The update of the trajectory to reflect the actual progress of the aircraft.

The interaction with the external entities is described as follows:

- Flight Data Distribution: flight data is provided to MONA for all eligible flights;
- Trajectory Prediction: the Planned and Tactical Trajectories are provided to MONA and form the basis upon which deviation is detected and reminders generated; actual progress of the aircraft is supplied to the trajectory prediction;
- Surveillance Data Distribution: the system track, containing the state vector, represents the actual aircraft position and velocity, and is used to detect deviation and to update progress;
- Planner & Tactical Controllers: reminders and deviation warnings are displayed to the controllers.

3.1.1.1.1 Conformance Monitoring

The conformance monitoring function compares the system tracks[1] with the corresponding flight clearances in order to warn the controller of any deviation of a flight from its clearance and, where possible, to establish the progress of the flight and to refine the prediction of the remaining trajectory[2] to be flown.

Conformance is monitored in three dimensions, though the monitoring performed varies according to the type of clearance issued. In principle, warnings of deviation are generated in cases where the controller might be required to act to re-clear an aircraft that is assumed to be deviating from its clearance or to re-coordinate an aircraft whose boundary estimate changes significantly.

[1] System track is a generic entity representing the surveillance data as transmitted by the surveillance system.

[2] Trajectory is the representation of the path of an aircraft, describing the horizontal and vertical profile over time.

If a planned[3] and a tactical[4] trajectory are defined, where possible, the system recalculates the trajectories that are active for a flight according to the actual behaviour of the aircraft.

Hereafter the top level requirements are included for this function. They should be understood as essential requirements describing an objective. Lower level requirements then specify a set of system requirements that meet the higher level objective and are not included in this section (see [1]).

Lateral Conformance:

- The system shall warn the controller where an aircraft is deviating from its assigned route, heading or track;
- The system shall warn the controller and/or conjecture the likely route of flight where an aircraft is deviating from its planned route;
- Where an aircraft is within required tolerances of its assigned route, heading or track, the system may update the trajectory with the actual aircraft path;

Longitudinal Conformance:

- The system shall refine the longitudinal estimate of the trajectory according to the actual progress of the aircraft;
- The system may warn the controller where a time estimate is changed such that a manual revision of the flight is required;
- The system may warn the controller where the aircraft speed is deviating from the assigned speed.

Vertical Conformance:

- The system shall warn the controller where an aircraft deviates from its assigned level;
- The system may warn the controller where an aircraft deviates from its assigned vertical rate;
- The system shall update the vertical estimate of the trajectory according to actual behaviour of the aircraft.

Progress Monitoring:

- The system shall detect significant flight events.

3.1.1.1.2 Automatic Reminders

Automatic reminders are provided to the controller for routine events that are performed at a time relative to a point in the planned trajectory.

Hereafter the top level requirements are included for this function. They should be understood as essential requirements describing an objective. Lower level requirements then specify a set of system requirements that meet the higher level objective and are not included in this section (see [1]).

- The system shall remind the controller to transfer an aircraft to the next sector;
- The system may remind the controller to coordinate a flight where automatic means are not available;
- The system may remind the controller to issue a manoeuvre clearance to the aircraft.

[3] Planned trajectory is a trajectory representing the most likely behaviour of a flight through an Area of Interest, from take-off to touch-down, over the medium term.

[4] Tactical trajectory is a trajectory representing the expected behaviour of the aircraft taking into account all clearances and other instructions issued to the aircraft but without making assumptions on subsequent clearances to be issued.

3.1.1.2 TCAS

TCAS (Traffic Collision Avoidance System) is an airborne system, which works independently of ground ATC systems. Its goal is to provide traffic and resolution advisories of surrounding traffic in the order of tens of seconds before the predicted time at closest point of approach (see [6]).

Since the beginning of its development, in 1981, TCAS has become an integral part of air transportation. The current version is TCAS II Version 7 and it is mandated for certain classes of civilian aircraft in many countries including US, Australia, India and most of the European countries. TCAS II Version 7 is the subject of this study and in the following it will be referred to as TCAS for the sake of simplicity.

The evolution of TCAS has been based on vast testing during air traffic operations. There has always been the need for a reasonable trade-off between timely advisories on one side, and nuisance alerts on the other side. Although TCAS has probably decreased the rate of mid air collisions to one third (see [6]), it cannot guarantee absolute collision prevention (see [7]).

TCAS is developed for environments in which aircraft density is up to 0.3 aircraft per square nautical mile, which means that an equipped aircraft can handle up to 24 aircraft within 5 NM. The lower are the speeds of the surrounding aircraft, the higher is the number of aircraft that can be safely and efficiently handled by TCAS.

The basic idea of conflict detection falls on computing time to the Closest Point of Approach (CPA) and, if altitude information is available, also the time to being co-altitude. Since there are big differences between aircraft speeds, multiple thresholds (using so-called sensitivity levels, which depend on aircraft altitude) and other parameters are incorporated.

When a new operational environment is under consideration, TCAS functionality should be reassessed in order to make sure it would still bring the expected safety benefits. Namely, TCAS functionality should fulfil the following conditions:

1. Provide timely and correct Traffic Advisory (TA) and Resolution Advisory (RA) when needed;

2. Not issue unnecessary (nuisance) alerts.

In the suggested TMA T1 concept, aircraft are expected to fly along SIDs and STARs with a lateral separation as low as 3 NM. Figure 2 depicts the situations that are in scope of this study: the five boxes depict the situations that are under investigation in the RESET project. Green lines show climbing trajectories, red lines show descending trajectories and blue lines show level trajectories. Fulfilment of the above mentioned objectives is therefore of high importance. In particular, the balance between timely alerts for deviated aircraft on one hand, and prevention of nuisance alerts for correctly positioned aircraft on the other hand, is the required TCAS outcome. The following two sections are devoted to these two items respectively.

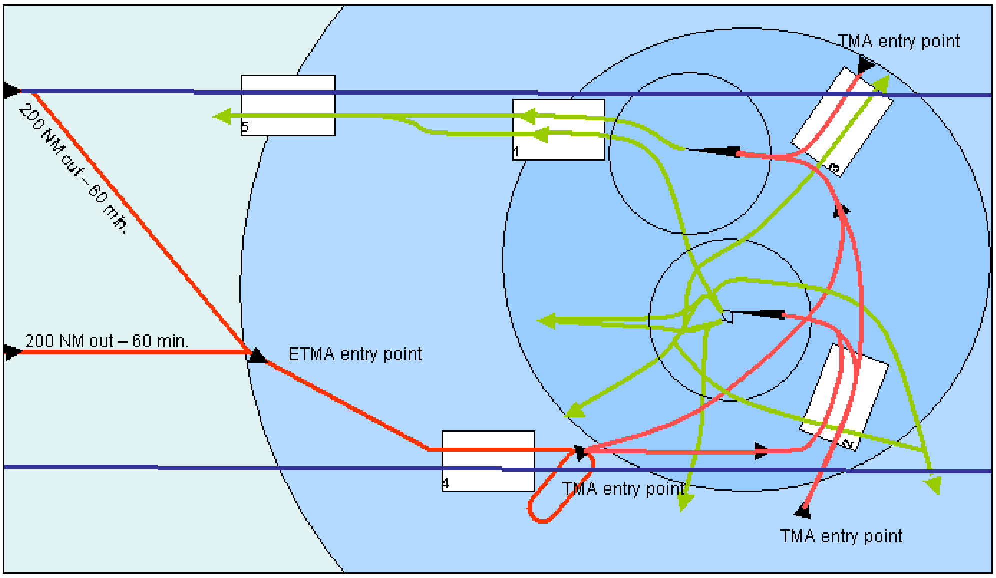

Figure 2: An example of TMA and ETMA.

3.1.1.2.1 Reliable TA/RA issuance

TCAS can provide timely and correct TA/RA advisory provided that:

- The other traffic is appropriately equipped;[5]
- The surveillance range is sufficient given the closing speed[6].

The first condition is general for the use of TCAS and there are no specific issues brought by this new operational concept.

The second condition is related to the so called interference limiting function that every TCAS has and that is working at altitudes up to 18.000 ft. This function ensures that no transponder is overly occupied by TCAS activities and also that TCAS does not induce interference issues to ground based ATC radars. The more TCAS units are detected within the detection range[7] of TCAS, the more the interrogation rate and power allocation must decrease. The decrease also depends on distribution of the TCAS units. Low interrogation rate, of course, affects the ability to detect and track targets sufficiently in advance before the advisory issuance. The minimum surveillance range that is always kept by the interference limiting function is 6 NM.

Several concerns arose about the ability of TCAS to generate timely advisories in high closing speed encounters in high traffic density TMAs. The conclusion of a SCRSP/WGA study (see [8]), based on TMA Frankfurt, is that the TCAS tracking range is just sufficient to provide timely RA even in the most critical altitude (FL 110). Another study (see [9]) was concerned with the influence of increased closing speeds and reduction of separations on the necessary interference limiting and consequently on the surveillance range. This study points out that (i) for arriving and departing aircraft with speeds higher than 314 kts with maximum interference limiting the surveillance range is not sufficient and can have negative impact on safety of collision avoidance, (ii) Operating TCAS II between altitudes 10.000 ft and 18.000 ft with reduced separations can result in strong interference limiting which in turn may impact the ability to provide the required surveillance range for collision avoidance.

[5] If the intruder is equipped with TCAS I or TCAS II or at least Mode C or Mode S transponder, both TA and RA can be issued. In the case of Mode A transponder, only TA can be issued since the altitude of the intruder is unavailable.

[6] Closing speed is the rate of change of the distance between two aircraft.

[7] The minimum required surveillance range is 14 NM, but the detection range uses to be about 30 NM.

In any case, equipping TCAS with Mode S extended squitter (ES), i.e. 1090MHz ADS-B and hybrid surveillance capability (see [6] and [10]) is envisaged as the most viable solution to the problems induced by interference limiting. This is done by passive tracking of the intruders (receiving ADS-B messages) with variable position validation with active interrogation.

The Mode S 1090MHz ES transmits 112-bit long messages (instead of 56 bits for standard Mode S messages). This enables sending additional 56 bits of ADS data, which leads to the following advantages:

1. Availability of position, velocity and intent data in the extended squitters helps improving the TCAS surveillance function if hybrid surveillance is used. In this case, the data from SSR surveillance are used to validate the ADS-B data while independence on the received data is still maintained.
2. The overall interrogation rate can be lowered while maintaining sufficient surveillance range. More specifically, the interrogation rate for very near threats will remain 1.0 Hz. On the other hand, distant targets would be based on ADS data validated by active TCAS surveillance with lower interrogation rate. Therefore, TCAS will be able to use full surveillance even in high traffic density.

Moreover, broadcasting intent information could potentially be used to reduce unnecessary alerts. On the other hand, the TCAS should still be able to provide advisories in case the intruder does not conform to its intent.

3.1.1.2.2 Nuisance alerts

Nuisance TAs and RAs are undesirable since they can not only disturb the crew, but also (in the case of RAs) affect the safety of the traffic situation by forcing the crew to perform a sudden manoeuvre in order to prevent a seeming conflict. This may be extremely dangerous if performed in lower altitudes (i.e., close to the ground).

In order to assess the disposition of the TCAS scenario to nuisance alerts in the TMA T1, a set of simple scenarios is defined, with a special emphasize on the most challenging ones. The scenarios are simulated using TCAS Simulation Interactive Module (TSIM) (see [11]). Each of the test scenarios involves two aircraft (the “own ship” and an intruder) on parallel tracks, flying in opposite directions. An example of a vertical view of a scenario simulated using TSIM is shown in Figure 3. The ownship (depicted by a small aircraft) is climbing while another aircraft is descending. The yellow part of the other aircraft’s trajectory shows positions where a TA was issued.

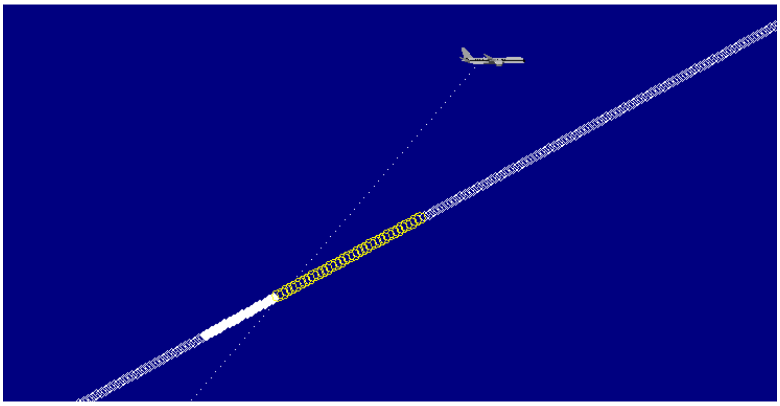

Figure 3: An example of a two aircraft scenario simulated in TSIM.

3.1.1.2.3 Simulations using TSIM

Conditions/assumptions:

Issuance of TA or RA is conditioned mainly by high closing speed and high vertical closing speed, which are used to compute the time to closest point of approach, or time to co-altitude, respectively. The distance at the CPA plays a role as well: if the distance is large, the advisory may not be issued. Applied thresholds are ruled by sensitivity levels. There is a general rule about the sensitivity level applied. In a simplified way it can be said that the lower the sensitivity level is, the smaller the protected volumes around the aircraft are, that is, the volumes the penetration of which triggers a TA or RA. However, the volume is not limited by distance criteria but rather by time criteria, hence for intruders with different speeds the protected volume is also different. Basically the sensitivity levels are governed by the altitudes at which the concerned aircraft are flying (see Table 1), but they can also be artificially lowered (either manually by the crew, or by uplink command from the ground). In these tests it is assumed that sensitivity is driven by altitude only.

Own altitude (feet)	Sensitivity level
< 1000	2
1000 – 2350	3
2350 – 5000	4
5000 – 10000	5
10000 – 20000	6
20000 – 42000	7
> 42000	7 (different parameters than above)

Table 1: TCAS sensitivity levels definition based on altitude.

The parameters are selected as follows:

- Altitude: TMA boundaries vary widely from airport to airport and depend on local conditions. Therefore, altitudes over 20.000 ft, where sensitivity level 7 would be used, are admitted;
- Speeds: In some TMAs there are speed restrictions (typically 250 knots). However, speeds up to 500 knots are used in higher altitudes in general;
- Vertical speeds: TCAS II Version 7 is designed to provide collision avoidance protection to aircraft that are closing vertically up to 10.000 fpm. In these tests vertical speeds up to 5.000 fpm are considered in lower altitudes (which is realistic, e.g., for some business jet aircraft during initial climb);
- Parallel tracks: Primarily, parallel tracks with lateral separations of 3 NM are tested. If an advisory is issued, 4 NM or 5 NM options are tested as well in order to see whether introducing larger separation helps.

Limitations of the simulated TCAS logic:

The simulations can give an insight into the expected behaviour of TCAS. However in real world the results may be slightly different. For instance, the surveillance function may be imperfect due to many factors, such as high density of TCAS units, altimetry instrumentation errors, and adverse manoeuvres by the intruders. This in turn can influence the time of intruder track establishment, which may have an impact on the issuance of an advisory.

Scenarios and tests:

The scenarios are divided according to the altitude of closest point of approach. This point is set at various altitudes so that different sensitivity levels as well as appropriate flight profiles (speeds, vertical speeds) can be used. The scenarios were defined so that there was enough time for the intruder track to be established, with the exception of Scenario 1 which takes place during initial climb. Usually, when there is not enough time to establish the track and the intruder just pops up close to the own ship, the intruder is more likely to be evaluated as a threat or a potential threat, however, the evaluation is updated as soon as track data are collected and more information is obtained.

The values used in the scenarios are inspired by a flight profile of the IAI 1124 Westwind aircraft (a medium size corporate jet). This aircraft was selected due to its high rate of climb.

In the first set of scenarios the own ship is climbing while the intruder is descending (the situation is symmetric so there is no need to simulate reversal roles). Generally, the aircraft fly with low airspeed and high rate of climb during the initial climb. The airspeed is gradually increasing while the rate of climb is decreasing. The rate of descent uses to be much lower than the rate of climb. However, the airspeed during descent is usually higher than the airspeed during initial phases of climb.

When an alert was triggered, the scenario was slightly changed in terms of lateral separation and/or speeds so that the benefit of relaxing the conditions could be evaluated.

Situation 5 in Figure 2 covers higher altitudes where climbing aircraft fly laterally separated from level aircraft. Such a situation (with high speeds) is considered in the second set of scenarios.

Each scenario provides results in terms of the alert issued. Where applicable, the duration of the alert is also provided. This value is only informative since in reality it would depend on many factors that are not possible to simulate.

1. Climb/descent scenarios:

Scenario No.	Altitude of CPA (ft) / Sensitivity level	Lateral Separation (NM)	Own ship Airspeed (kts)	Own ship Alt. rate (fpm)	Intruder Airspeed (kts)	Intruder Alt. rate (fpm)	Alert
1	4990 / 4	3	155	5000	250	-1500	None
2	9000 / 5	3	270	3500	250	-1500	TA (20 s)
3	9000 / 5	4	270	3500	250	-1500	None
4	14 000 / 6	3	450	3500	270	-1500	TA (46 s)
5	14 000 / 6	4	450	3500	270	-1500	TA (34 s)
6	14 000 / 6	5	450	3500	270	-1500	None
7	14 000 / 6	3	270	3500	250	-1500	TA (33 s)
8	14 000 / 6	4	270	3500	250	-1500	None
9	21 000 / 7	3	450	2500	270	-1500	TA (46 s)
10	21 000 / 7	4	450	2500	270	-1500	TA (35 s)
11	21 000 / 7	5	450	2500	270	-1500	None

Table 2: Climb/descent scenarios

2. Climb/level scenarios:

Scenario No.	Altitude of CPA [ft] / Sensitivity level	Lateral Separation [NM]	Own ship Airspeed [kts]	Own ship Alt. rate [fpm]	Intruder Airspeed [kts]	Intruder Alt. rate [fpm]	Alert
15	21 000 / 7	3	450	2500	450	0	TA (50 s)
16	21 000 / 7	4	450	2500	450	0	TA (44 s)
17	21 000 / 7	5	450	2500	450	0	TA (35 s)

Table 3: Climb/level scenarios

Analysis of results:

The 17 scenarios were selected in such a way that the TCAS behaviour is challenged, that is, that there are high, but still realistic high closing speeds and high vertical closing speeds and that the two aircraft are as close as possible at the closest point of approach, that is, 3, 4 or 5 nautical miles, depending on the selected lateral separation between the routes.

None of the scenarios leads to triggering of a RA. However, several scenarios, mainly those with high sensitivity levels, lead to issuance of a TA.

It is a question whether a TA in such a situation is undesirable, acceptable or even beneficial. On one hand, TA disturbs the crew and in nominal conditions can be perceived as a nuisance. On the other hand, if the two aircraft are flying with high speeds as close as almost 3 NM, it could provide additional situation awareness. This is, however, left to human factors assessments or human in the loop simulations.

Anyway, if TA is to be avoided, there are several possibilities:

- Set the lateral separation between TMA routes to 4 or 5 NM instead of 3 NM (as seen by comparison of, for example, scenarios 2 and 3);
- At higher altitude, the maximum speeds could be limited (as seen e.g. in scenarios 5 and 8);
- In some cases, only combination of both of the above could be effective (compare scenarios 4, 5, 7 and 8);
- At high altitudes (sensitivity level 7, i.e., above FL 200) it makes no sense to reduce the speeds, and it would not be effective from operational point of view. Instead, the lateral separation can be extended even further;
- The sensitivity level can be manually adjusted by the crew. Care must be taken since the TCAS should still be able to perform its main function, i.e., provide timely advisories in order to prevent mid air collisions;
- It may turn out that if TCAS is enhanced with the ADS data and if at the same time higher navigation accuracy is maintained, lower thresholds for TCAS alerts could be used while maintaining the same level of safety. This could prevent some of the TA from being issued. However, this potential futuristic solution would have to be deeply elaborated and validated.

3.1.1.2.4 Conclusions

The usage of TCAS in the TMA T1 scenario is not expected to bring any specific issues. The issue with the interference limiting function, which could potentially hamper the ability of TCAS to provide timely advisories in high density areas, is envisaged to be solved by the TCAS with Mode S 1090MHz ES and hybrid surveillance capability.

The tests of TCAS logic have shown that there would be TA triggered in some of the realistic scenarios. The first step is to assess whether this is a nuisance or not. In any case, potential short term solutions exist, such as increasing lateral separations to 4 or 5 NM, reducing speeds or adjusting sensitivity levels, even though some of them also bring some drawbacks in terms of performance (e.g., reducing speeds or increasing separation) or even safety (e.g., when the sensitivity level is manually lowered). However, the nuisance alerts occur in many other common situations so there is no reason why the TMA T1 scenario could not be brought into operation from the TCAS perspective.

3.1.2 Human Factors Assessment Input

The contribution of the Human Factors Case to the refinement of the T1 operational scenario described in the TMA DOD has been provided by:

- M1 – Fact finding report (see [2]) which covers the first stage in the HF Case process with the aim of understanding the RESET Project from a HF perspective by identifying what will change, who will be affected and how they will be affected with the reduction of lateral separation to 5NM in the TMA.

  This report has contributed to further identify the key actors involved in this operational scenario and how they will be affected in their roles and responsibilities and to provide a high level description of the current ATM operation versus T1 one;

- M2 – Issues Analysis Report (see [3]) which provides a description of the brainstorming session where HF hazards were identified, the process implemented for the HF Identification as well as the final outcome of the analysis.

  The mitigation strategies included in this report has fed mainly the sections regarding actors and ground equipment from the original TMA DOD. Some open issues were also identified that needs to be further assessed in the future.

After analyzing the results of the Human Factors Case, some aspects need to be readdressed in the future in order to enable the implementation of this operational scenario:

- A detailed procedure should be defined in case of communications failure, both in an aircraft and in a control centre, as a design requirement to ensure communication reliability;
- Further studies on the HMI regarding pilot situation awareness are required to avoid the pilot to be distracted by a saturated display with ADS-B IN data;
- A safety study should be performed to asses the risks in case of change in the route by an ATCO when vectorization is restricted. Also the need of including additional technology taking into account the information content and presentation, form and timeliness in FMS should be analysed;
- There is a lack of regulation regarding the implementation of ASAS Spacing. Training, instruction and a safety analysis are also required;
- Transition management and change of mind of the involved actors: although studies demonstrated the feasibility on the proposed systems and procedures, the actors' attitude may be conservative because of their risk perception:
  - Although studies demonstrated the feasibility of implementing RNP1 in T1-TMA scenario, a HF study is also required to prove that the risk perceives by pilot in these circumstances does not increase;
  - TCAS parameters should be reconciled and brought into agreement to create a common standard;
  - The change of philosophy in EFS implies an adaptation to the ATCOs who should be involved in its development to ensure that its design responds to their needs.

3.1.3 Safety Assessment Input

The contribution of the safety assessment to the refinement of the "Lateral separation between SIDs and STARs" operational scenario described in the TMA DOD has been mainly provided by results from the WP7.7 TBS Mitigation Workshop, aimed to suggest potential mitigation measures for the high ranking hazards and from D7.5 Part 2 TMA-T1:

- Monitoring and alerting Aids required by ATC and flight crew should comply with safety requirements;
- The factors with low (e.g. RNP) or high (e.g. reaction times) influence in the overall risk level. According to the developed model, it can be concluded that the conditional collision risk is highly sensitive to changes in any parameter that influences the time available to resolve a conflict between two aircraft: aircraft speed, angle of sharp turn, ATCo and flight crew average reaction time.

Training considerations have been highlighted by the experts as the implementation of this concept will directly impact in the current procedures of ATCos and flight crews.

3.1.4 Efficiency Assessment Input

TMA T1 efficiency assessment analyzes this operational scenario in terms of controller workload, flight duration and emissions by means of fast time simulation techniques.

The main contribution to the refinement of this Operational Scenario was headed to the expected benefits of the implementation of such a concept against the current lateral separation standards.

One important premise when modelling this new concept is that the TMA routes need to be redesigned. The new trajectories should be properly adapted to the specific airspace needs, as each Terminal Airspace has its own characteristics in terms of location, surroundings and size, and traffic density and complexity may vary on a daily, weekly and seasonal basis. Therefore, the final choice of the operational improvement/s to be implemented should be made by the local ANSP.

Further assessment is needed on the ATCO workload coming from the use of advanced systems mainly aimed to support conflict detection and resolution. As a consequence, the activity of the controller will be potentially reduced to a monitoring task what implies certain cognitive differences. Therefore it is suggested that this topic is re-addressed in the future.

3.1.5 Economy Assessment Input

Although there has been no input of the economy assessment in the TMA DOD, some conclusions can be extracted that support the implementation of lateral TMA separation operational scenario from an economy perspective.

The cost benefit analysis of a reduction of radar lateral separation minima applied in Rome TMA shows that the benefits outweigh the costs, both for the 2.5NM and the 2NM scenario with a 5NM lateral spacing between SIDs and STARs. The case of a 2NM reduction brings about the best and substantial CBA result. The CBA also brings about that the scenarios both lead to negative environmental effects, for which the reason is in the fleet mix in Rome TMA. A more modern fleet would lead to positive environmental results although this has not been proved.

On a stakeholder level, the conclusion is that ATC and the regulator only incur costs and do not have any benefits. Airlines have a positive case in the 2NM scenario, but not in the 2.5 NM scenario, while the CBA is positive for society only in both cases.

The CBA analysis, and RESET assessment activities as a whole, has validated concepts that are in E-OCVM phase V1 what indicates that some aspects of the concept are unknown or unclear at this stage. It means that many assumptions have been applied, regarding the efficiency analysis that provided input to the CBA and on the costs side. For the investment costs, some of the technical requirements of the concept were unknown, what made not possible to assess the costs accurately of certain system components. It is therefore recommended to further fine-tune the benefits assessment (including the efficiency input) and the costs assessment after the operational scenario has been further refined.

3.2 TBS operational scenario

3.2.1 Technological developments

3.2.1.1 General Description

Assuming the current systems as baseline, the specific new TBS procedures and functionality required to be specified, validated and approved for the deployment of this operational scenario include:

- The time-based separation rules;
- The TBS tool support for calculating the time-based separation and the required time spacing for each arrival pair;
- The TBS tool support to the approach controller for visualising the time-based separation and required time spacing for each arrival pair for:
    - Consistently turning arrival aircraft on to the localiser with the appropriate required time spacing;
    - Consistently refining the spacing set up soon after joining the localiser to the required time spacing;
    - Consistently monitoring for time separation infringement, particularly during the landing speed stabilisation phase of final approach;
- The TBS tool support to the tower runway controller for visualising the time based separation for each arrival pair to consistently monitor for time separation infringement, particularly during the landing speed stabilisation phase of final approach;
- The TBS tool support to the approach controller and the tower runway controller for automatically monitoring and warning of the risk of time-based separation infringement;
- The Airborne, AOC and ATC system support for informing approach control and the TBS tool support of the landing stabilisation speed intent of each arrival aircraft:
    - Initially using voice communication between the pilot and approach controller on first contact with the approach controller inputting the intent information using the approach controller electronic flight data facilities;
    - In the interim from the AOC system information generated during the departure preparation phase of the flight over data link to the approach controller TBS tool support;
    - Ultimately from the Airborne system information calculated by the pilots in the approach preparation phase, soon after top of descent, over data link to the approach controller TBS tool.

Alongside the new TBS system support functionality will be the procedures and practices improvements around the management of the diversity of the landing stabilisation speed profiles employed on final approach:

- Improvements to the consistency of the cockpit landing stabilisation procedures across airline operators and across aircraft types;
- Improvements to the pilot conformance to the final approach procedural airspeed procedures to the start of the landing stabilisation speed phase of final approach;
- Improvements to the pilot reporting of the intent to employ a non-conformant airspeed profile over the procedural airspeed phases of final approach;

- The new pilot reporting of the landing stabilisation airspeed intent on first contact with approach operations;
- Improvements to the approach controller consistency in the application of additional spacing on turning on to join the localiser for lead aircraft with slow landing stabilisation airspeed intent;
- Improvements to the approach controller consistency in the application of additional spacing for arrival pairs where the lead aircraft has a significantly slower landing stabilisation airspeed intent than the follower aircraft.

The new TBS tool support for calculating the time-based separation between each arrival pair has a number of dependencies on ATC system services that may need to be subject to operational improvements in order to satisfy the level of safety dependency of the separation related TBS tool support:

- Assigned arrival runway-in-use and planned and immediate changes;
- For each assigned arrival runway-in-use the separation policy for:
  - Radar separation and planned and immediate changes including not-in-trail separation across parallel dependent runways;
  - Runway occupancy related clearance to land separation and planned and immediate changes;
  - Wake turbulence separation and planned and immediate changes;
  - Visual separation and planned and immediate changes:
    - Application of reduced separation in the vicinity of the aerodrome;
    - Application of visibility conditions 2 and LVP separation.
  - Arrival sequence order intent and immediate changes:
    - Including the integrated arrival sequence order for parallel dependent runways;
    - Including interlaced mode departure gap intent and immediate changes;
    - Interlaced mode departure gap separation and immediate changes.
- For each arrival aircraft:
  - Arrival aircraft assigned runway intent and immediate changes, including the assigned runway intent on to the departure runway for specific arrivals in parallel segregated mode operations;
  - Aircraft type and wake turbulence category;
  - Approach controller specified separation for the specific arrival pair for example for an emergency.

The new TBS tool support for calculating the required time spacing between each arrival pair on turning on to join the localiser to observe the time-base separation to the runway threshold has the additional dependency for the landing stabilisation speed intent of each arrival aircraft.

It is expected that this dependency will present some challenges and may mean that limited TBS tool support for the required time spacing on turn-on can be provided initially with the approach controllers being expected to determine the additional time spacing above the distance-based separation to be set up on turn-on without TBS tool support. This is to be facilitated by the new pilot reporting of landing stabilisation speed intent on first contact to approach operations. A potential alternative to this is for the TBS tools support to use a 'standard' landing stabilisation speed profile for each aircraft type initially until AOC and ultimately down linked Airborne intent information becomes available.

FDP, AMAN and EFD or EFPS are the current ATC system services that can potentially satisfy the above dependencies. Operational improvements are expected to be needed to the approach controller procedures and practices and the associated system support for:

- Ensuring correct and timely arrival sequence order intent and arrival assigned runway intent information;
- Ensuring correct aircraft type and wake turbulence category information. This may include new automatic checking and correcting of this information through the down linking of this information from the arrival aircraft.

In order to mitigate against the arrival sequence order intent not being kept up to date or the approach controllers inadvertently deviating from the intent there is a need to check that the aircraft being turned on to each separation indicator is the intended aircraft:

- To enable the approach controller to visually check this, the separation indicator can be labelled with the call sign of the intended follower aircraft;
- This may include new automated checking and alerting when the aircraft being turned on to the separation indicator is not the intended aircraft.

In order to mitigate that the assigned runway intent not being kept up to date or the approach controllers inadvertently deviating from the intent there may be a need to check that each aircraft is being turned on to the intended extended runway centre-line. This may require automatic checking and alerting when an aircraft has not been turned on to the intended extended runway centre-line.

The new TBS tool support to the approach controller and tower runway controller for visualising the time-based separation and required time spacing for each arrival pair has a number of dependencies on ATC system services that may need to be subject to operational improvements in order to satisfy the level of safety dependency of the separation related TBS tool support:

- Approach surveillance system and surveillance display performance including update rate and timing, display resolution, separation visualisation support and spacing visualisation support;
- Tower ATC surveillance system and air traffic monitor display performance including update rate and timing, display resolution and separation visualisation support;
- Enhanced Mode S surveillance down linked IAS and Ground Speed airborne parameters for maintaining a ground effects profile of the wind conditions on final approach from turning on to join the localiser to approaching the runway threshold.

The new TBS tool support to the approach controller and the tower runway controller for automatically monitoring and warning of the risk of time-based separation infringement has a number of dependencies on ATC system services:

- Approach surveillance system update rate and timing;
- Enhanced Mode S surveillance down linked IAS and Ground Speed airborne parameters for supporting conformance monitoring of the airspeed profile on final approach from turning on to join the localiser to approaching the runway threshold;
- Approach surveillance display support for displaying the warnings of imminent or actual time separation infringements;
- Tower runway controller air traffic monitor support for displaying the warnings of imminent or actual time separation infringements.

To support the validation and prepare for deployment of the TBS operational scenario there is a need to establish baseline measures of current distance-based separation hazard risks and to establish the evidence for the TBS concept hazard risks. This is particularly required for the wake turbulence hazard risk so improvements are required on the monitoring and measuring of this risk. This will extend to the monitoring requirements for ensuring that the TBS concept continues to be safe during its deployment. This includes consideration of the following:

- Improving the consistency of the pilot reporting of wake turbulence encounters;
- Introducing airborne system support for automatically identifying and recording wake turbulence encounters;
- Introducing airline operation system support of the processing of system recorded wake turbulence encounters;
- Introducing ground system measurement and monitoring of wake turbulence encounter risk;
- Improving and further validating wake turbulence behaviour models, wake turbulence encounter hazard risk models and wake turbulence encounter effects models.

3.2.1.2 List of ATC Operation and Support System Developments

1. ATC Separation Tool Support:
    - Separation Calculation;
    - Separation Minimum Display;
    - Surveillance Display Separation Minimum Visualisation Support.
2. ATC Spacing Tool Support[8]:
    - Localiser Turn-On Spacing Calculation;
    - Localiser Turn-On Spacing Display;
    - Surveillance Display Localiser Turn-On Spacing Visualisation Support.
3. Sequence Order and Runway Assignment Intention Tool Support:
    - AMAN and EFD/EFPS Integration;
    - AMAN and DMAN Integration;
    - Sequence Order and Runway Assignment Intention Conformance Monitoring.
4. Surveillance System and Surveillance Display Support:
    - Surveillance Update Rate and Timing;
    - Surveillance Display Resolution;
    - Surveillance Display Separation Minimum Visualisation Reliability;
    - Surveillance Display Spacing Visualisation Reliability.
5. Aircraft Wake Category and Aircraft Type Verification Support:
    - Radio Telephony Verification and EFD/EFPS Correction Support;
    - Aircraft Data Link Verification and Correction Support.
6. Aircraft Approach Intentions Notification Support:

[8] This tool was modeled through the Chevron during TBS Human In the Loop sessions

   - Radio Telephony Notification and EFD/EFPS Support;
   - Airline Operations System Notification Support;
   - Aircraft Data Link Notification Support.
7. Aircraft Derived Meteorological Data Support:
   - Wind Conditions Ground Speed Effects Profile on Approach;
   - Wind Conditions Profile on Approach.
8. Forecast Meteorological Data Support:
   - Wind Conditions Profile on Approach;
   - Visibility Conditions in the Vicinity of the Aerodrome.
9. Spacing Delivery Conformance Monitoring and Timely Intervention Support:
   - Approach Speed Profile Conformance Monitoring;
   - Separation Minimum Conformance Monitoring;
   - Separation Encroachment Warning.
10. Expedited Runway Vacation Support:
    - Brake to Vacate Support.
11. Wake Turbulence Hazard Risk Monitoring on Approach:
    - Controller Reporting of Wake Turbulence Encounters;
    - Correlation and Operational Analysis of Pilot, Controller and Flight Systems Data Recorded Wake Turbulence Encounters;
    - Correlation Data Support to the Ground Sensor Wake Turbulence Behaviour Monitoring Measurements;
    - Operational Risk Monitoring Analysis using the Wake Turbulence Behaviour Monitoring Measurements.
12. Metering of Arrival Aircraft onto Intermediate Approach:
    - Separation Minimum Display;
    - Localiser Turn-On Spacing Display;
    - Initial Approach Fix Expected Approach Time Support;
    - Final Approach Fix CTA Support.

3.2.1.3 List of Aircraft Operations System Developments

1. Aircraft Wake Category and Aircraft Type Verification Support:
   - Aircraft Data Link Verification Support.
2. Aircraft Approach Intentions Notification Support:
   - Aircraft Data Link Notification Support.
3. Aircraft Derived Meteorological Data Support:
   - Aircraft Data Link Airborne Parameters Support.
4. Expedited Runway Vacation Support:
   - Brake to Vacate Support.
5. Wake Turbulence Hazard Risk Monitoring on Approach:

- Pilot Reporting of Wake Turbulence Encounters;
- Flight Systems Data Recording of Wake Turbulence Encounters.

3.2.1.4 List of Airline Operations and Support System Developments

1. Aircraft Approach Intentions Notification Support:
   - Airline Operations System Notification Support.
2. Wake Turbulence Hazard Risk Monitoring on Approach:
   - Processing of Pilot Reported Wake Turbulence Encounters;
   - Processing of Flight Systems Data Recorded Wake Turbulence Encounters.

3.2.1.5 List of Airport Infrastructure, Operation and Support System Developments

1. Expedited Runway Vacation Support:
   - Rapid Exit Taxiway Design and Positioning;
   - Brake to Vacate Support.
2. Forecast Meteorological Data Support:
   - Wind Conditions Profile on Approach;
   - Visibility Conditions in the Vicinity of the Aerodrome.
3. Wake Turbulence Hazard Risk Monitoring on Approach:
   - Ground Sensor Wake Turbulence Behaviour Monitoring Measurements.
4. Meteorological Conditions Monitoring and Measurements:
   - Wind Conditions Aloft Profile on Approach;
   - Wind Conditions Aloft Profile for Correlation with Wake Turbulence Behaviour Monitoring Measurements;
   - Atmospheric Turbulence Aloft Profile for Correlation with Wake Turbulence Behaviour Monitoring Measurements.

3.2.1.6 List of Specialist Technical Support Developments

1. Wake Turbulence Hazard Risk Modelling:
   - Wake Turbulence Behaviour Modelling;
   - Wake Turbulence Encounter Hazard Risk Modelling;
   - Wake Turbulence Encounter Effects Modelling.

3.2.2 Human Factors Assessment Input

The contribution of the Human Factors Case to the refinement of the TBS operational scenario described in the TMA DOD has been provided by:

- M1 – Fact finding report (see [55) which covers the first stage in the HF Case process with the aim of understanding the operational concept from a HF perspective by identifying what will change, who will be affected and how they will be affected with the implementation of Time Based Separation in the TMA.

  This report has contributed to further detail the roles and responsibilities of the key actors involved in the operation and also to provide a high level description of the current ATM operation versus the TBS one. It strengths the planning controller's role and describes some ATC instructions.

- M2 – Issues Analysis Report (see [5]) which provides a description of the brainstorming session where HF hazards were identified, the process implemented for the HF Identification as well as the final outcome of the analysis.

  The mitigation strategies included in this report has fed mainly the sections regarding actors and enablers and ATCO supporting tool from the original TMA DOD. Some open issues were also identified that needs to be further assessed in the future.

After analyzing the results of the Human Factors Case, the following major areas have been identified for further assessment in the HF Case:

- Develop a supporting tool to assist the Approach Controller in directing flights to intermediate approach;
- Management of the time-spacing reductions associated to different stabilization speeds of the leading and following aircraft;
- Identify those areas which ensure that pilot/cockpit behaviour provides consistent performances that allow time-based separation;
- Expedite runway for leading aircraft;
- Reduction of the radar separation minimum on the glide slope from the current reduced radar separation minimum to at least a 2NM reduced radar separation. It particularly applies to arrival pairs where both aircraft are employing slow landing stabilisation speeds;
- MET services data provision: integrate nowcast wind conditions within profile information on the approach paths from the initial approach fixes to the runway threshold;
- Integration of the TBS supporting tools and associated HMI in the current controller working positions of the Approach and Tower Controllers;
- Training has been identified during all the previous items as a key factor to implement the TBS operational scenario.

Other recommendations coming out of the preliminary HF Case are:

- Carry out a full stakeholder consultation to ensure that the TBS concept is acceptable and feasible to all stakeholders (airline, ANSP, regulator,);
- Assess the acceptability of the wake vortex encounter risk;
- Assess the legal responsibilities for the approach controllers.

3.2.3 Safety Assessment Input

The contribution of the safety assessment to the refinement of the "Time Based Separation" operational scenario described in the TMA DOD has been mainly provided by results from the WP7.7 TBS Mitigation Workshop, aimed to suggest potential mitigation measures for the high ranking hazards. These potential mitigation measures have fed mainly the section regarding the proposed Time Based Separation ATC Support Tool and the Hierarchical Task Analysis from those coming from the HIL assessment and the support pack respectively.

After analyzing the results of the safety case (see ref [18]), some aspects need to be readdressed in the future in order to enable the implementation of this operational scenario:

- Assess the possibility of using an additional time buffer to cope with unforeseen separation problems resulting from the catch-up effect within 4NM to threshold. This time buffer is needed always the aircraft pairs have large deviation in reference speed;
- Regarding the algorithm of the ATCO support tool, several recommendations were advised:

  - Incorporate the wind information (speed and direction) from ADS-B. This algorithm should then provide better estimations of the chevron position taking into account the track of the follower aircraft before joining the center-line;
  - Integrate approach speed downlinked from the aircraft thanks to ADS-B out;
  - Integrate dynamic changes of the mean ROT used to estimate the time spacing.
- Further assess the HMI of the ATCO support tool in terms of:
  - Visualization;
  - Provision to show the airspeed of the leading aircraft close to the chevron;
  - Label the chevrons with the callsigns of the follower. In this case, AMAN sequence will be reflected in the main ATCO display, improving his/her cognitive process.
- In terms of new procedures the following assessments should be accomplished:
  - Establish a procedure for the final approach controller to check the sequence list and manually update it (if needed) in order to potentially prevent wrong sequences;
  - Establish a procedure to automatically update the AMAN sequence to tackle with GA/MAP traffic;
  - If aircraft type is not downlinked by ADS-B, establish a procedure by which on first radio contact with approach control, flight crew will state the aircraft type.
- Investigate the development of a monitoring tool aimed to compare AMAN sequence with current sequence and launch alerts if necessary;
- Dedicated training programmes should be established for both flight crews and ATCOs when the concept is judged to be ready for implementation;
- Assess the introduction of incentive policies in the landing taxes, associated with techniques aimed to reduce the runway occupancy time.

3.2.4 Economy Assessment Input

Although there has been no input of the economy assessment in the TMA DOD, some conclusions can be extracted that support the implementation of TBS operational scenario from an economy perspective.

The cost-benefit analysis shows that there is a positive balance of benefits and costs if TBS concept of operation is applied at Madrid Barajas airport, although the character of Barajas is a relatively low occurrence of strong headwind conditions. Benefits stem from prevention in capacity loss in situations with such strong headwind conditions. One could derive from this that the benefits would be larger if TBS is applied on airports where strong headwind conditions occur more frequently.

The cost-benefit assessment has been carried out by applying TBS performance data from other airports on the situation of Madrid for data availability reasons. Also, the safety effects have not been directly included in the cost-benefit analysis. However, the cost-benefit results that there is still quite some ‘room’ for additional costs for applying safety mitigation measures.

After analyzing the results of the Economic assessment, the following areas have been identified for further assessment:

- To make an assessment of the application of TBS at the top 20 airports in Europe, including the ones with a high frequency occurrence of strong headwind conditions;
- To include in such assessment an in-depth analysis of wind velocity development during each day of year;
- To assess how the safety mitigating measures impact the recuperation rate of TBS, and in turn how this affects the cost-benefit results.

3.2.5 HIL Assessment Input

The Real Time Simulation scope is focused on applying time based separations on arrivals in order to maintain landing capacity under strong head wind conditions.

The main contribution of this activity to the refinement of the TBS operational scenario described in the TMA DOD has been the definition and validation of the TBS ATC support tool (display with chevron). This decision aid will help the controller to ensure that the time separation is not violated, showing the minimum separation that is allowed between every pair of aircraft.

Controllers involved in the simulation made some suggestions regarding the chevron display that should be further validated in the future:

- Add the groundspeed to the chevron's data label, what would help the controller to estimate an appropriate buffer to reduce the risk of overtaking;
- Use the chevron display as an aid in the training of the final director to be able to set up the required spacing on long final as they could see the final results of their actions and make adjustments;
- Display two chevrons: one acting as spacing "target" chevron for the controller and the other as "boundary" chevron for the minimum separation;
- Chevron shape as the one used in the RESET simulations has the drawback that when the follower is very close to the chevron, it is hard to see if it is in front, behind, or on top of the minimum separation point;
- What is the maximum distance from the runway threshold to begin displaying the time separation indicator;
- When the separation indicator should stop being displayed on final approach or whether to display the chevron to the threshold.

Some of the transition criteria identified for the TBS concept to be implemented are:

- The feasibility and safety of the concept have to be assured what will require, among others, a definition of the system requirements needed to use this separation and an assessment of the workload for controller and pilot;
- The stakeholders have to accept it what implies a detailed business analysis which points out the advantages and costs of the concept, including the tool development and training;
- New procedures have to be defined and validated, including the contingency procedures. The roles and responsibilities have to be defined and accepted by all the involved actors. The Human Factor analysis has to study the training, organisation and human-machine interaction too;
- New controller tools must be developed and validated to support the TBS concept. The accuracy and integrity of the tool has to be proven, and real time simulations and trials have to be used to prove the capabilities of the tool and to check that the tool is accepted by the controllers and adapted to their needs and preferences;
- The environmental impact of the TBS concept has to be analysed: noise and emissions have to be evaluated;
- Legislation will have to accommodate TBS: the legal definition of TBS separation minima values and the relationship between distance based separation and TBS (transition point from one to other, conditions for the use of TBS) have to be accurately defined;
- The algorithm for TBS has to be certified, maintained and implemented in a conformed manner across Europe.

4 Refinement of Airport DOD – TIPH/V4LUW operational scenario

4.1 Technological developments

4.1.1 A-SMGCS

Technological research in this section is mainly based on EMMA and EMMA 2 research projects that address A-SMGCS implementation.

A-SMGCS is the framework for all concepts concerning surveillance, routing, planning and control of movements on the manoeuvring area at an airport including the proposed ”Line Up and Wait in All Visibility Conditions” (V4LUW) procedure. A-SMGCS at its most refined and advanced level is aimed at providing a safe concept and system that works in all weather conditions by providing all actors with an excellent situation awareness, prediction of conflicts, proposals for conflict resolution and reliable detection and alerts in case of runway and taxi incursions as well as collision avoidance systems.

A-SMGCS currently utilises Mode S Multilateration (MLAT) technology, for the detection and identification of cooperative aircraft and vehicles, and Surface Movement Radar (SMR) for the detection of all aircraft, vehicles, and obstacles. These technologies and the associated requirements have been validated and in many operational installations throughout Europe and other parts of the world.

A-SMGCS is normally described by the level of refinement and precision it can deliver data as aid for the airport and airside operation. The implementation of A-SMGCS is being achieved through the implementation of these levels, forming a coherent series of increasing system complexity:

These levels are:

- *Level 1* provides surveillance, display systems and procedures to permit comprehensive ATCO situation awareness;
- *Level 2* consists of Level 1 functions together with automated monitoring and alerting functions, initially including the prediction of conflicts on active runways or incursions into restricted areas;
- *Levels 3 and 4* correspond to the introduction of routing, automatic guidance and planning functions, but still have to be clearly defined[9].

RESET Line Up and Wait in All Visibility Conditions is based on A-SMGCS level 3.

There are three main users of an A-SMGCS: Air traffic controllers (ATCOs), pilots, and aerodrome vehicle drivers. In accordance to the requirements of these users the following A-SMGCS level 3/4 services have been addressed:

1. Services to Air Traffic Controllers (ATCOs):

- Surveillance
- Control:
    - Conflict Prediction, Detection and Alerting;
    - Conflict Resolution;
    - TAXI-CPDLC;
    - Sectorisation, Transfer of Control, and Co-ordination.

[9] See http://www.eurocontrol.int/airports/public/standard_page/APR2_Projects_ASMGCS_2.html

- Routing / Planning:
    - Manual Routing;
    - Semi-automatic Routing;
    - Automatic Routing;
    - Departure Management.
- Guidance[10]:
    - Ground based Guidance;
    - Onboard based Guidance.

2. Services to Flight Crews:

- Airport Moving Map Function;
- Surface Movement Alerting function;
- Ground Traffic Display Function;
- Traffic Conflict Detection Function;
- TAXI-CPDLC;
- Braking and steering cues Function;
- HUD Surface Guidance Symbology Function;
- Ground- Air Database Upload.

3. Services to Vehicle Drivers:

- Airport Moving Map Function;
- Surface Movement Alerting Function;
- Ground Traffic Display Function (Surveillance);
- Vehicle Dispatch and Guidance by Data Link;
- Remarks on Vehicle Equipage.

4. Integrated Human Machine Interfaces (for all users)

4.1.1.1 Surveillance Service

Surveillance service provides controllers (eventually pilots and vehicle drivers) with situational awareness on the movement area (i.e. a surveillance display showing the position and identification of all aircraft and vehicles). There are four steps of implementation.

The first three surveillance service steps provide position, identification and state vector (heading, speed) of aircraft and vehicles in the manoeuvring and APRON area to ATCOs. The fourth surveillance service step also includes the state vector of aircraft (and/or vehicles) on the manoeuvring and APRON area to ATCOs through the use of alternative surveillance technologies, including dependent surveillance provided by ADS-B.

Aircraft Prerequisites:

- Mode-S Transponder;

[10] "Guidance" is mentioned under the "ATCO services" as it is one of four basic A-SMGCS functions: Surveillance, Control, Routing /Planning, and Guidance. However, the real recipients of this service are pilots and aerodrome vehicle drivers, where the ATCO is supported by an A-SMGCS to provide the guidance service.

- Step 4 is strongly related to the certification and implementation of the avionic equipment which is providing the quality and reliability of position and state vector data.

Technical Enablers Availability and Complexity:

Compared to Mode-S multilateration, there is an increased complexity relating to the equipage of all aircraft with an appropriate means for position and state vector acquisition on the airport surface with the required level of service.

The main technical enablers are identified as follows:

- Provision of traffic information (identity, position, state vector): available today (except for ADS-B Out):
    - Cooperative sensors (Multilateration, ADS-B and SSR);
    - Non-cooperative sensors (SMR, PSR, and others that meets the A-SMGCS operational requirements as defined in the EMMA2 SPOR and EMMA ORD documents);
    - Vehicle equipment (Transmitter and receiver).
- Provision of traffic context information: available today (digital airport chart);
- Human – machine interface: available today.

4.1.1.2 Control Service

Control service provides conflict detection and alerting on runways (and eventually the whole movement area). There are five steps of implementation.

The first step in control service implementation consists in the detection and alerting for conflicts (risk of collision) between aircraft and vehicles as well as in infringements of restricted areas, runways and taxiways by either aircraft or vehicles. The detection of runway and taxiway conflicts (potential loss of separation) is made on the basis of information provided by the surveillance service and using pre-defined rules for the trigger of timely alerts to ATCOs.

In the implementation of the second step "Conformance monitoring" service monitors the behaviour of the movements of aircraft/vehicles to check if they do what they are supposed to do. The service permanently looks for deviations from the instruction given by the ATCO (route conformance, clearance conformance…), and "Conflicting clearances detection" service performs a cross-check of the set of clearances provided at the same time on an airport in order to ensure their consistency.

Transfer/assumption of control in general means transfer/assumption of responsibility, information, and communication. In a conventional A-SMGCS the paper strip is passed between ATCOs, and the Flight Crew is prompted to contact the next position on the respective frequency via voice-communications. The introduction of automation of surface movement planning and electronic flight strips supports the ATCOs coordination between Ground and Tower Controllers and adjacent Approach controllers.

In the implementation of the third step in control service TAXI-CPDLC service allows the ATCO to provide the flight crew with ground specific information messages and to issue ground clearances via data-link instead of using voice. Since TAXI-CPDLC is used to upload the taxi route onboard of the aircraft (graphical depiction on the airport moving map), this service may also be classified as a Guidance Service.

The fourth step in control service implementation proposes automated advice to the controller for conflict resolution. Additional research deserves to be carried out for examination and validation.

The fifth and last step of the Control service proposes automated conflict resolution. Similarly to step 4, additional research deserves to be carried out for examination and validation.

Ground Prerequisite:

- Surveillance service (step 1);
- Routing (step 2 semi automatic or step 3 automatic) for detecting non conformance to taxi routing clearance.

Aircraft Prerequisite:

The implementation of the service depends on the availability of CPDLC on board of the aircraft; such a system exists today for en-route operations but requires additional developments to meet Flight Crew requirements for surface movement (graphical interface).

Technical Enablers Availability and Complexity:

- Surveillance service at least step 1;
- Conflict prediction, detection and alerting system/algorithm: available today;
- HMI: reuse of surveillance HMI used today;
- Control Step 1 technical enablers;
- Electronic Flight Strips including processing of ATCO clearances: available today;
- Flight Data Management ensuring data synchronisation among adjacent sectors/positions: available today;
- Conformance monitoring algorithms/systems: prior to 2013;
- Point to point data link to enable TAXI-CPDLC: 2013-2020.

4.1.1.3 Routing / Planning Service

ATCO is responsible for taxi clearance(s) but the service maintains and automatically updates the route (track) and timing information. The flight planning (pre-tactical and tactical) function has to be added to increase efficiency of the routing services. Planning support can be further increased by the implementation of an automated departure management tool (DMAN) that provides an optimised departure sequence and (runway usage).

Ground Prerequisite:

- Surveillance service step 2 (aircraft position and identification on manoeuvring and apron area);
- Flight plan data processing system (to get ETOT, ELDT, CTOT, RWY, Gate/Stand, A/C Type);
- The A-SMGCS control function (to know about LVP, crossings and all other prevailing constraints).

Technical Enablers Availability and Complexity:

- Routing algorithm:
  - Shortest distance criteria;
  - Infrastructural/operational constraints;
  - Minimizing crossing conflicts.
- Appropriate user friendly HMI, that isn't time consuming for taxi route selection or searching for alternatives;
- DMAN;
- EFS: report on the flight progress (i.e. timeline) indicating ETOT, CTOT and TSAT;
- Airport configuration – operational procedures applied available in the system.

It is important that the cleared taxi route is made available within the system without major extra expenses by the ATCO. The following recommendations should be considered when developing and implementing a routing service:

- Preferably enable working with the routing service both via the traffic situation display (TSD) and the EFS;
- Guarantee high accuracy of start and end point of the route, in order to better enable other services like “route deviation alerting” that depend on the information;
- Design the routing function that takes into account surveillance information in order to detect the current position of the aircraft or vehicle and to define the start point of the taxi route (e.g. automatic detection of RWY exit for landing aircraft);
- Plan a routing service able to give partial routes, if ground-taxi control is shared by more than one ATCO. Each ATCO will then receive only the required information.

4.1.1.4 Guidance Service

Guidance service provides pilots and drivers indications enabling them to follow an assigned route. Automated A-SMGCS ground based guidance should provide visual aids, which will consist of:

- Selectively and/or segment-wise switched centre line lights, and
- Selectively switched stop bars

This provides clear indications to flight crews and vehicle drivers to allow them to follow their assigned routes and it is operated by the A-SMGCS based on the clearances input by the ATCO.

Ground Prerequisite:

- Surveillance service step 2 (aircraft position and identification on manoeuvring and apron area);
- Routing service step2 (semi-automatic routing).

Technical Enablers Availability and Complexity:

The main required enablers are:

- Automated Airfield Lighting Control System (segment switchable lights);
- Controller HMI (Switchboard or Lighting Display);
- Interfaces to Control and Surveillance Function.

Development plans schedule to deliver the required enablers on the medium term (2013-2020).

It shall be noted that the ground lighting is part of the aerodrome infrastructure and is implemented in relation to the landing system selected (ILS CAT-I to CAT-III).

4.1.1.5 Other Services

➢ **CONFLICT PREDICTION, DETECTION AND ALERTING**

Conflict prediction, detection and alerting functions are based on surveillance-based E-SCA (Enhanced Situation Conflict Alerting) and Advanced Runway Safety Net (A-RSN) systems in support of a safety assessment. They are used to cross check the consistency of the set of clearances and instructions provided at the same time on an airport.

A-RSN adds a safety layer to the B-RSN (basic surveillance-based runway safety net) by taking into account the instructions given by ATCOs, which are processed via EFS inputs. The A-RSN is considered as an add-on to the B-RSN. The A-RSN detects aircraft in the Runway Protection Area (RPA) whose behaviour is incompatible with the instructions given by the ATCO. The advantage of an A-RSN is twofold: it improves the anticipation of conflict detection through the processing of instructions issued by the controllers; and it is designed to complement a B-RSN in an airport already provided with a well configured one, thus improving the runway safety net capability without having to configure entirely a new system.

The following recommendations should be considered when developing an A-RSN:

- The design of the EFS (interaction means for the ATCO) should be elaborated enough to allow applying working methods in use so as not to reduce the A-RSN capabilities.
- If the system does not allow the input of necessary information, nuisance alerts are triggered that may diminish the A-RSN utility and acceptability.

➢ **AIRPORT MOVING MAP**

This function supports the Flight Crew during surface movement operations by improving their situational awareness about own-ship position and heading on the aerodrome layout.

The Surface Movement Alerting (SMA) function will be a safety support tool to avoid runway incursions by preventing the unauthorised entrance, crossing of runways as a result of Flight Crew navigational errors

Technical Enablers Availability and Complexity:

- Digital database of the airport surface using adequate data format for instance ARINC 816 format (available today);
- Required high accuracy of aircraft position (available today).

➢ **SURFACE MOVEMENT ALERTING IN THE COCKPIT**

The function can be used in two modes: when TAXI-CPDLC functionality is not available, the function uses only D-ATIS/NOTAM information. In case TAXI-CPDLC is available, the function uses clearance information to enable a more precise alerting scheme.

- The status information about runways and taxiways that should be provided to the crew is active runway direction and closed or partially closed runways and taxiways. In case of conflict possibility an alert should come early enough to give the crew time to change their course;
- In case TAXI-CPDLC is available, the crew should be alerted when trying to enter a runway without the corresponding clearance.

➢ **TRAFFIC CONFLICT DETECTION AND GROUND TRAFFIC DISPLAY**

The Ground Traffic Display Function enhances the traffic situational awareness on-board through the display of other aircraft / vehicles respective positions, identity and headings. The Conflict Detection function raises the awareness of the Flight Crew about potential conflict(s) with other traffic.

Technical Enablers Availability and Complexity:

- ADS-B In, for reception of other aircraft/vehicles position (available today);
- ADS-B Out, emission of position of each aircraft/vehicles position: available today but expected to be on all aircraft in 2020+;
- TIS-B: technology is available but no plan for deployment exists today.

➢ **TAXI-CPDLC**

The TAXI-CPDLC service relies on the exchange of taxi route related information between the ATCO and the crew. To provide a safe and efficient service, it is then recommended that both ground and cockpit systems integrity should be guaranteed and that the databases for routing should be shared between ground and onboard.

The TAXI-Controller Pilot Data Link Communication (TAXI-CPDLC) services support the Flight Crew for ATC Controller – Flight Crew dialogs during surface movements (start-up, push-back, taxi clearances) and the reception of taxi route information dispatched by the ground system. At a later stage it is envisaged that clearances such as taxi route revisions or hold short instructions will be communicated using CPDLC as well. It is expected to be operational in the not too distant future to solve safety and efficiency problems associated with the anticipated increase in traffic.

Technical Enablers Availability and Complexity

- A proper data link that fits the performance needs for TAXI-CPDLC;
- Airport moving map with enhancement features, including TAXI-CPDLC function in order to check graphically the TAXI-CPDLC message;
- TAXI-CPDLC communication interface and respective HMI

➢ **BRAKING AND STEERING CUES**

The Braking and Steering Cues (BSC) display subsystem is an avionic function that will support the Flight Crew during surface movement operations. The concept for the BSC function is that it provides tactical support to the Flight Crew, as a complement to other parts of the A-SMGCS that provide general surface situation awareness information. The BSC function has two roles:

- Braking support to optimise the runway occupancy times, by assisting the Flight Crew to control the aircraft deceleration in order to exit the runway as planned, or to warn the Flight Crew as early as possible if actual braking performance is not sufficient to exit as planned;
- Steering and braking support to the Flight Crew during taxi operations. Examples where the BSC function will contribute to taxi operations include:
    - Braking cues in the event that taxi speeds are too high when approaching a turn;
    - Steering cues for taxi manoeuvres.
- Speed-control cues to allow the Flight Crew to increase speed where appropriate to reduce overall taxi time whilst minimising wear and tear on the undercarriage.

Technical Enablers Availability and Complexity

- On-board HMI or Head Up Display (option);
- Required high accuracy of aircraft position if HUD used

➢ **HUD SURFACE GUIDANCE SYMBOLOGY**

A head up display (HUD) turned out as a very promising tool to support the taxiing pilot to navigate and steer the aircraft along its cleared taxi route, particularly in very adverse sight conditions. A HUD increases the pilots' local situation awareness by emphasising the outside view and providing additional information, which are superimposed on the real outside view, e.g. the edges of taxiways or other traffic.

The Head-Up Navigation Subsystem is an avionic function designed to support the Flight Crew e.g. during taxi operations, through the Head Up Display (HUD) Surface Guidance. The concept for the Surface Guidance Symbology Function on the HUD is that it provides through adapted symbology tactical support to the Flight Crew; the HUD Surface Guidance is complementary to other on-board applications that provide general surface situation awareness information.

Technical Enablers Availability and Complexity:

- Head Up Display (for ground movement assistance);
- Functional Digital airport database.

Ground to Air Database Upload Function/Service to Vehicle Drivers:

Since every equipped car broadcasts its GPS position, it is proposed to display this position on a moving map in order to enhance the situational awareness of drivers. Besides displaying the vehicle position, the device is meant to trigger an alert when the vehicle infringed a restricted pre-defined area. The following recommendations are to be considered when implementing service to vehicle drivers:

a) Ensure that the system accommodates every speed and direction necessary for operational use;

b) Ensure that the alerting system triggers alerts at incursion of restricted area;

c) Ensure that the equipment is easy to install;

d) Check that boot time is quick;

e) The design of the map should be carefully considered so that HMI usability requirements are met (e.g. use of colour, information readability, thickness of the lines…);

f) Ensure the timeliness and integrity of the information presented.

The implementation roadmap of these services is shown in next figure. Also an example of the technical requirements developed in EMMA 2 and concerning the Control Service Functional and Performance have been included in Annex I (see section 6).

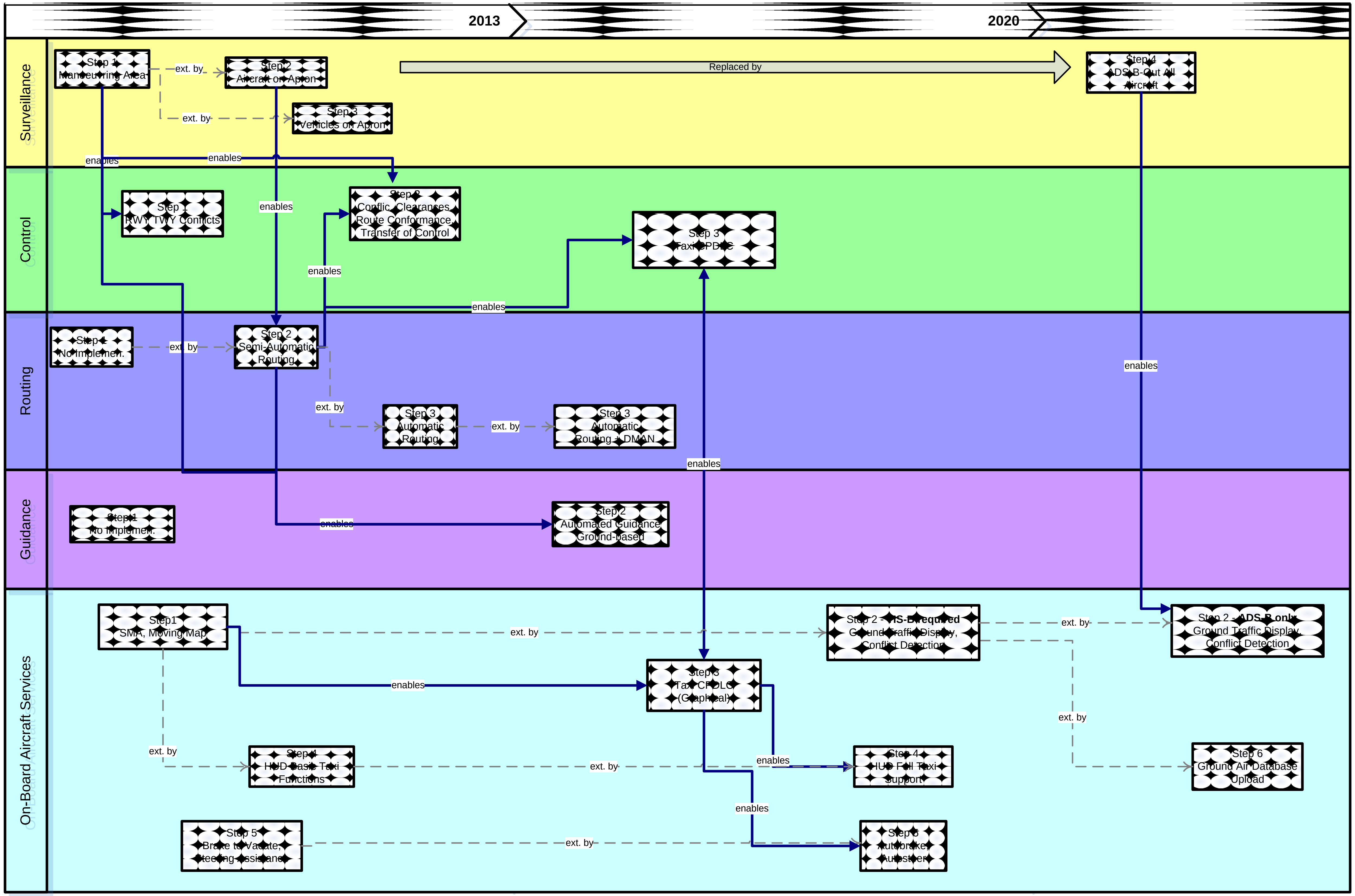

Figure 4: Roadmap for the implementation of A-SMGCS

4.1.2 Other technologies relevant to V4LUW

It is aimed to use new means to operate the A-SMGCS, to augment the surveillance function and to provide improved situational awareness for A-SMGCS users.

➢ **ADS-B**

Mode S ADS-B technology as currently specified in DO-260A may not meet the needs of A-SMGCS:

- In order to be useful for A-SMGCS applications, ADS-B will need to meet the requirements of A-SMGCS, in particular with regard to position accuracy, update rate, latency (timeliness) and integrity. Adequate coverage and continuity of service needs also to be ensured;
- Line-of-sight coverage is needed, which means that multiple ADS-B receiving stations will be required to provide complete coverage of the entire manoeuvring area of an aerodrome;
- It is recommended that the EUROCONTROL CASCADE OFG and EUROCAE WG-51 working groups take heed of the A-SMGCS performance requirements in their current work on ADS-B APT and ATSA-SURF;
- The use of portable Mode S squitter beacons is recommended for surface vehicles.

➢ **TIS-B**

The TIS-B ground system equipment demonstrated technical maturity and operational feasibility. For the on-board side, it is important to ensure that requirements for avionic equipment capture the level of integrity and timeliness needed to provide true situational awareness in the rapidly changing aerodrome surface traffic environment. Additional observations and recommendations for TIS-B:

- Requirements for update rate and timeliness of information transfer need to be ensured;
- Adequate coverage and continuity of service needs also to be ensured;
- Line-of-sight coverage is needed;
- More than one TIS-B antenna and transmitter is likely to be required to provide complete coverage of the entire manoeuvring area of an aerodrome;
- Be aware that MLAT systems installed prior to 2005 may not be able to distinguish between ADS-B and TIS-B messages. This would result in two problems:
    - The jumping target problem, when targets are detected by the MLAT system both at their real position and at the position of the TIS-B transmitting antenna, and
    - In the loop-back problem, when targets detected by the MLAT system are processed by the SDF and transmitted by the TIS-B system, and then again received by the MLAT system, causing a continuous loop. Steps must be taken to address this problem.

➢ **ELECTRONIC FLIGHT STRIPS (EFS)**

Using the higher-level A-SMGCS services requires proper human-machine-interfaces (HMIs). Besides the Traffic Situation Display (TSD), electronic flight strips (EFS) were demonstrated to play an important role here. EFSs provide a mean to operate the new A-SMGCS services by displaying the system output and allowing the ATCO the necessary interaction. Well-designed human-machine interfaces are an absolute pre-condition for a safe and efficient handling of the new A-SMGCS services. The following recommendations should be considered when developing EFS systems:

- Follow a user-centred approach with a sufficient number of iterative validation loops;

- Benefit from proven lay-out of the paper strips by modifying as little as possible the operating methods and workflow but being also sufficiently open-minded to exploit the new opportunities electronic strips can provide and fit them to the current needs;
- Even when not all higher-level services are used in the beginning, the EFS design should be made flexible enough to easily adopt higher-level services at a later stage (e.g. dealing with data link clearances);
- Still valid and still of utmost importance: Keep the need for controller interaction to an acceptable minimum;
- The information shown in the different fields of a flight strip should always be represented at the same position on the strip independent of the life-cycle of the strip and independent of the controller working position at which the strip appears;
- Ensure that the movement of each flight strip is under the full control of the controller responsible for the flight.

➢ **DEPARTURE MANAGEMENT (DMAN)**

DMAN supports the ATCO to better time and sequence the outbound traffic. ATCOs like the additional information provided by DMAN and admit that it would help them to plan the outbound traffic more efficiently, to avoid excessive queues at the runway holding points and to shorten the stop times during taxiing. To exploit the full benefit in the near future, the following recommendations should be considered:

- The highest potential of DMAN is under conditions of extensive departure peaks;
- Plan to integrate the DMAN into a CDM environment, which would enable the DMAN to work with a broader planning horizon, which would of course also improve the DMAN planning output;
- Take into account that a considerable amount of time is needed to adapt the tool to the particularities of the concerned airport and its local procedures;
- DMAN should receive information provided by the surveillance and clearance inputs of the ATCO;
- DMAN should also consider the aircraft type.

➢ **GROUND TRAFFIC DISPLAY**

The function strongly relies on the quality of received traffic data from ADS-B or TIS-B systems. The function will be useless and even hazardous if the accuracy of the traffic data (position, heading, ground speed, etc…) is not sufficient.

Ground traffic display should provide information to the crew about position, heading and the ground speed indications to allow pilots to anticipate potential conflicts, also the call sign and the type of each traffic because it facilitates the communication with ATC. As well as the conflicting traffic highlighted on the map.

➢ **TRAFFIC CONFLICT DETECTION**

The Traffic Conflict Detection (TCD) function is capable of being used appropriately on the surface movement area. Visual warnings presented on the EMM and on the PFD as well as audible warnings attract pilots' attention in case of traffic conflicts.

The only use of ADS-B data could not meet the needed accuracy to reliably detect potential conflict situations. It is recommended to use only TIS-B or TIS-B and ADS-B data together. Further recommendations are:

- Implement an intelligent traffic filter onboard in order to limit the traffic amount to those aircraft and vehicles that might enter into a conflict with the own ship to prevent overloading the onboard TCD function with irrelevant traffic that could delay the TCD processing;

- The use of secondary conflicts intelligent resolution software in order to avoid secondary conflicts (enter into another conflict when solving a previous conflict);
- It is recommended to further develop a harmonised safety net, which exploits best the coexistence of on-board or/and ground detected conflicts, and to bring it to a regulatory basis.

4.1.3 Next steps

Some general issues need to be addressed in order to enable these new services:

- ADS-B will need to meet the requirements of A-SMGCS, in particular with regard to position accuracy, update rate, latency (timeliness) and integrity. Adequate coverage and continuity of service needs also to be ensured;
- The on-board side of TIS-B, it is important to ensure that requirements for avionic equipment capture the level of integrity and timeliness needed to provide true situational awareness in the rapidly changing aerodrome surface traffic environment;
- Well-designed human-machine interfaces are an absolute pre-condition for a safe and efficient handling of the new A-SMGCS services;
- The cockpit HMIs should remain intuitive regarding TAXI-CPDLC applications;
- Ground forwarding/SWIM concept is needed for the taxi-in function.

4.2 Human Factors Assessment Input

The contribution of the Human Factors Case to the refinement of the “Line Up and Wait in All Visibility Conditions” operational scenario described in the Airport DOD has been provided by:

- M2 – Issues Analysis Report (see [12]) which provides a description of the brainstorming session where HFs were identified, the process implemented for the HF Identification as well as the final outcome of the analysis.

  The report includes mitigation strategies how to possibly overcome identified HF issues. Some open issues were also identified that needs to be further assessed in the future.

- Results from the WP7.7 workshop aimed to suggest potential mitigation measures for the high ranking hazards. From the hazards assessed, only those covering human factors aspects will be considered here.

  The main input from this workshop was a change in the nomenclature suggested both by controllers and pilots who attended to this meeting: Line Up and Wait in All Visibility Conditions replaces the previous Taxi Into Position and Hold. This change is justified as the operation “line-up and wait” which is already used on airports today. The major change suggested by RESET with this operational scenario is that this operation can be also used under very low visibility conditions.

After analyzing the results of the Human Factors Case, some aspects need to be readdressed in the future in order to enable the implementation of this operational scenario:

In general it is complex to make an exhaustive assessment of all aspects of the proposed V4LUW concept at an early stage of the project as RESET is in. Additionally, the proposed V4LUW concept is build on a lot of assumptions regarding technologies which are not (fully) developed yet. For these reasons, Human in the loop studies are recommended to complete the current assessment of this operational scenario. They can provide information about feasibility of the concept, acceptability of the concept and the associated systems, efficiency, or usability of new systems and their interfaces as some examples:

- Human in the loop is recommended in order to investigate the achievable benefits of this operation in very low visibility conditions. Issues related to phraseology and communication can be classified as more critical in low visibility conditions, since there is no other mean to cross-check then the supporting systems;
- Once the technologies and supporting systems are fully developed and ready for operation special attention has to be paid to training needs related to new supporting tools for all actors involved, in order to familiarize and build trust into the system, as well as in the resulting increase in cooperation between the system and all involved actors;
- Safety studies should be performed to assess risks related to accuracy and availability of data/information, and to assess risks associated with malfunctions and errors related to the systems involved;
- HF studies regarding stress, workload should be conducted in order to derive information regarding benefits that could be expected;
- Studies regarding responsibilities, distributed responsibilities, and a possible shift in responsibilities should be conducted, since all actors will be provided with the same information. In case of a system failure on one side, aircraft or ground, clear rules regarding responsibilities have to be in place;
- It is recommended to conduct a cost-benefit analysis from the airliners and retrofit point of view (ADS-B in/out; ATSA-SURF; ATSA-AIRB; CDTI; etc.) in order to highlight the benefits of the proposed concept.

4.3 Safety Assessment Input

The contribution of the preliminary safety assessment to the refinement of the “Line Up and Wait in All Visibility Conditions” operational scenario described in the Airport DOD has been mainly provided by results from the WP7.7 V4LUW Mitigation Workshop, aimed to suggest potential mitigation measures for the high ranking hazards. From the hazards assessed, only those covering safety aspects will be considered here. The mitigation strategies identified during this workshop has fed mainly the sections regarding actors and enablers from the original Airport DOD.

After analyzing the results of the safety assessment, some aspects need to be readdressed in the future in order to enable the implementation of this operational scenario:

- Further studies on controllers’ workload should be conducted to determine their stress levels and therefore if they would apply on those circumstances a V4LUW procedure. However, if controllers’ workload is mitigated then pilots’ workload could be increased as a result. Controllers and pilots’ workload is considered a good issue for real time simulations;
- Training sessions for pilots are recommended since there are some non-integrated new systems in the cockpit, also a transition period should be considered in order to pilots get used to the new procedure.

  It is proposed the use of a display/representation of information regarding conflict traffics and specific warnings on cockpit for landing aircrafts;
- Reporting on pilots’ intention would be appreciated and strongly recommended for controllers’ use, since it provides advanced information of what could happen in the near future. I.e. information about aircraft increasing or decreasing its speed provides information of what the intention of the pilot is. This new and completely different means to get information of the future aircraft behaviour should be further investigated.

4.4 Efficiency Assessment Input

Airport efficiency assessment analyzes V4LUW concept in terms of efficiency by means of fast time simulation techniques.

The selected validation scenario was Barcelona – El Prat Airport and the traffic sample was created according to the expected demand in the year 2020 (based on a 2009 real database and mathematically increased to double the peak hour value of 2005 traffic), both based on D4.3.2 RESET Airport DOD. Twelve exercises were developed by means of modifying visibility conditions and runway mode operations.

The experiment was based on the hypothesis that it was possible to reach de “x2” traffic growth RESET objective, and results were obtained in form of delays. Delays based on Line Up and Wait procedures and V4LUW procedures were compared.

One of the main advantages on the use of V4LUW procedures is that results are not affected by visibility conditions; therefore departure delays are noticeably smaller than in case of using Line Up and Wait procedures. V4LUW procedures do not affect considerably arrival delays.

However, results were extremely dependant on the validation scenario and can not be extrapolated to global level because of two reasons:

- The experiment has only been run in one validation scenario (one airport and only one traffic sample);
- The simulations were run using the current infrastructures in Barcelona – El Prat airport, but the traffic sample corresponds to the 2020 expected traffic demand. Therefore the results do not fit the future situation, although the trend is outlined.

The main contribution to the refinement of the DOD was headed to the expected benefits of the implementation of the V4LUW Concept against the current use of the Line Up and Wait procedures, and how these results are dependant to the visibility conditions and the runway operation mode.

Although the results from the Airport Efficiency Assessment show all an increase in runway capacity (and a remarkably reduction on departure delays), they are limited to local level. Moreover, this experiment was developed under nominal conditions, in the basis of no fail or anomalous behaviour. These assumptions imply that results can not be extrapolated to global level.

4.5 Economy Assessment Input

Some conclusions can be extracted that support the implementation of “Line Up and Wait in all Visibility Conditions” from an economy perspective.

Application of the V4LUAW concept at Barcelona airport shows a positive cost-benefit result. The benefits outweigh the costs, dependent on a number of factors. This is to some extent remarkable, as Barcelona airport has 350 days a year good visibility conditions. Nevertheless, with modest traffic demand growth rates foreseen, the airport will face capacity problems in the medium term. The application of the V4LUAW concept will bring a modest relief to this, which nevertheless impacts the benefits significantly in a positive way. The benefits stem from:

- increased capacity in clear visibility conditions;
- reduced number of cancellations in bad visibility conditions.

The conclusions drawn above do not include the safety impact. A number of safety mitigating measures have been proposed, that may impact the results of the cost-benefit analysis in two ways:

- additional costs as a result of mitigation measures;
- decreased performance of the TIPH concept with a downward impact on the benefits.

Finally, the cost-benefit analysis has assumed a full implementation of A-SMGCS level 3. Such full implementation may in reality take a while. This means that benefits will come later, and investments may be made later as well. These may have an impact on the cost-benefit result.

After analyzing the results of the Economic assessment, the following areas have been identified for further assessment:

- to assess costs and benefits of the V4LUAW concept applied at airports with less good visibility conditions than Barcelona airport;
- to assess how the costs and benefits are if V4LUAW is applied at a number of large airports in Europe (e.g. the top10 or top20 airports);
- to assess how safety mitigating measures impact the V4LUAW concept performance and in turn how this impacts the benefits of V4LUAW.

5 Conclusions

This report has presented how the results coming from the different assessment activities carried out in RESET has been incorporated in the corresponding DOD. Specifically, the following activities were presented in this report:

- Methodology followed;
- Refinement of the TMA DOD:
    - For the lateral TMA separation, feedback from safety, human factors, efficiency and economy assessments have been considered;
    - For the TBS operational scenarios, feedback from safety, human factors, human in the loop and economy assessments have been considered;
- Refinement of the Airport DOD, including the V4LUW operational scenario, previously referred to as TIPH concept in other RESET documents. Input from safety, human factors, efficiency and economy has been incorporated.

Although economy assessment has been considered as part of the activities performed within WP8, it did not provide any input to the DODs. Something similar happened with the efficiency assessments; however they confirmed the expected benefits that the implementation of the operational scenarios will bring out. Therefore, both the preliminary safety and human factors cases were mainly feeding back the initial DODs in terms of the description of roles and responsibilities and of the technological enablers involved in the operation. In TBS it should be also highlighted the role of the Human in the Loop as one of the main feeders of this operational scenario.

In all cases and due to the early stage of maturity of the proposed concepts, some aspects have been advised to be readdressed in the future to support the implementation of the three operational scenarios.

Besides the technology development needed in order to implement these operational concepts has been also stressed:

- Regarding Lateral TMA separation, the technology research has been focused both on air-side (TCAS) and ground-side (MONA);
- Regarding TBS, several lists of envisaged system developments have been included related to ATC, aircraft, airline and airport operations;
- Related to airport operational scenario, A-SGMCS level 3 has been identified and assessed as the main enabler of this concept.

6 Annex I – A-SGMCS Technical Requirements

Requirement	Parent Requirements
Basic Functions	
The Control function should continuously process the target reports from the SDF to compare the traffic situation in real time with a set of predefined alert situations.	The control function of an A-SMGCS should detect conflicts and provide resolutions.
The Control function should output an alert report to clients whenever a predefined alert situation occurs.	
Alert Situations	
The Control function should detect any predefined conflict situation on the runway and generate a timely conflict alert report.	The Control function of an A-SMGCS should provide alerts for incursions onto runways and activate protection devices.
	Short-term alerts should be provided by the A-SMGCS within enough time to enable the appropriate remedial action when the predicted spacing will be below preset/predefined minima.
The Control function should detect whenever a target crosses any redefined runway strip ground boundary and generate an incursion alert report.	The function should provide runway incursion alert, whereby an alert is triggered when a movement likely to enter an active runway (runway trip) is detected.
The conflict situations should be configurable from the Configuration Database	The A-SMGCS should detect any incursion into areas used for aircraft movement and the runway strips, and within any designated protected area as required by airport authorities.
The runway strip boundaries should be configurable from the configuration Database	The runway protection area should be composed of two boundaries: a ground boundary to detect the aircraft/vehicles on the surface, an air boundary to detect airborne aircraft.

Requirement	Parent Requirements
The length of the ground boundary should at least include the runway strip. The width of the ground boundary should be defined differently according to good/poor visibility conditions.	The length of the ground boundary should at least include the runway strip. The width should be defined differently according to the meteorological conditions.
The air boundary should be defined as a flight time to threshold and take into account the two stages of alert, INFORMATION and ALARM, as well as the visibility conditions.	The air boundary should be defined as a flight time to threshold and would take into account the two stages of alert, INFORMATION and ALARM, as well as the meteorological conditions: • Non-LVP: INFORMATION around T1 = 30s ALARM around T2 = 15s • LVP: INFORMATION around T1 = 45s ALARM around T2 = 30s.
The Control function should make use of relevant traffic context information received from the Configuration Database and/or from the Controller HMI.	For the conflict/infringement detection, additional updated and correct traffic context information should be provided to the system such as: • Airport configuration: runways in use, runways status, restricted areas • Applied procedures and working methods: LVP, multiple line-ups.
The Control function should detect whenever a target enters any predefined protected area and generate a protected area alert report.	The control function of an A-SMGCS should provide alerts for incursions into critical and sensitive areas established for radio navigation aids.
	The control function of an A-SMGCS should provide alerts for incursions into emergency areas.
	The control function of an A-SMGCS should provide alerts for incursions onto taxiways and activate protection devices.
The protected areas should be configurable from the Configuration Database	
The Control function should detect whenever an aircraft target enters any predefined restricted area and generate a restricted area alert report. Targets other than aircraft targets should not trigger the alert.	The function should provide area penetration alert, whereby an alert is triggered when a movement likely to enter a critical or restricted area is detected.

<table>
<tr><th>Requirement</th><th>Parent Requirements</th></tr>
<tr><td>The restricted areas should be configurable from the Configuration Database</td><td></td></tr>
<tr><td rowspan="2">Once a route has been assigned to a mobile, and the mobile has started on that route, the Control function should detect when the target begins to deviate from that route by more than a predefined distance and generate a deviation alert report.</td><td>The function should provide deviation alert, whereby an alert is triggered when the computed deviation will be more than preset/predefined maximum deviation.</td></tr>
<tr><td>The function should provide taxiway (or an inactive runway being used as a taxiway) or an apron incursion alert, whereby an alert is triggered when a movement likely to enter a taxiway or apron in use, which does not belong to the assigned route, is detected.</td></tr>
<tr><td>The deviation limit should be configurable from the Configuration Database</td><td></td></tr>
<tr><td colspan="2">Stages of Alert</td></tr>
<tr><td>Conflict alerts should be configurable in two stages (1 and 2) according to the severity of the situation. Stage 2 (ALARM) is more severe than Stage 1 (INFORMATION).</td><td>The conflict prediction, detection and alerting service should provide 2 stages of alert: Stage 1 alert is used to inform the controller that a situation which is potentially dangerous may occur that he/she needs to be made aware of. According to the situation, the controller receiving a Stage 1 alert may take a specific action to resolve the alert if needed. This is called the INFORMATION step. Stage 2 alert is used to inform the controller that a critical situation is developing which needs immediate action. This is called the ALARM step.</td></tr>
<tr><td>Incursion alerts, restricted area alerts and deviation alerts should be configurable from the Configuration Database [9.1.1] as either Stage 1 or Stage 2 according to local requirements at the airport.</td><td></td></tr>
<tr><td>To be decided</td><td>Distinctive medium-term alerts should be provided well in advance to enable the appropriate remedial action to be taken with respect to: a) Conflict prediction; b) Conflict detection; and c) Conflict resolution</td></tr>
<tr><td colspan="2">Alert Reports</td></tr>
</table>

Requirement	Parent Requirements
As a minimum, each alert report transmitted from the Control function to clients should include the following information: • Data Source Identifier • Alert Report Identifier • Type of alert (runway, taxiway, apron, etc.) • Alert severity level • Time of Alert • Identity of target(s) in alert situation	The output of an alert report which may be used by the HMI should at least include: • Data Source Identifier • Alert Report Identifier • Type of alert • Alert severity level • Time of alert • Identity of target(s) in alert situation
	Priorities should be established so as to ensure system logic performs efficiently. Conflict alerting priorities should be as follows: a) Runway conflicts b) Taxiway conflicts c) Apron/stand/gate conflicts.
An alert report should be transmitted for each target position update for as long as the alert situation persists.	The information should be displayed continuously while the conflict is present.
	Conflict information should be unambiguously displayed on a surveillance display or by other appropriate means.
Conflict Resolution	
To be decided	Once a conflict has been detected, an A-SMGCS should either automatically resolve the conflict or, on request from the controller, provide the most suitable solution.

Requirement	Parent Requirements
	The ATCO should remain the supreme authority to resolve a conflict situation.
	A prerequisite for a reasonable and efficiently working automatic support is that the conflict resolution function is provided with at least all traffic information the ATCO is aware of.
Data integrity	
The probability of detection of an alert situation should be greater than 99.9%	The probability of detection of an alert situation should be greater than 99.9%
The probability of false Alert should be less than 10E-3.	The probability of false alert should be less than 10E-3.
	The number of false alerts should be sufficiently low to meet local safety objectives and to ensure that users do not, consciously or sub-consciously, downgrade the importance of alerts.
Having received the target report from the surveillance element, the time taken for the Control function to detect and report any alert situation should be not more than 0.5 s.	Delays due to the control service should be kept small compared to other delays in the system, particularly with regard to human action, air-craft braking times, etc. In the absence of a specific operational requirement, the proposed minimum performance figure for the ART should be 0.5s.

Table 4: A-SMGCS technical requirements[11]

[11] See http://www.dlr.de/emma2/maindoc/2-D112a_ATR-GND_V1.0.pdf, section 5.2.1, pages 64-71 for more information.

7 Annex II – Refined TMA DOD

See the document RST-WP4-INE-004-D4.3.1 Refined TMA DOD-v5.0.doc

8 Annex III – Refined Airport DOD

See the document RST-WP4-INE-006-Refined D4.3.2 Airport DoD v2.0.doc

9 Annex IV – Terms and References

9.1 Glossary of Terms

Abbreviation	Long Name
ADS-B	Automatic Dependent Surveillance Broadcast
AMAN	Arrival MANager
ANSP	Air Navigation Service Provider
AOC	Airline Operational Control
APT	Airport
A-RSN	Advanced Runway Safety Net
ARINC	Technical standard (aviation)
ART	Alert Response Time
ASAS	Airborne Separation Assistance Systems
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATR	A-SMGCS Technical Requirements
B-RSN	Basic Surveillance-based Runway Safety Net
BSC	Braking and Steering Cues
CBA	Cost- Benefit Analysis
CDM	Collaborative Decision Making

Abbreviation	Long Name
CDTI	Cockpit Display of Traffic Information
CPA	Closest Point of Approach
CPDLC	Controller Pilot Data Link Communication
CTA	Calculated Time Arrival
CTOT	Calculated Take-Off Time (CFMU)
DBS	Distance Based Separation
DMAN	Departure MANager
DOD	Detailed Operational Description
EC	European Commission
EFS	Electronic Flight Stripes
ELDT	Estimated Landing Time
EMM	Electronic Moving Map
EMMA	European airport Movement Management by A-SMGCS
EP3	Episode 3
E-SCA	Enhanced Situation Conflict Alerting
ETOT	Estimated Take Off Time
FASTI	First ATC System Tools Implementation
FDP	Flight Data Processing
FMS	Flight Management System
GA	Go Around
GND	Ground
HF	Human Factors
HIL	Human-In-the-Loop
HMI	Human-Machine Interaction
HUD	Head Up Display
IAS	Indicated Air Speed

Abbreviation	Long Name
ILS	Instrument Landing System
JU	Joint Undertaking
LVP	Low Visibility Procedures
MAP	Missed Approach Procedure
MLAT	Multi-Lateration
MONA	MONitoring Aids
NM	Nautical Mile
NOTAM	Notice To Airmen
OFG	Operational Focus Group
ORD	Operational Requirements Document
OSED	Operational Service and Environment Description
PFD	Probability of False Detection
PSR	Primary Surveillance Radar
RA	Resolution Advisory
RBT	Reference Business Trajectory
RESET	Reduced SEparaTion minima
RNP	Required Navigation Performance
RPA	Reported Position Accuracy
RTCA	Radio Technical Commission for Aeronautics
RWY	Runway
SDF	Surveillance Data Fusion
SID	Standard Instrumental Departure
SMA	Surface Movement Alerting
SMGCS	Surface Movement Guidance and Control Systems
SMR	Surface Movement Radar
SPOR	Services, Procedures, and Operational Requirements

Abbreviation	Long Name
SSR	Secondary Surveillance Radar
STAR	Standard Arrival
STCA	Short Term Conflict Alert
SURF	Surface
SWIM	System Wide Information Management
TA	Traffic Advisory
TBS	Time Based Separation
TCAS	Traffic Collision Avoidance System
TCD	Traffic Conflict Detection
TIPH	Taxi-Into Position and Hold
TIS-B	Traffic Information Service - Broadcast
TSAT	Target Start Approval Time
TSD	Traffic Situation Display
TSIM	TCAS Simulation Interactive Module
V4LUW	Line up and wait in all visibility conditions
WP	Work Package

9.2 Reference documents

[1] FASTI Operational Requirement for Monitoring Aids, EUROCONTROL, v0.2, 25/03/2008

[2] D7.2 – Human Factors Case; M1 – Fact Finding Report T1-TMA, 20/05/2009

[3] D7.2 – Human Factors Case; M2 – Issues Analysis Report T1-TMA, 24/07/2009

[4] D7.2 – Human Factors Case; M1 – Fact Finding Report TBS, 09/05/2010

[5] D7.2 – Human Factors Case; M2 – Issues Analysis Report TBS, 26/03/2010

[6] Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II), Version 7.1, RTCA, 2008

[7] Introduction to TCAS II Version 7, US Department of Transportation, FAA, 2000

[8] Ability of ACAS Surveillance to Support Timely RAs In High Closing Speed Encounters In High Density Airspace Above 10,000 Feet Altitude, R.G. Sandholm and G. Harris, SCRSP/WGA, IP/A/5-179

[9] Impact of operational changes in the air traffic control and separation standards on ACAS II surveillance performance, R.G. Sandholm, SCRSP/WGA, IP A/10

[10] ACAS hybrid surveillance, K. Carpenter, ASP/WG1, WP/ASP01-10, 2006

[11] Readme of the verification test suite for the collision avoidance subsystem specified in DO-185B Volume II, H. Men, RTCA Paper No. 104-08/PMC-621, 2008

[12] D7.2 – Human Factors Case; M2 – Issues Analysis Report V4LUW, 24/07/2009

[13] WP7.7 working document – Elicitation of experts on potential mitigating measures for high ranking hazards

[14] D7.4 Part 2 – Preliminary Safety Case report, TMA-T1, 23/07/2010

[15] D4.3.1 – RESET TMA DOD, 01/08/08

[16] D4.3.2 – RESET Airport DOD, 01/08/08

[17] D7.5 Part 2 – TMA/T1 v0.6, 23/07/2010

[18] D7.5 Part 3 – TBS v1.0, 17/09/2010