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SESAR Solution PJ.02-01-04 SPR/INTEROP-OSED for V2 - Part V - Performance Assessment Report (PAR)

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PJ.02-W2 AART

AIRPORT, AIRSIDE AND RUNWAY THROUGHPUT

This Performance Assessment Report is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 874477 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document contains the Performance Assessment Report for the SESAR 2020 Wave 1 SESAR Solution 02-01 (WTS (for Arrivals) based on Static Aircraft Characteristics) which consists of the extrapolation to ECAC wide level of the performance assessment results conducted according at V3 level of maturity for the concepts in PJ.02-01-04 scope and the process applied to obtain the results. This report covers the concepts that contribute to WTS (for Arrivals) based on Static Aircraft Characteristics:

- Static Pairwise Separations (S-PWS) - Wake turbulence separations for arrivals based on static aircraft characteristics (AO-0306);
- Weather Dependent Separations (WDS) - weather dependant reductions of wake turbulence separations on the final approach (AO-0310);
- Optimised Runway Delivery (ORD) - a controller tool to support the application of static pairwise separations and weather dependent separations on the final approach (AO-0328).

As no additional validation exercises have been conducted for PJ.02-01-04 in SESAR 2020 Wave 2 the contents of this document have not changed since SESAR 2020 Wave 1.

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1 Executive Summary

This document provides the Performance Assessment Report (PAR) for SESAR 2020 Wave 1 Solution 02-01-04 (WTS (for Arrivals) based on Static Aircraft Characteristics).

The PAR is consolidating Solution performance validation results addressing KPIs/PIs and metrics from the SESAR2020 Performance Framework [2].

This Performance Assessment Report provides the results for the three concepts areas of the SESAR Solution 02-01-04.

- AO-0328: Optimised Runway Delivery on Final Approach (ORD);
- AO-0306: Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics (PWS-A);
- AO-0310: Weather-dependent reductions of Wake Turbulence Separations for final approach (WDS-A).

As no additional validation exercises have been conducted for PJ.02-01-04 in SESAR 2020 Wave 2 the contents of this document have not changed since SESAR 2020 Wave 1.

Definition of Solution Scenarios:

Throughout the document, the arrivals tools solutions will be referred to in simplified forms for convenience to the reader. These are:

- **ORD** (AO-0328);
- **PWS-A** - PWS-A (A0-0306) and TBA (A0-0303) with ORD (AO-0328) tool support;
- **WDS-A** – WDS-A (A0-0310) in the context of PWS-A (A0-0306) and TBA (A0-0303) with ORD (AO-0328) tool support;

Assessment Results Summary:

The following tables summarise the assessment outcomes per KPI (Table 1) and mandatory PI (Table 2) against Validation Targets in case of KPI from PJ.19 0. The impact of a Solution on the performances is described in the Benefit and Impact Mechanisms. All the KPIs and mandatory PIs from the Benefit Mechanisms expected to be impacted by the solution have been assessed via validation activities (RTS, FTS, expert judgment etc.).

There are three cases:

1. An assessment result of 0 with confidence level High, Medium or Low indicates that the Solution is expected to impact in a marginal way the KPI or mandatory PI;
2. An assessment result (positive or negative) different than 0 with confidence level High, Medium or Low indicates that the Solution is expected to impact the KPI or mandatory PI;
3. An assessment result of N/A (Not Applicable) with confidence level N/A indicates that the Solution is not expected to impact at all the KPI or mandatory PI consistently with the Benefit Mechanism.

KPI	Validation Targets – Network Level (ECAC Wide)	Performance Benefits at Network Level (ECAC Wide or Local depending on the KPI)	Confidence in Results
FEFF1: Fuel Efficiency - Actual average fuel burn per flight	26.7 kg	**Arrivals Concepts Solutions** Flights Impacted = 9850000 (flights/year) x 59.5% (high density airports contributions) x 50% (arrivals contribution) = 2931038 flights ORD (AO-0328) tool support for RECAT-EU TBS = 7.2-21.7 kg reduction in fuel consumption per flight at ECAC level, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) & TBS (AO-0303) with ORD (AO-0328) tool support for PWS-A TBS = 3-16 kg reduction in fuel consumption per flight at ECAC level, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) & TBS (AO-0303) in the context of RECAT-EU TBS with ORD (AO-0328) tool support = 27.4-40.46 kg reduction in fuel consumption per flight at ECAC level, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Low
CAP3: Airport Capacity – Peak Runway Throughput (Mixed mode).	2.6%	**Arrivals Concepts Solutions** ORD (AO-0328) – 7.9% increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 0.01% increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 0.01% increase in movements/hour, compared to TBS (AO-0303)	Low

		FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	
PRD1: Predictability – Average of Difference in actual & Flight Plan or RBT durations	0.27%	**Arrivals Concepts Solutions** Number of flights impacts = 2931038 flights ORD (AO-0328) = 1.045 min^2 (2.13%) reduction in flight variance, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) = 1.579 min^2 (3.22%) reduction in flight variance, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) = 1.412 min^2 (2.88%) reduction in flight variance	Low

Table 1: KPI Assessment Results Summary

Mandatory PI	Performance Benefits Expectations at Network Level (ECAC Wide or Local depending on the KPI)	Confidence in Results
FEFF2: CO2 Emissions.	**Arrivals Concepts Solutions** ORD (AO-0328) – 22.67-68.48 reduction Kg CO_2 per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 86.59-163.73 reduction Kg CO_2 per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 86.59-127.44 reduction Kg CO_2 per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Low
FEFF3: Reduction in average flight duration.	**Arrivals Concepts Solutions** ORD (AO-0328) – 0.16-0.45 reduction minutes per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 0.62-1.07 reduction minutes/flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Low

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	WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 0.62-0.83 reduction minutes/flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	
CAP3.2: Peak Arrival throughput per hour (segregated mode)	**Arrivals Concepts Solutions** ORD (AO-0328) – 0.3-0.9 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 1.3-2.4 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 0.9-2.8 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Low
CAP4: Un-accommodated traffic reduction	**Arrivals Concepts Solutions** ORD (AO-0328) – 109.5-328.5 increase in flights/year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 474-876 increase in flights/year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 328.5-1022 increase in flights/year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Low
RES1: Loss of Airport Capacity Avoided	**Arrivals Concepts Solutions** ORD (AO-0328) – 0 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 0-3 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 0-2 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Low
RES1.1: Airport time to recover	**Arrivals Concepts Solutions**	Low

from non-nominal to nominal condition	ORD (AO-0328) – 0.6-0.9 minutes gain, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 0.6-7.15 minutes gain, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 0.68-4.8 minutes gain, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	
RES2: Loss of Airspace Capacity Avoided.	**Arrivals Concepts Solutions** ORD (AO-0328) – 0 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 0-3 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 0-2 increase in movements/hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Low
RES4: Minutes of delays.	**Arrivals Concepts Solutions** ORD (AO-0328) – 0.8-1 minutes gain, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 2.48-7.83 minutes gain, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 1-5.4 minutes gain, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Low
RE5: Number of cancellations.	**Arrivals Concepts Solutions** ORD (AO-0328) – 0, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 0, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 0, compared to TBS (AO-0303) FTD Indicator	Low

	only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	
HP1: Consistency of human role with respect to human capabilities and limitations	See Section 4.7.	N/A
HP2: Suitability of technical system in supporting the tasks of human actors	See Section 4.7.	N/A
HP3: Adequacy of team structure and team communication in supporting the human actors	See Section 4.7.	N/A
HP4: Feasibility with regard to HP-related transition factors	See Section 4.7.	N/A

Table 2 Mandatory PIs Assessment Summary

2 Introduction

2.1 Purpose of the document

The Performance Assessment[1] covers the Key Performance Areas (KPAs) defined in the SESAR2020 Performance Framework [2]. The Key Performance Indicators (KPIs) and the mandatory Performance Indicators (PIs) are assessed, but also additional PIs as needed to capture the performance impacts of the Solution. It considers the guidance document on KPIs/PIs [2] for practical considerations, on metrics for example.

The purpose of this document is to present the performance assessment results from the validation exercises at SESAR Solution level. The KPA performance results are used for the performance assessment at strategy level and provide inputs to the SESAR Joint Undertaking (SJU) for decisions on the SESAR2020 Programme.

In addition to the results, this document presents the assumptions and mechanisms (how the validation exercises results have been consolidated) used to achieve this performance assessment result.

One Performance Assessment Report shall be produced or iterated per Solution.

2.2 Intended readership

In general, this document provides the ATM stakeholders (e.g. airspace users, ANSPs, airports, airspace industry) and SJU performance data for the Solution addressed.

Produced by the Solution project, the main recipient in the SESAR performance management process is PJ.19, which will aggregate all the performance assessment results from the SESAR2020 solution projects PJ.01-PJ.18 and provide the data to PJ.20 for considering the performance data for the European ATM Master Plan. The aggregation will be done at higher levels suitable for use at Master Planning Level, such as deployment scenarios. Additionally, the consolidation process will be carried out annually, based on the SESAR Solution's available inputs.

In addition, other intended readership are the SESAR Solution PJ.02-01-04 project members, the other solutions in SESAR Project PJ.02 Increased Runway and Airport Throughput, the related solutions in SESAR Project PJ.01 Enhanced Arrivals and Departures, the related solutions in SESAR Project PJ.04 Total Airport Management and the related solutions in SESAR Project PJ.09 Advanced Demand & Capacity Balancing.

[1] The opinions expressed herein reflect the authors view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

2.3 Inputs from other projects

The document includes information from the following SESAR 1 projects:

- B.05 D72 [6]: SESAR 1 Final Performance Assessment, where are described the principles used in SESAR1 for producing the performance assessment report.

PJ.19 will manage and provide:

- PJ.19.04.01 D4.1 [2]: Performance Framework (2018), guidance on KPIs and Data collection supports.
- PJ.19.04.03 D4.0.1: S2020 Common assumptions, used to aggregate results obtained during validation exercises (and captured into validation reports) into KPIs at the ECAC level, which will in turn be captured in Performance Assessment Reports and used as inputs to the CBAs produced by the Solution projects. Where are also included performance aggregation assumptions, with traffic data items.
- For guidance and support PJ.19 have put in place the Community of Practice (CoP)[2] within STELLAR, gathering experts and providing best practices.

2.4 Glossary of terms

See the AIRM Glossary [1] for a comprehensive glossary of terms.

2.5 Acronyms and Terminology

Acronym	Definition
AIM	Accident Incident Model
AIRM	ATM Information Reference Model
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
APP	Approach
APT	Airport
ARES	Airspace REServation
ATC	Air Traffic Control

2 https://stellar.sesarju.eu/?link=true&domainName=saas&redirectUrl=%2Fjsp%2Fproject%2Fproject.jsp%3FobjId%3Dxrn%3Aview%3Axrn%3Adatabase%3Aondb%2Ftable%2F59_anonymous%402333834.13%403834139.13

ATCO	Air Traffic Control Officer
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
BAD	Benefits Assessment Date
BAER	Benefit Assessment Equipment Rate
BIM	Benefit Impact Mechanism
CAP	Capacity
CBA	Cost Benefit Analysis
CDG	Charles De Gaulle
CFIT	Controlled Flight into Terrain
CREDOS	Crosswind Reduced Separations for Departure Operations
CRT	Criteria
CSPR	Closely Spaced Parallel Runway Operations
CWP	Controller Working Position
DB	Deployment Baseline
DBS	Distance-Based Separation
DOD	Detailed Operational Description
E-ATMS	European Air Traffic Management System
E-OCVM	European Operational Concept Validation Methodology
EARTH	Increased runway and airport throughput
EASA	European Aviation Safety Agency
EATMA	European ATM Architecture
ECAC	European Civil Aviation Conference
ECTL	EUROCONTROL
FEFF	Fuel Efficiency
FTS	Fast Time Simulation
GBAS	Ground Based Augmentation System
HMI	Human-Machine Interface
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ISRM	Information Services Reference Model
ITD	Integrated Technology Demonstrators

ITM	Intermediate Approach controller
KPA	Key Performance Area
KPI	Key Performance Indicator
LVP	Low-Visibility Procedures
MAC	Mid-Air Collision
MET	Meteorological services for air navigation
MRS	Minimum Radar Separation
N/A	Not Applicable
OBJ	Objective
ORD	Optimised Runway Delivery
OI	Operational Improvement
OSD	Optimised Separation Delivery
OSED	Operational Service and Environment Definition
PAR	Performance Assessment Report
PBN	Performance Based Navigation
PI	Performance Indicator
PRD	Predictability
PRU	Performance Review Unit
PWS	Pair Wise Separation(s)
QoS	Quality of Service
RBT	Reference Business / Mission Trajectory
RECAT	Re-categorisation of Wake Turbulence Separation Minima
RES	Resilience
RIMCAS	Runway Incursion Monitoring and Conflict Alert System
ROT	Runway Occupancy Time
RSP	Required Surveillance Performance
RTS	Real-Time Simulation
RWY	Runway
SAC	Safety Criteria
SAF	SAFety
SAR	Safety Assessment Report
SESAR	Single European Sky ATM Research Programme

SESAR2020 Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SID	Standard Instrument Departure
SJU	SESAR Joint Undertaking
SPR	Safety and Performance Requirements
SRM	Safety Reference Material
STATFOR	EUROCONTROL Statistics and Forecasts Service
SWIM	System-Wide Information Management
TBS	Time-Based Separation
TEAM	Tactically-Enhanced Arrivals Mode
TMA	Tactical Manoeuvring Area
TWR	Tower
TWY	TaxiWaY
VALP	Validation Plan
VALR	Validation Report
VALS	Validation Strategy
WDS	Weather-Dependant Separation
WTA	Wake Turbulence-induced Accident
WTC	Wake Turbulence Category

Table 3: Acronyms and terminology

3 Solution Scope

3.1 Detailed Description of the Solution

The arrivals concepts solutions consist of Wake Turbulence Separations for Arrivals based on Static Aircraft Characteristics (PWS-A), Optimised Runway Delivery on Final Approach (ORD) and Weather-Dependent Reductions of Wake Turbulence Separations for Final Approach (WDS-A).

ORD is the ATC support tool to enable consistent and efficient delivery of the required separation or spacing between arrival pairs on final approach to the runway landing threshold through providing Target Distance Indicators (TDIs) to the controllers.

PWS-A is the efficient aircraft type pairwise wake separation rules for final approach consisting of both the 96 x 96 aircraft type based pairwise wake separation minima and the twenty wake category (20-CAT) based wake separation minima for arrival pairs involving other aircraft types.

WDS-A is the conditional reduction or suspension of wake separation minima on final approach, applicable under pre-defined wind conditions, so as to enable runway throughput increase compared to the applicable standard weather independent wake separation minima. This is on the basis that under the pre-defined wind conditions the wake turbulence generated by the lead aircraft is either wind transported out of the path of the follower aircraft on final approach or has decayed sufficiently to be acceptable to be encountered by the follower aircraft.

The wake separation minima on final approach are defined as both distance-based minima and time-based minima, and so may be applied as either distance-based minima or time-based minima.

Revising the wake separation minima aims to increase arrival runway capacity, efficiency, predictability and resilience while maintaining or increasing safety.

3.2 Detailed Description of relationship with other Solutions

The figure below shows types of relationship that can exist between Solutions:

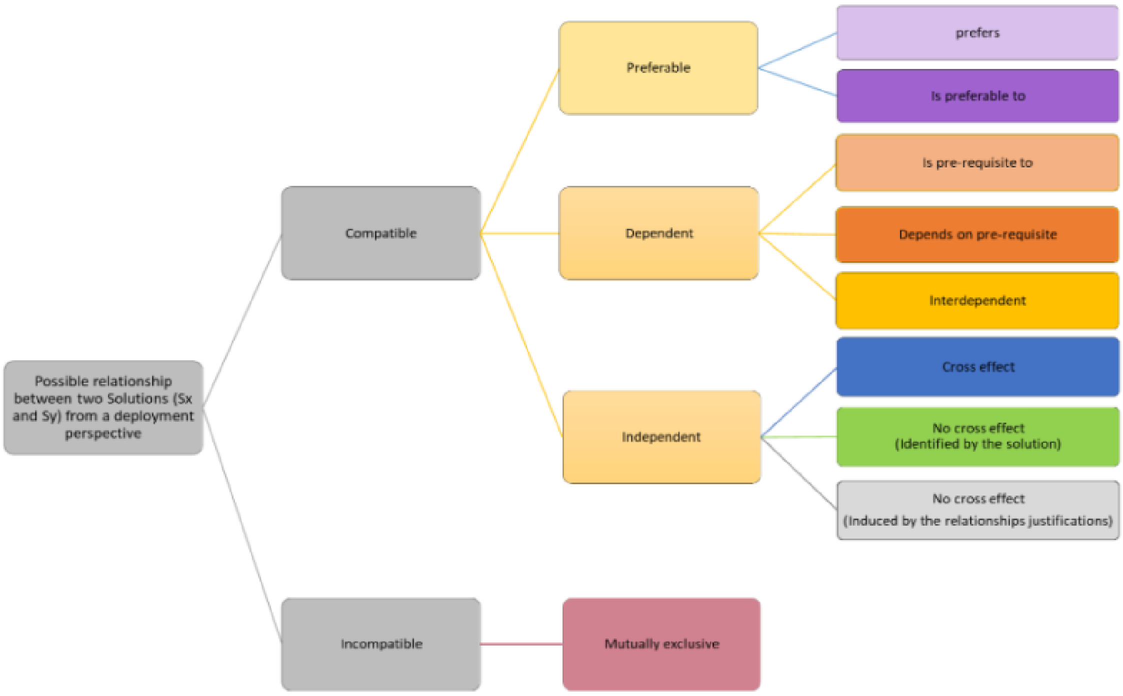

Figure 1: Possible relationships between two solutions from a deployment perspective

Solution Number	Solution Title	Relationship	Rational for the relationship
PJ.02-08	Traffic optimisation on single and multiple runway airports	Compatible, Independent, cross effect	Solution 8 provides enhanced prediction of Runway Occupancy Time to be integrated in the ATCO support tool to compute the separations to apply for optimizing runway throughput. Solution 8 provides integrated arrival and departure sequence that can support PJ.02-01-04 concepts. PJ.02-01-04 can provide wake separation requirements to be considered in the refinement of the (more stable) integrated arrival sequence.
PJ.02-03	Minimum-Pair separations based on RSP	Compatible - independent - cross effect	Solution 3 is focused on the Required Surveillance Performance (RSP) for a 2 NM Minimum Radar Separation (MRS) on final approach. It has provided the expected requirements and specifications for the RSP such as the MRS update rate of 4s to be used in the RTS. The ECTL RTS for PJ.02.01/PJ.02.03 has considered PWS-A at both the current 2.5 NM MRS and at a future 2 NM MRS.

PJ.02-02	Enhanced arrival procedures	Compatible - independent - cross effect	Solution 2 look at procedures that could provide noise and capacity benefits. This procedure may need additional separation buffer. Solution 2 will provide requirements, specifications and procedures for GBAS operations that are expected for the validation activities. Solution 1 provides requirements for wake separation based on pair. The results of Solution 1 simulations will be an input for Solution 2. The decrease/increase of separations can be defined at the granularity of aircraft type, but since the separation reductions are always bigger than the separation increases, cross benefits are expected in terms of APT capacity when the solutions for arrivals are combined.
PJ.01-07	Approach Improvement through Assisted Visual Separation	Compatible - independent - cross effect	PJ.02-01-04 and PJ.01-07 coordination to provide PJ.01-07 with needed expertise on wake turbulence issues. PJ.02-01-04 look at the wake turbulence monitoring on airborne cockpit point of view. No impact on APT CAP (as airborne only enhancement for wake monitoring). Cross effect as may improve situation awareness of the pilot and therefore may improve SAF and HP.
PJ.18-04b	MET information	Compatible – preferable - prefers	PJ.18-04b: PJ.02-01-04 prefers PJ.18-04b as better wind conditions have a positive effect, although this can be difficult to quantify.

Table 4: Relationships with other Solutions

4 Solution Performance Assessment

4.1 Assessment Sources and Summary of Validation Exercise Performance Results

No previous Validation Exercises (pre-SESAR2020, etc.) relevant for this assessment have been identified.

SESAR Validation Exercises of this Solution are listed below:

Exercise ID	Exercise Title	Release	Maturity	Status
RTS1	WDS-A with ORD for Arrivals, on single Runway (RWY) in segregated mode, for Paris CDG airport (encompassing transition from/to Distance or Time Based (DBS or TBS) standard separations)	9	V3	Completed
RTS3a	PWS-A with ORD for Arrivals, and PWS-D with OSD for Departures, on single RWY in mixed mode, for Vienna airport	9	V3	Completed
RTS3b	ORD for Arrivals, on single RWY segregated mode operations, for Copenhagen airport	9	V3	Completed
RTS4a	ORD for Arrivals, and PWS-D with OSD for Departures, on a single RWY in mixed mode, for Vienna airport	9	V3	Completed
RTS4b	PWS-A with ORD for Arrivals on CSPR runways, and PWS-D with OSD for Departures, on partially segregated runway, for Paris CDG airport	9	V3	Completed
RTS6	RTS conducted by ENAIRE to evaluate the feasibility of WDS-A for Arrivals, and PWS-D with OSD for Departures on parallel RWYs operating in segregated mode for Barcelona airport	9	V3	Completed
FTS9	Fast Time Simulations for CBA of different concepts (ORD, ORD with WDS-A, ORD with PWS-A, ORD with WDS-A and PWS-A for Arrivals, on single Runway (RWY) in segregated mode, for generic	9	V3	Completed

	airports based on ''trombone'' approach with 2 STARs as in Vienna Airport)			

Table 5: SESAR2020 Validation Exercises

The following table provides a summary of information collected from available performance outcomes:

Exercise	OI Step	Exercise scenario & scope	Performance Results
RTS1	AO-0328 (ORD) AO-0310 (WDS-A)	WDS-A with ORD for Arrivals, on single Runway (RWY) in segregated mode, for Paris CDG. Very high complexity TMA and Very Large airport Operational environment.	SAF: Controllers were able to safely and successfully deliver the aircraft under time-based weather dependent separations on the final approach using the ORD tool. All controllers reported in both the post exercise debriefs and post simulation questionnaires that WDS with the ORD tool was operationally acceptable in the dual approach environment. CAP: Using WDS with the ORD tool the average arrival throughput was 41.41 aircraft per hour while RECAT-EU without ORD tool had an average throughput of 36.6 aircraft per hour (equivalent to 13% increase in movements/hour).
RTS3a	AO-0328 (ORD) AO-0306 (PWS-A)	PWS-A with ORD for Arrivals, and PWS-D with OSD for Departures, on single RWY in mixed mode, for Vienna airport	SAF: TB PWS-A with ORD tool is operationally feasible in mixed mode runway operations and controllers are able to safely and successfully deliver the aircraft under Time Based PWS-A on the final approach using the ORD tool. HP: Controllers provide feedback that TB PWS-A separation scheme with the ORD tool is operationally acceptable in single runway mixed mode environment. CAP: ORD (AO-0328) – 7.9% increase in movements/hour with ORD and mixed mode procedures of single consecutive arrivals and departures PWS-A (AO-0306) – 0.01% increase in movements/hour with ORD and mixed mode procedures of single consecutive arrivals and departures.
RTS3b	AO-0328 (ORD)	ORD for Arrivals, on single RWY segregated, for Copenhagen airport	SAF: Safe controller working practice was observed during the simulation runs and no specific increase of the risk of potential for human error was observed. HP: TBS with ORD was found to be operationally feasible in a PBN approach environment in segregated runway operations such as those tested in the RTS. CAP: More a/c were handled per hour with TBS and the ORD tool compared to the reference scenario (ICAO

			without ORD) only 36.8 to 38.8 aircraft landed per hour during the reference runs, while 38.0 up to 42.0 arrivals landed per hour during the solution runs.
RTS4a	AO-0328 (ORD) AO-0306 (PWS-A) AO-0329 (OSD) AO-0323 (PWS-D)	PWS-A with ORD for Arrivals, and PWS-D with OSD for Departures, on a single RWY in mixed mode, for Vienna airport	HP: Controllers provide feedback that is operationally feasible to use the ORD tool in the mixed mode single runway operations to support the delivery of gap spacings in the arrival flow to allow for departures. Pair wise separations for departures using the OSD tool in mixed mode runway operations in the low wind conditions tested were reported to be operationally feasible. SAF: Safe working practices were observed during the simulation and the controllers reported that PWS with OSD tool did not increase the risk of human error in any way.
RTS4b	AO-0328 (ORD) AO-0306 (PWS-A) AO-0329 (OSD) AO-0323 (PWS-D)	PWS-A with ORD for Arrivals on CSPR runways, and PWS-D with OSD for Departures, on partially segregated runway, for Paris CDG airport	CAP: increase of 4.7 ac/h on departures with PWS-D and OSD when compared to reference scenario (ICAO separation). Increase of 2.5 ac/hour on arrivals with PWS-A and ORD when compared to reference scenario (RECAT-EU separation). HP: the ORD tool with PWS – A concept in CSPR at CDG airport is operationally feasible in approach environment only. OSD with PWS-D in CSPR are considered to be operationally feasible by providing additional functionalities to support the mixed mode runway operations. SAF: approach controllers were observed to apply safe standard practices during TB-PWS-A with ORD in CSPR for Arrivals operations.
RTS6	AO-0310 (WDS-A) AO-0329 (OSD) AO-0323 (PWS-D)	RTS conducted by ENAIRE to evaluate the feasibility of WDS-A for Arrivals, and PWS-D with OSD for Departures on parallel RWYs operating in segregated mode for Barcelona airport.	Departures Runway Capacity results showed an 8.65% increase in runway throughput compared to ICAO separations and a 2.81% increase compared to RECAT-EU separations. Mean Taxi-out time reduced by 2.36 minutes compared to ICAO separations and 0.32 minutes compared to RECAT-EU separations. Predictability (variability in taxi-out time) reduced by 39.7% compared to ICAO separations and 5.3% compared to RECAT-EU

FTS9	AO-0328 (ORD) AO-0306 (PWS-A) AO-0310 (WDS-A)	This FTS assessed the performance impact of the different wake separation solutions on arrivals of the different concepts when solutions are deployed in combination (e.g. PWS-A with ORD tool) and/or when solutions are deployed individually. The FTS covered a generic environment derived from Vienna airport	CAP: WDS-A tested in different crosswind conditions. For Strong Crosswind the capacity increase goes from a minimum of 2.31% to a maximum of about 10%. PWS-A tested in different wind conditions. For Strong Headwind the capacity increases from a minimum of 5.3% to a maximum of 5.9% coordinated. RECAT-EU TBS with ORD tested in different headwind conditions, with throughput increase up to 2.1%. All solutions scenarios compared to reference scenario RECAT-EU with FTD only. FEFF: WDS-A up to 3% fuel saving, PWS-A up to 3.7% fuel saving, ORD up to 1.5% fuel saving. All solutions scenarios compared to reference scenario RECAT-EU with FTD only. PRD: reduction in flying time. For WDS the standard deviation when considering the different wind conditions is in the range of 0.55-0.57 minutes, for PWS-A is 0.57-0.62 minutes, for ORD only is 0.40 minutes.

Table 6: Summary of Validation Results.

4.2 Conditions / Assumptions for Applicability

The following Table 7 summarises the applicable operating environments.

OE	Applicable sub-OE	Special characteristics
TMA	TMA Very High Complexity	Very High complexity ATC operational unit mainly providing Approach Control Services in a part of the airspace under control has a complexity score of equal or more than 10
	TMA High Complexity	High complexity ATC operational unit mainly providing Approach Control Services in a part of the airspace under control has a complexity score of between 6 and 10
	TMA Medium Complexity	Medium complexity ATC operational unit mainly providing Approach Control Services in a part of the airspace under control has a complexity score of between 2 and 6
Network	Network	Contribution of the network to ATM performance
Airport	Very Large Airport	Airports with more than 250k movements per year
	Large Airport	Airports with more or equal than 150k and less or equal than 250k movements per year

	Medium Airport	Airports with more or equal than 40k and less than 150k movements per year

Table 7: Applicable Operating Environments.

The following Table 8 summarises the essential deployment details:

BAD	Specific geographical and/or stakeholder deployment
31-08-2026	Very Large Airports, Large Airports, Medium Airports environment operating at capacity constrained levels.

Table 8: Deployment details.

Equipage details and how equipage influences benefits in the ramp-up phase is given in Table 9:

Min flight equipage rate	Opt flight equipage rate	BAER	AUs that need to equip	Start of flight equipage	End of flight equipage
N/A	N/A	N/A	N/A	N/A	N/A

Table 9: Influence of Equipage on benefits.

4.3 Safety

4.3.1 Safety Design drivers and Performance Mechanism

This section firstly defines the set of SAfety Criteria applicable to the operational scenarios for the arrivals concepts solutions and secondly defines the performance mechanisms associated with safety.

4.3.1.1 Safety Criteria

SAfety Criteria (SAC) define the acceptable level of safety (i.e. accident and incident risk level) to be achieved by the Solution under assessment, considering its impact on the ATM/ANS functional system and its operation.

The SAC setting is driven by the analysis of the impact of the Change on the relevant AIM models and it needs to be consistent with the SESAR safety performance targets defined by PJ 19.04. The following AIM models have been considered to be relevant for the arrival solutions:

- Wake Turbulence on Final Approach (WT on FAP);
- Mid-Air Collision on Final Approach (MAC on FAP);
- Runway Collision (RWY Col).

The Safety Assessment addresses all the PJ02.01 OI steps for arrivals, namely:

- AO-0306: Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics (Static Pairwise Separation for Arrivals (S-PWS-A));
- AO-0310: Weather-dependent reductions of Wake Turbulence separations for final approach (Weather Dependent Separation for Arrivals (WDS-A));
- AO-0328: Optimised Runway Delivery on Final Approach (ORD).

Two sets of safety criteria are formulated:

- A first one aimed at ensuring an appropriate Separation design i.e. definition of WT separation minima which, if correctly applied in operation, guarantee safe operations on final approach segment and initial common approach path respectively;
- A second one aimed at ensuring correct Separation delivery i.e. that the defined WT separation minima are correctly applied by ATC.

SEPARATION DESIGN

The following definition will be employed to designate a **pair of aircraft**:

Two consecutive arrivals on the same runway, or on Closely Spaced Parallel RWYs (CSPR), or an arrival following a departure in mixed mode on the same runway or on CSPR.

A SAC is defined for each Arrival WT separation mode within the scope (PWS-A, WDS-A) driven by the applicable WT Accident AIM model (WT on FAP).

- on risk of WT Encounter on Final Approach related to correct application of the WT scheme under consideration (see in AIM WT on Final Approach model the outcome of precursor Wake Encounter (WE) 6S “Imminent wake encounter under fault-free conditions” not mitigated by barrier B2 “Wake encounter avoidance”)

A-TB-WDS-Tw-SAC#1: The probability per approach of wake turbulence encounter of a given severity for a given traffic pair spaced at WDS Total wind minima on Final Approach segment for any applicable total wind conditions shall not increase compared to the same traffic pair spaced at reference distance WTC-based minima in reasonable worst-case conditions*.

* Reasonable worst-case conditions recognized for WT separation design

A-TB-WDS-Xw-SAC#1: The probability per approach of wake turbulence encounter of a given severity for a given traffic pair spaced at WDS Cross wind minima on Final Approach segment for any applicable cross wind conditions shall not increase compared to the same traffic pair spaced at reference distance WTC-based minima in reasonable worst-case conditions*.

RECAT-EU-PWS-SAC#1: For an aircraft type pair at RECAT-EU-PWS minima on Final Approach segment, the pair-wise wake turbulence encounter severity shall not be higher than the severity of reference aircraft type pair (selected as acceptable baseline with proven extensive operations) at ICAO minima and in reasonable worst-case conditions*

The strategy intended for meeting the above SACs will rely upon the analysis of experimental data (traffic, meteo, wake) possibly combined with modelling.

Once the Design has met the SAC above, the following safety issue still remains to be addressed:

Safety issue: The frequency of wake turbulence encounters at lower severity levels might increase due to the reduced separation minima. As the frequency of wake turbulence encounters at each level of severity depends on local traffic mix, local wind conditions and proportion of time of application of the concept, there is a need to find a suitable way for controlling the associated potential for WT-related risk increase.

An additional SAC, to be derived on each WT separation mode, is defined in order to cap the safety risk from the case where the correctly defined WT separation minima are not correctly applied, with potential for severe wake encounter higher than if those minima were correctly applied.

- on risk of Imminent wake encounter under unmanaged under-separation (see WE 6F in AIM WTA Final Approach model):

> **A-SAC#F1:** The probability per approach of imminent wake encounter under unmanaged under-separation on Final Approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

The strategy intended for meeting the A-SAC#F1 relies upon qualitatively showing that the use of the tool will involve a significant reduction of the frequency of unmanaged under-separations which will compensate for the risk increase brought in by the higher probability of imminent wake encounter associated to those unmanaged under-separations.

SEPARATION DELIVERY

A set of SACs, to be derived on each WT separation mode, are defined in order to ensure that the defined WT separation minima are correctly applied for separation delivery, i.e. that the right Functional System in terms of People, Procedures, Equipment (e.g. separation delivery tool) is designed such as to enable safe operation in each separation mode. The correct application of WT separation minima needs to account for the additional separation constraints imposed by the Surveillance separation (during interception and along the final approach path) and the need of preventing RWY collision[3]. For achieving that, the safety risk related to under-separation and its precursors needs to be controlled, driven by the AIM WT on Final Approach models and accounting for constraints imposed by the MRS minima and by the AIM RWY collision model.

- on risk of Unmanaged under-separation (WT) in adequate separation mode during interception and final approach (see WE 7F.1 in AIM WT on Final Approach model):

> **A-SAC#F2:** The probability per approach of Unmanaged under-separation (WT) in adequate separation mode during interception & final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

- on risk of Unmanaged under-separation induced by inadequate selection & management of separation mode i.e. selection of and transition between any adequate modes of operation i.e. A-WDS-Tw, A-WDS-Xw, DBS (see WE 7F.2 in AIM WT accident on Final Approach model):

[3] In case of aircraft inability to recover from a severe wake encounter a wake accident will occur (encompassing loss of control or uncontrolled flight into terrain; that is not related to the Controlled Flight into Terrain accident and associated AIM model)

A-SAC#F3: The probability per approach of unmanaged under-separation (WT) during interception & final approach shall not increase due to inadequate selection of or transition between any adequate modes of operation

- on risk of Imminent infringement (WT) during interception and final approach (see WE 8 in AIM WT accident on Final Approach model):

A-SAC#F4: The probability per approach of Imminent infringement (WT) during Interception & final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

- on risk of Imminent collision during interception and final approach path (see in AIM MAC FAP model MF4):

A-SAC#F6: The probability per approach of Imminent collision during interception and final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline).

- on risk of Imminent infringement (radar separation) during interception and final approach path (see in AIM MAC FAP model MF5.1 and MF7.1):

A-SAC#F7: The probability per approach of Imminent infringement (radar separation) during interception and final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline).

- on risk of Crew/Aircraft induced spacing conflicts (spacing conflicts induced by Crew/Aircraft and not related to ATC instructions for speed adjustment) during interception and final approach (see WE 10/11 in AIM WT accident on Final Approach model):

A-SAC#F5: The probability per approach of Crew/Aircraft induced spacing conflicts during interception & final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

- on risk of Imminent Inappropriate Landing (see in AIM RWY collision model the precursor RP2.4 which might be caused by e.g. spacing management by APP ATCO without considering ROT constraint or APP ATCO clearing a/c to land while another a/c has been cleared for line-up (applicable only in mixed mode) and which outcome is mitigated by B2: ATC Collision Avoidance involving e.g. last moment detection by TWR ATCO with or without Runway Incursion Monitoring and Conflict Alert System RIMCAS):

A-SAC#R1: The probability per approach of Runway Conflict resulting from Conflicting ATC clearances shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

- on risk of Runway conflict due to premature landing or unauthorised RWY entry of ac/vehicle (see in AIM RWY collision model in the precursor RP2.1 which might be caused by e.g. TWR

ATCO failure to correctly monitor the RWY and to initiate Go around and which outcome is mitigated by B2: ATC Runway Collision Avoidance involving last moment detection by TWR ATCO with or without RIMCAS):

A-SAC#R2: The probability per approach of Runway conflict not prevented by ATC involving unauthorised runway entry of AC/vehicle shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

4.3.1.2 Performance Mechanism

The Performance Mechanisms in the BIMs that relate to Safety are as follows:

- Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics (AO-0306 – PWS-A) including Optimised Runway Delivery (AO-0328 - ORD)
  - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will allow controllers to deliver aircraft with greater accuracy than today. Improving spacing accuracy will reduce the number of aircraft that are under-separated which links to Safety.
  - Controller reliance on target indicators may impact Task Performance (i.e. Workload, Situational Awareness and User Acceptance). Overall workload will not increase. It is expected that workload will increase for some tasks such as using the new Sequencing tool HMI. However the benefits of tool support (i.e. the target distance indicators) will reduce workload in other areas so no changes are expected to Safety. Reduced Situational Awareness (less aware of aircraft type), if below acceptable levels, could result in a decreased Safety.
  - Using PWS-A will not increase the frequency of potential WV encounters for a given wind and a given traffic pair compared to reference traffic pair at current standard operations in reasonable worst case conditions. No increase in potential WVEs, will not impact safety performance – links to Safety.
- WDS (for arrivals) (AO-0310 – WDS-A) including Optimised Runway Delivery (AO-0328 – ORD)
  - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will allow controllers to deliver aircraft with greater accuracy than today. Improving spacing accuracy will reduce the number of aircraft that are under-separated which links to Safety.
  - Controller reliance on target indicators may impact Task Performance (i.e. Workload, Situational Awareness and User Acceptance). Overall workload will not increase. It is expected that workload will increase for some tasks such as using the new Sequencing tool HMI. However the benefits of tool support (i.e. the target distance indicators) will reduce workload in other areas so no changes are expected to Safety. Reduced Situational Awareness (less aware of aircraft type), if below acceptable levels, could result in a decreased Safety.

- Using WDS-A will not increase the frequency of potential WV encounters for a given wind and a given traffic pair compared to reference traffic pair at current standard operations in reasonable worst case conditions. No increase in potential WVEs, will not impact safety performance – links to Safety.

- Optimised Runway Delivery (AO-0328 – ORD)
  - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will allow controllers to deliver aircraft with greater accuracy than today. Improving spacing accuracy will reduce the number of aircraft that are under-separated which links to Safety.
  - Controller reliance on target indicators may impact Task Performance (i.e. Workload, Situational Awareness and User Acceptance). Overall workload will not increase. It is expected that workload will increase for some tasks such as using the new Sequencing tool HMI. However the benefits of tool support (i.e. the target distance indicators) will reduce workload in other areas so no changes are expected to Safety. Reduced Situational Awareness (less aware of aircraft type), if below acceptable levels, could result in a decreased Safety.
  - Using ORD will not increase the frequency of potential WV encounters for a given wind and a given traffic pair compared to reference traffic pair at current standard operations in reasonable worst case conditions. No increase in potential WVEs, will not impact safety performance – links to Safety.

4.3.2 Data collection and Assessment

The information reported here has been extracted from sections 3.10 and 4.6 from the SAR[3]

From the Safety Criteria listed in the previous section and by following the SRM process, Safety Objectives (SO) have been developed within the success approach (ensuring that the design enables safe operations in absence of failure within the solution scope) and the failure approach (via identification of operational hazards). Therefore, the Safety Criteria are implicitly achieved by the design through the demonstration that the design meets the aforementioned SOs. The safety demonstration, documented in the SAR [3] is based on a combination of evidences gathered from the validation exercises and evidences produced within the safety assessment based on safety workshops, reviews and interviews with relevant operational and technical experts.

Moreover, safety validation objectives (which were subsequently traced back to the relevant SACs) were derived for each of the validation exercises in PJ02.01. The validation results are summarized in the table below, whilst indicating the level of safety evidence that has been obtained for each of the applicable validation safety objective.

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage	Validation results & Level of safety evidence
RTS01 - Conducted by EUROCONTROL to assess the application of time based Weather Dependent Separations (WDS -AO-0310) with Optimised Runway Delivery (ORD - AO-0328) for arriving aircraft using the Paris CDG airport and approach environment	**OBJ-PJ02.01-V3-VALP-SA1:** To assess the impact of weather dependent separations on the final approach on operational safety compared to current wake vortex separation scheme	**CRT-PJ02.01-V3-VALP-SA1-001:** There is evidence that the level of operational safety is maintained and not negatively impacted under weather dependent separations on the final approach compared to the current operations applying wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	The controllers were seen to apply the safe standard practices when using the WDS with ORD tool in the simulation. Controllers reported that thanks to the reduced workload, stress levels, increased situation awareness compared to RECAT EU without ORD tool, they were able to allocate spare resources to other tasks, such as preventing runway incursions or detecting possible separation infringements. More specifically, controllers reported that when working in the Tower, the ORD/separation delivery tool increases their awareness of potential separation infringements enabling an easier and earlier identification. The above evidence suggests that the potential for human error with safety implication will as a minimum, not increase compared to using RECAT with no ORD tool. Meanwhile a **Safety issue** subsists: the ITM ATCO situation awareness might be altered in the dual arrival environment (CDG North

				and South arrivals) because by focusing on the ITDs, the ITM position does not systematically check the altitude of the a/c corresponding to the other ITM, as they would in RECAT EU, with potential for separation loss. The impact of the sudden loss of one or multiple/all indicators (i.e. during degraded mode of operations) has been assessed in debriefings. Conclusion: - Multiple indicators: safety risk could be mitigated through an adaptation of the working methods, applying a higher separation than in RECAT EU and accepting a temporary increase in workload (situation judged as similar to manage as switching to LVP procedures in normal operations); One indicator: applying RECAT-EU to the affected aircraft (making use of the distance vector) or instructing a go-around solves the issue.
		CRT-PJ02.01-V3-VALP-SA1-002: There is evidence that WDS with ORD tool for arrivals does not increase the number of minor under-separations	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#R1	The number of minor under-separated aircraft (less than or equal to 0.5 NM but more than 0.1NM) on the final approach is lower with Solution scenario compared to Reference scenario. Moreover, the under

		and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.		separation was at most 0.25NM with Solution scenario, whilst several pairs were under-separated more than 0.25NM with Reference scenario. No pairs were observed to be delivered with a major under-separation (more than 0.5NM) when applying WDS with ORD tool (note that in Reference scenario 5% of the pairs were delivered with major under-separation for South operations and none for North, that being related to the fact that no TWR ATCO was involved on the South position (as such, very few Go-arounds have been initiated in order to prevent major under-separation). Additionally, the number of go-arounds related to separation was larger with Reference scenario than with Solution scenario. The analysis of the separation infringements before alignment did not reveal any cause imputable to the use of the ORD tool, neither related to transitioning between separation rules on the Base leg nor related to the Dual approach operations (conflicts North vs South). ATC can safely handle the mode switch provided they are notified in advance about the change in wind conditions and the

				imminent need to transition from one separation scheme to another. An advanced warning of the mode transition is required in order to temporarily limit or regulate the flow of inbound traffic (e.g. through metering) during the switch of separation scheme in order to manage the change and the controller workload.
		CRT-PJ02.01-V3-VALP-SA1-003: The probability of Go around due to inadequate consideration of ROT constraint is not increased	A-SAC#R1	Only two Go-Arounds due to ROT constraint have been recorded in Reference scenario, and none with the Solution scenario – that complies with the success criteria, but is not a statistically representative evidence
RTS2 - Conducted by EUROCONTROL to assess the application of wake turbulence separations based on static aircraft characteristics for arriving aircraft (static PairWise Separations - PWS-A -AO-0310) with ORD (AO-0328)	**OBJ-PJ2.02-V3-VALP-SA2:** To assess the impact of static pairwise separations for arrivals with ORD tool on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of time based Static Pair Wise separations for arrivals PWS-A with ORD tool on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	The controllers were seen to apply the safe standard practices when applying TB-PWS MRS 2.5NM with ORD tool in the simulation. No increase of potential human error was observed during the exercises.
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals	A-SAC#F1, A-SAC#F2, A-	No under spacings were observed in RTS02 for either the solution scenario TB PWS with the ORD tool or the reference scenario. There was no increase in separation non-

		does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	SAC#F3, A-SAC#F4	conformances before alignment or on the base leg due to the use of TB PWS with ORD tool. Therefore no increase in separation infringements were observed in RTS02 with TB PWS and the ORD tool compared to the reference scenario. However, the validity of this conclusion is limited by the low relevance of the statistics involved due to the limited number of runs.
		CRT-PJ2.01-V3-VALP-SA2-003: that time based Static Pair Wise separations for arrivals PWS-A with ORD tool maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1	The number of ROT related Go-arounds is of same order of magnitude in TB PWS-A 2.5NM MRS ORD solution scenario compared to the ICAO DBS reference scenario.
RTS03a - Conducted by EUROCONTROL to assess the application of wake turbulence separations based on static aircraft characteristics for arriving aircraft (static PairWise Separations -	**OBJ-PJ2.02-V3-VALP-SA3:** To assess the impact of the ORD tool on operational safety compared to current operations applying wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of time based Static Pair Wise separations for arrivals PWS-A with ORD tool on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	Safe standard controller working practices were observed with the ORD tool in the 2A-2D-2A mixed mode runway procedures. No new potential causes for human error and no increase in the potential severity of existing human errors were observed or reported to be introduced by the ORD tool

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PWS-A -AO-0310) with ORD (AO-0328).	without ORD tool in single runway mixed mode operations under nominal conditions.	runway mixed mode operations under nominal conditions. **CRT-PJ2.01-V3-VALP-SA3-001 :** To assess the impact of the ORD tool on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.		or PWS procedures under nominal conditions. No new observations/remarks compared to previous simulations (e.g. RTS1) regarding the loss of separation indicators (ITD/FTD). Safe standard controller working practices were observed with the ORD tool in the alternating arrival departure sequence mixed mode runway procedures assessed. No new potential causes for human error and no increase in the potential severity of existing human errors were observed or reported to be introduced by the ORD tool under nominal conditions.
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4	The number of minor under-separated aircraft (less than or equal to 0.5NM) on the final approach in single runway mixed mode operations was not higher and was even reduced under Time Based PWS-A with ORD tool compared to the reference scenario. The number of major under-separated aircraft (more than 0.5NM) on the final approach in single runway mixed mode operations was reduced under Time Based PWS-A with ORD tool compared to the reference scenario.

		CRT-PJ2.01-V3-VALP-SA3-003 : To collect partial supporting evidence that the ORD tool maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario		No separation infringements have occurred before alignment to runway centreline and when the aircraft are within 25 NM from the runway threshold (i.e. including base leg). However, more analysis is needed as the number of exercise runs and scenarios assessed was limited.
		CRT-PJ2.01-V3-VALP-SA2-003: that time based Static Pair Wise separations for arrivals PWS-A with ORD tool maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1	*For RTS03a:* There was one go-around instructed by TWR controller in total in the TB PWS-A with ORD tool exercises compared to the no go-arounds in the reference scenario. However, more analysis is needed as the number of exercise runs and scenarios assessed was limited. Number of go-arounds was not higher in the TB spacing with ORD tool exercises compared to DB spacings with no ORD tool. In fact there were more go-rounds within the DB spacings with no ORD tool: 3 go-arounds were observed for the runs without the ORD tool, as opposed to no go-arounds being observed during the runs with the ORD tool.

				However, more analysis is needed to validate this finding due to the limited statistical analysis that can be performed based on the collected real time simulation data and to the limited number of scenarios and conditions tested
RTS03b - Conducted by EUROCONTROL to assess the application and the operational feasibility of time based separations with the Optimised Runway Delivery (ORD - AO-0328) tool in a Performance Based Navigation environment	**OBJ-PJ2.02-V3-VALP-SA3:** To assess the impact of the ORD tool with separation requirements based on the current wake vortex categories compared to no ORD tool on operational safety.	**CRT-PJ2.01-V3-VALP-SA3-001:** To assess the impact of TBS with the ORD tool on operational safety compared to distance based separation in segregated runways mode operations under nominal conditions.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	Safe controller working practice was observed during the simulation runs and no specific increase of the risk of potential for human error was observed. However, in the final debriefing controllers reported that while working with the ORD tool, a controller might become less aware about the aircraft distances on the final approach and consequently have a lower level of situational awareness. That issue could further lead to human error in degraded modes when no tool is present.
		CRT-PJ2.01-V3-VALP-SA3-002: To collect partial supporting evidence that TBS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#R1	Regarding under-spacing, for ATCO1, the reference scenario run presents 4 under-spaced aircraft pairs, while none were observed during the corresponding solution scenario runs. For ATCO2 and ATCO3, no under-spaced aircraft pairs were observed during the reference scenario runs whereas one case of a small under-spacing is observed for one of the two solution

		vortex separation scheme without ORD tool.		scenario runs (run #7 for ATCO2 and run #3 for ATCO3). For separation before alignment on the centre line no infringements were observed for ATCO2 and ATCO3 whereas for ATCO 1, 1 and 2 separation infringements were observed for the solution scenario runs 5 and 11 respectively
		CRT-PJ2.01-V3-VALP-SA3-003: To collect partial supporting evidence that TBS with ORD tool maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1	More go-arounds have been observed for the reference scenario run compared to the solution scenario runs: for the three ATCOs, between 2 and 3 go-arounds were performed during the reference scenario run while none were observed for the corresponding solution scenario runs except for one exercise where 2 were observed. In post exercise debriefings controllers reported that the go arounds were mainly due to the fact that the compression after the DF was not the same as in Copenhagen and this effect had a stronger impact in Reference scenario with PBN than in the Solution scenario.
RTS04b - Conducted by EUROCONTROL The aim was to assess the operational	**OBJ-PJ2.02-V3-VALP-SA2:** To assess the impact of static pairwise separations	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of arrivals PWS-A with the ORD tool in CSPR environment on	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-	Both ININ and ITMN approach controllers were observed to apply safe standard

feasibility of time based static Pair-Wise Separation (S-PWS-A - AO-0310) with Optimised Runway Delivery (ORD - AO-0328) for arriving aircraft in a closely spaced parallel runway environment; RTS4b was conducted using the Paris CDG airport and approach environment.	for arrivals with ORD tool on operational safety compared to current wake vortex separation scheme	operational safety compared to current operations applying wake vortex separation scheme without ORD tool in a non-CSPR environment under nominal conditions.	SAC#R1, A-SAC#R2, A-SAC#R3	practices during TB-PWS-A with ORD in CSPR for Arrivals operations. However, at CDG, the TWR ATCOs is already complex and the tower runway controller is already working at high capacity in the peak periods, having to manage crossings, departures on RWY27L and arrivals on RWY27R. Adding, to this environment, an un-steady flow of arrivals on RWY28L due to CSPR (partially segregated operations), was considered to be unacceptable from a safety point of view for the CDG TWR ATCOs.
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals in a CSPR environment does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4	The number of under-separations (small and large) being at least not higher in the solution scenario arrivals runs (TB PWS with the ORD tool under CSPR/DT) compared to the reference scenario runs (RECAT EU with no tool support and no CSPR i.e. segregated runway operations). Additionally there was no increase observed in separation non-conformances before alignment or on the base leg due to the PWS-A with ORD in CSPR/DT.

		CRT-PJ2.01-V3-VALP-SA2-003: To collect partial supporting evidence that time based Static Pair Wise separations for arrivals PWS-A with ORD tool under CSPR maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario.	A-SAC#R1	No increase of ROT related go around was observed in Solution scenario (TB PWS with ORD in CSPR/DT environment) compared to Reference scenario.
RTS06 – Conducted by CRIDA/ENAIRE to assess OI Step AO-0310 Weather Dependent Separations for Arrivals (WDS-A).	**OBJ-PJ2.02-V3-VALP-SA1:** To assess the impact of weather dependent separations on the final approach on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA1-001:** There is evidence that the level of operational safety is maintained and not negatively impacted under weather dependent separations on the final approach with ORD tool compared to the current operations applying wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	Compared to ICAO DBS the results could be summarized as follows: • The percentage of infringements increased a 4% in solution scenarios. Due to several technical problems only two scenarios could be compared hence these results are not conclusive. More runs should be performed to guarantee that the level of infringements does not increase. • The number of go-around is higher in reference scenarios • The data of experienced workload obtained from the questionnaires show that the workload was very similar comparing the solution and reference scenarios runs.

				Taking into account these results, safety did not get worse in solution scenarios, however more runs should be executed in future steps to guarantee it.
FTS09 – conducted by EUROCONTROL to support the CBA for the Arrivals Concepts Solutions wake separation concepts. To assess the performance impact of the different wake separation solutions on arrivals of the different concepts both when solutions are deployed in combination (e.g. PWS-A with ORD tool) and/or when solutions are deployed individually. The FTS takes as input the expected traffic sequence at IAF and different parameters (WV separation, MRS, ROT, etc.) to provide an estimate of the expected throughput and spacing between landing aircraft.	No Safety Validation Objective needed to be set for this FTS			

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4.3.3 Extrapolation to ECAC wide

The results obtained from the validation activities are for the moment limited to the specific set of aerodrome environments the concepts have been simulated in. This is in terms of layout and configuration (single runway segregated operations – arrivals or departures, closely spaced parallel runways in mix mode, single runway segregated departures with TEAM operations) as well as in terms of traffic mix (mix and proportion of aircraft types and wake categories) and traffic demand (demand profile over the busy operational hours) as per the traffic in Very Large, Large and Medium Airports with Very High, High and Medium Complexity TMAs.

These results could be extrapolated to similar aerodromes in ECAC, but not enough evidence is available to extrapolate this statement to the rest of aerodromes in other categories. The number of aerodromes to which this Solution could be applied while ensuring the level of safety is maintained needs then to be defined.

4.3.4 Discussion of Assessment Result

With regard to all the success criteria about the quantification of the under-separations and go-arounds:

- Based on the data collected in the RTS and due to the limited number of scenarios and conditions that can be tested in an RTS, only a limited statistical analysis could be performed for these success criteria, as the data is insufficient to derive a significant statistical conclusion. However, these results do give an indication of trends. Thus, this quantitative data in combination with the qualitative safety data/results obtained from the RTS and other safety-related activities (e.g. workshops, HAZIDs) enables us to conclude that safety is not negatively impacted.

With regard to abnormal and degraded mode of operations:

- Even though some degraded mode of operations has been tested in the simulations, this is not true for all the abnormal and degraded modes due to the limitation of the simulation environment. However, anything that has not been tested in simulations was at least brainstormed in workshops with relevant experts.

4.3.5 Additional Comments and Notes

No additional comments.

4.4 Environment: Fuel Efficiency / CO2 emissions

Often fuel efficiency is improved through a reduction of flight or taxi time. This time benefit is also assessed, in this section, as it is additional input for the business case.

4.4.1 Performance Mechanism

The arrivals OI are focused on reduction and optimising separations between aircraft during traffic peak. 2 OIs (WDS-A and PWS-A) review the minimum wake separations to be applied between consecutive arrivals, the ORD OI further enhance the separation delivery tool that supports the ATCO in providing separations and spacing. By delivering aircraft with further optimised wake separations at threshold there is a positive impact on arrival delay and thus a reduction of flying time that impacts fuel burn and emissions. The Performance Mechanisms in the BIMs that relate to Fuel Efficiency are as follows:

- Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics (AO-0306 – PWS-A) including Optimised Runway Delivery (AO-0328 - ORD)
    - Reduction of separations and spacing will reduce the average delay per flight. As airborne delay uses more fuel (e.g. in case of holding), a reduction in this delay will result in reduced fuel burn in the TMA. This has a positive impact on Fuel Efficiency.
    - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will reduce the margins delivered. This may increase the go-around rate and will affect Fuel Efficiency.
- WDS (for arrivals) (AO-0310 – WDS-A) including Optimised Runway Delivery (AO-0328 – ORD)
    - Reduction of separations and spacing will reduce the average delay per flight. As airborne delay uses more fuel (e.g. in case of holding), a reduction in this delay will result in reduced fuel burn in the TMA. This has a positive impact on Fuel Efficiency.
    - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will reduce the margins delivered. This may increase the go-around rate and will affect Fuel Efficiency.
- Optimised Runway Delivery (AO-0328 – ORD)
    - Optimised separations and spacing delivery will reduce the average delay per flight. As airborne delay uses more fuel (e.g. in case of holding), a reduction in this delay will result in reduced fuel burn in the TMA. This has a positive impact on Fuel Efficiency.
    - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will reduce the margins delivered. This may increase the go-around rate and will affect Fuel Efficiency.

4.4.2 Assessment Data (Exercises and Expectations)

Fuel Efficiency benefits due to the application of operational concepts addressed by PJ.02-01-04 have been identified, taking into account:

- average flight duration;
- Number of go-around (effect on increased flying time duration).

Fuel efficiency has been assessed in FTS9. See VALR for details about the exercise.

The fuel burn savings is computed based on the comparison of the averaged flying time per flight. Because the aircraft flights are released in all runs at the same positions, the traffic pressure and the applicable separation minima will impact the aircraft trajectories and hence their flying time. Moreover, a go-around also significantly increases the flying time which is taken into account by the model.

The relationship between averaged flying time reduction compared to reference scenario and fuel burn savings is then established using assumptions found in [9]. In particular, the fuel burn rates for arrival management per RECAT category is obtained as an average of the value provided for several aircraft (see Figure 2). The value for Cat-A and Cat-C aircraft types are obtained from Cat-B value weighted by the differences in averaged MLW per category, see Table 10. Two scenarios are considered: aircraft weight at 50 % of max useful load and aircraft weight at 65% of max useful load. Table 10 also provided the mean fuel burn rate for each traffic sample obtained as the average weighted by the traffic mix of each traffic sample. Because of the higher fraction of heavy aircraft types, Traffic samples 2 and 4 show slightly larger fuel burn rate compared to Traffic sample 1 and 3.

Value: Fuel burn rates (kg/minutes) in flight phases where delay can occur for most flying and representative A/C types.

Flight phase:	Taxi	En route		Arrival management	
Weight: (% of max useful load)	N/A	65	80	50	65
Scheduled AC Type					
B738	12.0	37.7	40.7	36.0	38.3
A320	11.5	38.5	41.7	35.6	37.4
A319	10.0	34.8	37.4	35.6	37.0
A321	13.5	41.7	45.1	40.9	43.1
E190	9.0	28.8	31.2	27.7	28.9
DH8D	-	17.1	17.7	14.5	15.0
B737	12.0	33.3	35.9	32.7	34.6
CRJ9	-	25.2	27.2	17.0	18.1
A332	25.0	94.4	102.5	80.4	85.7
B77W	32.7	144.4	159.4	110.9	125.8
Business AC Type					
C56X	-	7.7	8.2	7.7	7.9
BE20	-	3.9	4.2	4.3	4.4
PC12	-	2.4	2.6	3.7	3.8
C510	-	4.7	4.9	4.8	5.0
F2TH	-	11.5	12.6	9.3	9.7
Rotorcraft AC Type					
S92	N/A	8.8	9.5	6.9	7.3
A139	N/A	5.8	6.1	4.8	5.0
EC25	N/A	9.0	9.6	6.9	7.3
EC55	N/A	4.7	4.9	3.7	3.9

Source: EUROCONTROL BADA (Base of Aircraft Data) http://www.eurocontrol.int/services/bada

Figure 2: Fuel burn rates for various aircraft types in flight phases

	fuel burn rate arrival [kg/min] 50 % max useful load	fuel burn rate arrival [kg/min] 65 % max useful load
Cat-A	162.6*	179.8*
Cat-B	95.7	105.8
Cat-C	61.1*	67.5*
Cat-D	36.2	38.1
Cat-E	19.7	20.7
Cat-F	6.0	6.2
Mean Traf sample 1/3	38.1	41.0
Mean Traf sample 2/4	41.7	45.0

Table 10: mean fuel burn for arrival per RECAT-EU category and for traffic samples 1/3 and 2/4. (*) Values for Cat-A and Cat-C are obtained from Cat-B values weighted by the difference in averaged MLW of the category

[9] also reports an average fuel burn per minute of flight of 49 kg when considering all phases of flight and all aircraft types, see [9].

Value 1	1) Average fuel burn per minute of flight = 49 kg 2) Average fuel burn per nautical mile (NM) of flight = 11 kg
Source 1	ICAO (2007) - "Global Aviation Plan", ICAO, Doc 9750 AN/963, 3rd Ed. 2007 (Attachment 1, App-H08) http://www.icao.int/publications/Documents/9750_3ed_en.pdf
Description 1	1) This number is derived by dividing the total JET A1 consumption (55 billion US gal) by the total of minutes flown (3.4 billion) by all airlines (scheduled and non-scheduled) as per IATA statistics for 2005. 2) This number is derived by dividing the total JET A1 consumption (55 billion US gal) by the total of kilometres flown (27.9 billion) by all airlines (scheduled and non-scheduled) as per IATA statistics for 2005.

Figure 3: Averaged fuel burn rate in flight

Note that this average depends on the aircraft traffic mix. [9] provides the percentage of most frequent aircraft in Europe. Using that list the traffic mix per RECAT category is obtained and provided in the Table below.

	% in traffic mix
Cat-A	1%
Cat-B	17%
Cat-C	5%
Cat-D	40%
Cat-E	27%
Cat-F	10%

Table 11: traffic mix based on RECAT-EU categories using the percentage of aircraft types

For this traffic mix, the arrival fuel burn rate is 42.3 kg/min (at 50% max useful load) and 45.6 kg/min (at 65% max useful load). A corrected average fuel burn rate is then obtained by weighting the average fuel burn per flight by the ratio of fuel burn rate for arrival. It reads:

$$Fuel\ burn\ rate = 49\frac{kg}{min}\ \frac{1}{2}\left(\frac{fuel\ burn\ rate\ arrival\ 50\%}{42.3\ kg/min} + \frac{fuel\ burn\ rate\ arrival\ 65\%}{45.6\ kg/min}\right).$$

The obtained values are 44 kg/min for Traffic samples 1 and 3 and 48.4 for Traffic samples 2 and 4.

Fuel burn rate #1 = 44 kg/min

Fuel burn rate #2 = 48.4 kg/min

The average fuel burn per flight in Europe is then computed based on the mean flight duration, as reported in Figure 4, multiplied by the average fuel burn rate. It reads:

$$Fuel\ burn\ per\ flight = Fuel\ burn\ rate\ x\ 91.5\ min$$

Depending on traffic samples:

Average Fuel burn per flight #1 = 4026 kg

Average Fuel burn per flight #2 = 4428.6 kg

Value 1	Average time from Take-off to Landing Year: 2016 – Minutes: 91.5 Year: 2015 – Minutes: 91.3 *(Values based on flights in the ESRA08[22] area)*
Source 1	EUROCONTROL - Performance Review Report (PRR 2016), July 2017 http://www.eurocontrol.int/publications/performance-review-report-prr-2016 EUROCONTROL - Performance Review Report (PRR 2015), June 2016 http://www.eurocontrol.int/publications/performance-review-report-prr-2015

Figure 4: Averaged flying time for IFR flights

The mean percentage of fuel burn saving per flight is then estimated as the mean difference of flying time per flight compared to the reference multiplied by the mean fuel burn rate of the traffic sample divided by the mean fuel burn per flight. It reads:

$$fuel\ burn\ saving\ [\%] = \frac{\Delta Flying\ time\ [min]\ x\ fuel\ burn\ rate\ [kg/min]}{Fuel\ burn\ per\ flight\ [kg]}$$

CO_2/Fuel ratio = 3.15 [9]

All OIs have been assessed in the exercise separately and together (to apply WDS-A and PWS-A ORD is required) as reported in the table below:

Wind	low headwind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU TBS with ORD (AO-0328)	0.3%	1.5%	0.4%	1.1%	-	-
RECAT-EU-PWS TBS with ORD (AO-0328 and AO-0306)	1.9%	3.7%	1.9%	3.3%	-	-
RECAT-EU WDS with ORD (AO-0328 and AO-0310)	-	-	-	-	0.7%	3.1%
RECAT-EU-PWS WDS with ORD (AO-0328, AO-0306 and AO-0310)	-	-	-	-	2.1%	3.4%

Table 12: Summary of the fuel burn savings if operating the test scheme versus RECAT-EU TBS with FTD only (reference scenario) at maximum test case traffic pressure for the various separation schemes and modes and in various wind conditions

4.4.3 Extrapolation to ECAC wide

The following PJ.19 common assumptions have been used:

- High density airports traffic contribution to total airport traffic = 59.5%
- Arrivals traffic contribution to total traffic = 50%
- Average ECAC flight time = 90 minutes

Then as described above, the average fuel burn per flight and the fuel burn rate depending on traffic samples have been used for the calculations. The fuel burn rate assumption below is not aligned to the calculation above (based on the common assumptions document), but instead it has been provided by PJ19 following their review:

- Average Fuel burn per flight #1 = 4026 kg
- Average Fuel burn per flight #2 = 4428.6 kg
- Fuel burn rate #1 = 20 kg/min
- Fuel burn rate #2 = 48.4 kg/min

FEFF3, FEFF2 and FEFF1 for AO-0328 (ORD)

Reference Scenario- RECAT-EU TBS with FTD only.

Solution Scenario- RECAT-EU TBS with ORD.

FEFF3

1. Flight time reduction per arrival #1 = 0.55 min. This is the lowest benefit obtained assessing traffic sample with higher percentage of medium aircraft, from FTS9 results.
2. Flight time reduction (FEFF3) at ECAC level #1 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 0.55 minutes (flight-time reduction per arrival#1) = 0.16 minutes per flight
3. Relative flight time reduction at ECAC level #1= 0.16 minutes (flight time reduction at ECAC level) / 90 minutes (average ECAC flight time) * 100 = 0.17%

4. Flight time reduction per arrival #2 = 1.51 min. This is the maximum benefit obtained assessing traffic sample with higher percentage of heavier aircraft, from FTS9 results.

5. Flight time reduction (FEFF3) at ECAC level #2 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 1.51 minutes (flight-time reduction per arrival#2) = 0.45 minutes per flight

6. Relative flight time reduction at ECAC level #2= 0.45 minutes (flight time reduction at ECAC level) / 90 minutes (average ECAC flight time) * 100 = 0.5%

FEFF1

As explained above the fuel burn rate for arrival is 44-48.4 kg/min depending on traffic mix.

1. Fuel consumption reduction per arrival #1 = 0.55 (flight time reduction per arrival) #1 * 44 (fuel burn rate for arrival #1) = 24.2 kg/flight

2. Relative fuel consumption reduction #1 = 24.2 kg/flight (fuel consumption reduction on arrival #1) / 4026 kg (Average fuel burn per flight #1) * 100 = 0.59%

3. Fuel consumption reduction (FEFF1) at ECAC level #1 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 0.59% (relative fuel consumption reduction #1) = 0.17% = 7.2 kg/flight

4. Fuel consumption reduction per arrival #2 = 1.51 (flight time reduction per arrival #2) * 48.4 (fuel burn rate for arrival #2)= 73.08 kg/flight

5. Relative fuel consumption reduction #2 = 73.08 kg/flight (fuel consumption reduction on arrival #2) / 4428.6 kg (Average fuel burn per flight #2) * 100= 1.6%

6. Fuel consumption reduction (FEFF1) at ECAC level #2 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 1.6% (relative fuel consumption reduction #1) = 0.48% = 21.7 kg/flight

FEFF2

1. CO_2 emission reduction per arrival #1 = 24.2 (Fuel consumption reduction on arrival #1) * 3.15 (CO_2/Fuel Ratio) = 76.23 kg CO_2 per flight

2. Relative CO_2 emission reduction on arrival #1 = 76.23 (CO_2 emission reduction #1) / 4026 (Average Fuel burn per flight #1) / 3.15 (CO_2/Fuel ratio) * 100 = 0.6%

-

3. Relative CO2 emission reduction on arrival #1 (FEFF2) at ECAC level = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * x 0.6% (Relative CO2 emission reduction on arrival #1) = 0.17% = 22.67 kg CO_2/flight

4. CO_2 emission reduction on arrival #2 = 73.08 (Fuel consumption reduction on arrival #2) * 3.15 (CO_2/Fuel Ratio) = 230.2 kg CO_2 per flight

5. Relative CO_2 emission reduction on arrival #2 = 230.2 (CO_2 emission reduction #2) / 4428.6 (Average Fuel burn per flight #1) / 3.15 (CO_2/Fuel ratio) * 100= 1.6%

6. Relative CO2 emission reduction on arrival #2 (FEFF2) at ECAC level = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * x 1.6% (Relative CO2 emission reduction on arrival #1) = 0.47% = 68.48 kg CO_2/flight

FEFF3, FEFF2 and FEFF1 for AO-0306 (PWS-A)

Reference Scenario- RECAT-EU TBS with FTD only.

Solution Scenario- RECAT-EU-PWS TBS with ORD.

FEFF3

1. Flight time reduction per arrival #1 = 2.1 min. This is the lowest benefit obtained assessing traffic sample with higher percentage of medium aircraft, from FTS9 results.

2. Flight time reduction (FEFF3) at ECAC level #1 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 2.1 minutes (flight-time reduction per arrival#1) = 0.62 minutes per flight

3. Relative flight time reduction at ECAC level #1= 0.62 minutes (flight time reduction at ECAC level) / 90 minutes (average ECAC flight time) * 100 = 0.68%

4. Flight time reduction per arrival #2 = 3.61 min. This is the maximum benefit obtained assessing traffic sample with higher percentage of heavier aircraft, from FTS9 results.

5. Flight time reduction (FEFF3) at ECAC level #2 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 3.61 minutes (flight-time reduction per arrival#2) = 1.07 minutes per flight

6. Relative flight time reduction at ECAC level #2= 1.07 minutes (flight time reduction at ECAC level) / 90 minutes (average ECAC flight time) * 100 = 1.18%

FEFF1

As explained above the fuel burn rate for arrival is 20-48.4 kg/min depending on traffic mix.

1. Fuel consumption reduction per arrival #1 = 2.1 (flight time reduction per arrival) #1 * 20 (fuel burn rate for arrival #1) = 42 kg/flight

2. Relative fuel consumption reduction #1 = 42 kg/flight (fuel consumption reduction on arrival #1) / 4026 kg (Average fuel burn per flight #1) * 100 = 1.1%

3. Fuel consumption reduction (FEFF1) at ECAC level #1 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 1.1% (relative fuel consumption reduction #1) * 3(peak)/16(hours in operation) = 0.06% = 3kg/flight

4. Fuel consumption reduction per arrival #2 = 3.61 (flight time reduction per arrival #2) * 48.4 (fuel burn rate for arrival #2) = 174.72 kg/flight

5. Relative fuel consumption reduction #2 = 174.72 kg/flight (fuel consumption reduction on arrival #2) / 5280 kg (Average fuel burn per flight #2) * 100= 3.33%

6. Fuel consumption reduction (FEFF1) at ECAC level #2 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 3.33% (relative fuel consumption reduction #1) = 0.3% = 16 kg/flight

FEFF2

1. CO_2 emission reduction per arrival #1 = 92.4 (Fuel consumption reduction per arrival #1) * 3.15 (CO_2/Fuel Ratio) = 291.06 kg CO_2 per flight

2. Relative CO_2 emission reduction on arrival #1 = 291.06 (CO_2 emission reduction #1) / 4026 (Average Fuel burn per flight #1) / 3.15 (CO_2/Fuel ratio) * 100 = 2.29%

3. Relative CO2 emission reduction on arrival #1 (FEFF2) at ECAC level = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 2.29% (Relative CO2 emission reduction on arrival #1) = 0.68% = 86.59 kg CO_2/flight

4. CO_2 emission reduction on arrival #2 = 174.72 (Fuel consumption reduction per arrival #2) * 3.15 (CO_2/Fuel Ratio) = 550.36 kg CO_2 per flight

5. Relative CO_2 emission reduction on arrival #2 = 550.36 (CO_2 emission reduction #2) / 4428.6 (Average Fuel burn per flight #2) / 3.15 (CO_2/Fuel ratio) * 100= 3.94%

6. Relative CO2 emission reduction on arrival #2 (FEFF2) at ECAC level = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * x 3.94% (Relative CO2 emission reduction on arrival #2) = 1.17% = 163.73 kg CO_2/flight

FEFF3, FEFF2 and FEFF1 for AO-0316 (WDS-A)

Reference Scenario- RECAT-EU TBS with FTD only.

Solution Scenario- RECAT-EU-PWS WDS with ORD.

FEFF3

1. Flight time reduction per arrival #1 = 2.1 min. This is the lowest benefit obtained assessing traffic sample with higher percentage of medium aircraft, considering 10 knots crosswind for concept applicability, from FTS9 results.

2. Flight time reduction (FEFF3) at ECAC level #1 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 2.1 minutes (flight-time reduction per arrival#1) = 0.62 minutes per flight

3. Relative flight time reduction at ECAC level #1= 0.62 minutes (flight time reduction at ECAC level) / 90 minutes (average ECAC flight time) * 100 = 0.68%

4. Flight time reduction per arrival #2 = 2.81 min. This is the maximum benefit obtained assessing traffic sample with higher percentage of heavier aircraft, from FTS9 results.

5. Flight time reduction (FEFF3) at ECAC level #2 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 2.61 minutes (flight-time reduction per arrival#2) = 0.83 minutes per flight

6. Relative flight time reduction at ECAC level #2= 0.83 minutes (flight time reduction at ECAC level) / 90 minutes (average ECAC flight time) * 100 = 0.92%

FEFF1

As explained above the fuel burn rate for arrival is 44-48.4 kg/min depending on traffic mix.

1. Fuel consumption reduction per arrival #1 = 2.1 (flight time reduction per arrival) #1 * 44 (fuel burn rate for arrival #1) = 92.4 kg/flight
2. Relative fuel consumption reduction #1 = 92.4 kg/flight (fuel consumption reduction on arrival #1) / 4026 kg (Average fuel burn per flight #1) * 100 = 2.29%
3. Fuel consumption reduction (FEFF1) at ECAC level #1 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 2.29% (relative fuel consumption reduction #1) = 0.68% = 27.4 kg/flight
4. Fuel consumption reduction per arrival #2 = 2.81 (flight time reduction per arrival #2) * 48.4 (fuel burn rate for arrival #2) = 136 kg/flight
5. Relative fuel consumption reduction #2 = 136 kg/flight (fuel consumption reduction on arrival #2) / 4428.6 kg (Average fuel burn per flight #2) * 100= 3.07%
6. Fuel consumption reduction (FEFF1) at ECAC level #2 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 3.07% (relative fuel consumption reduction #1) = 0.91% = 40.46 kg/flight

FEFF2

1. CO_2 emission reduction per arrival #1 = 92.4 (Fuel consumption reduction per arrival #1) * 3.15 (CO_2/Fuel Ratio) = 291.06 kg CO_2 per flight
2. Relative CO_2 emission reduction on arrival #1 = 291.06 (CO_2 emission reduction #1) / 4026 (Average Fuel burn per flight #1) / 3.15 (CO_2/Fuel ratio) * 100 = 2.29%
3. Relative CO2 emission reduction on arrival #1 (FEFF2) at ECAC level = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * x 2.29% (Relative CO2 emission reduction on arrival #1) = 0.68% = 86.59 kg CO_2/flight
4. CO_2 emission reduction on arrival #2 = 136 (Fuel consumption reduction per arrival #2) * 3.15 (CO_2/Fuel Ratio) = 428.4 kg CO_2 per flight
5. Relative CO_2 emission reduction on arrival #2 = 428.4 (CO_2 emission reduction #2) / 4428.6 (Average Fuel burn per flight #2) / 3.15 (CO_2/Fuel ratio) * 100= 3.07%
6. Relative CO2 emission reduction on arrival #2 (FEFF2) at ECAC level = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * x 3.07% (Relative CO2 emission reduction on arrival #2) = 0.91% = 127.44 kg CO_2/flight

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
FEFF1 Actual Average fuel burn per flight	Kg fuel per movement	Total amount of actual fuel burn divided by the number of movements	YES	ORD (AO-0328) tool support for RECAT-EU TBS – **7.2-21.7 reduction** kg of fuel per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **3-16 reduction** kg of fuel per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **27.4-40.4 reduction** kg of fuel per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	ORD (AO-0328) tool support for RECAT-EU TBS – **0.17%-0.48% reduction** kg of fuel per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0.06%-3% reduction** kg of fuel per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.68%-0.91% reduction** kg of fuel per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.
FEFF2 Actual Average CO_2 Emission per flight	Kg CO_2 per flight	Amount of fuel burn x 3.15 (CO_2 emission index) divided by the number of flights	YES	ORD (AO-0328) – **22.67-68.48 reduction** Kg CO_2 per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **86.59-163.73 reduction** Kg CO_2 per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **86.59-127.44 reduction** Kg CO_2 per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	ORD (AO-0328) –**0.17%-0.47% reduction** Kg CO_2 per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0.68%-1.17% reduction** Kg CO_2 per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310 in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.68%-0.91% reduction** minutes per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.
FEFF3 Reduction in average	Minutes per flight	Average actual flight duration measured in the	YES	ORD (AO-0328) – **0.16-0.45 reduction** minutes per flight, compared to TBS (AO-0303) FTD Indicator only tool support	ORD (AO-0328) – **0.17%-0.5% reduction** minutes per flight, compared to TBS (AO-0303) FTD Indicator only tool support for

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
flight duration		Reference Scenario – Average flight duration measured in the Solution Scenario		for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0.62-1.07 reduction** minutes per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.62-0.83 reduction** minutes per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0.68%-1.18% reduction** minutes per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.68%-0.92% reduction** minutes per flight, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.

Table 13: Fuel burn and CO2 emissions saving for Mandatory KPIs /Pis

4.4.4 Discussion of Assessment Result

The performance target indicates a reduction of 26.7 kg per flight. The expected performance benefits (considering different traffic samples and wind conditions) are in this range with the performance target with the exception of the OI AO-0328 (ORD) when deployed alone. For ORD the best result is 21 kg reduction, still close to the validation target.

The confidence in these results is low.

4.4.5 Additional Comments and Notes

Please note that WDS-A results are lower than PWS-A because WDS-A can be applied only when both aircrafts are established on the centreline. Outside of the centreline, wind direction, wake vortices transportation uncertainty and great variability of an aircraft pair relative positions (in terms of relative heading and altitude) leads to not being able to apply the reduced WDS-A separation and so the TMA separation minima apply instead. Depending on the aircraft pair, on the interception position and the difference in ground speed of leader and follower aircraft, the follower aircraft through airspeed management might reach the WDS-A minima or not, this behaviour is reproduced in the FTS.

The statement above is also valid for all the others KPI results of WDS-A.

Following the late PJ19 review in December 2019 and due to the different common assumptions proposed that were not available when this document was produced it was decided to quantify the benefits in the PAGAR for FEFF1 as follows:

Max Fuel consumption reduction (FEFF1) at ECAC level #2 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 3.33% (3.61 minutes at 48,4kg fuel rate with 5280kg average ECAC flight) relative fuel consumption flight #1) x 5(peak)/16(hours In operation) = 0.3% = 16kg/flight

Min Fuel consumption reduction (FEFF1) at ECAC level #2 = 50% (arrivals traffic contribution) * 59.5% (high density airports traffic contribution) * 1.1% (2.1 minutes at 20kg fuel rate with 5280kg average ECAC flight) relative fuel consumption flight #1) x 3(peak)/16(hours In operation) = 0.06% = 3 kg/flight

Average the min and max = 9.5kg/flights

The confidence in these results is low.

4.5 Airport Capacity (Runway Throughput Flights/Hour)

4.5.1 Performance Mechanism

- The arrivals OI are focused on reduction and optimising separations between aircraft during traffic peak. 2 OIs (WDS-A and PWS-A) further optimise the minimum wake separations to be applied between consecutive arrivals, the ORD OI further enhance the separation delivery tool that supports the ATCO in providing separations and spacing. By delivering aircraft with further optimised wake separations at threshold there is a reduction of the overall wake separation that is required that affects runway throughput. The Performance Mechanisms in the BIMs that relate to Airport Capacity (Runway Throughput Flights per Hour) are as follows: Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics (AO-0306 – PWS-A) including Optimised Runway Delivery (AO-0328 - ORD)
    - The use of PWS-A is expected to reduce wake separation between arrivals. The use of ORD impacts the separation and spacing delivery between arrivals. The resulting optimised separation and spacing delivery increases the runway throughput. The higher the throughput, the higher the number of movements, leading to a positive impact on Capacity.
    - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will reduce the margins delivered. This may increase the go-around rate and will affect Capacity.
    - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will allow controllers to deliver aircraft with greater accuracy than today. Improving spacing accuracy will enable more aircraft to be sequenced with reduced spacing which links to Capacity.
- WDS (for arrivals) (AO-0310 – WDS-A) including Optimised Runway Delivery (AO-0328 – ORD)
    - The use of WDS-A (e.g. for WDS based on crosswind when crosswind is above the activation threshold) is expected to reduce the separation between arrivals. The use of ORD impacts the separation and spacing delivered between arrivals. The resulting optimised separation and spacing delivery increases the runway throughput. Increased average runway throughput will result in an increase Capacity.

- With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will reduce the margins delivered. This may increase the go-around rate and will affect Capacity.
- With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will allow controllers to deliver aircraft with greater accuracy than today. Improving spacing accuracy will enable more aircraft to be sequenced with reduced spacing which links to Capacity.

- Optimised Runway Delivery (AO-0328 – ORD)
  - The use of ORD impacts the separation and spacing delivery between arrivals. The resulting optimised separation and spacing delivery increases the runway throughput. The higher the throughput, the higher the number of movements, leading to a positive impact on Capacity.
  - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will reduce the margins delivered. This may increase the go-around rate and will affect Capacity.
  - With the use of the target indicators, the accuracy of the spacing between aircraft is improved compared to what is achieved today (e.g. distance between pair of aircraft closer to separation minima) and will reduce the margins delivered. Improving spacing accuracy will enable more aircraft to be sequenced with reduced spacing which links to Capacity.

4.5.2 Assessment Data (Exercises and Expectations)

CAP3:
The results for CAP3 are taken from the RTS3a validation exercise with mixed mode procedures of single consecutive arrivals and departures. The RTS3a used in combination two OIs: **ORD + PWS-A.** It has to be noted that the OIs concerning wake turbulence reductions (PWS-A and WDS-A) have a limited impact on separations in mixed mode as the most effective use of runway in mixed mode is to alternate 1 arrival and 1 departure in the sequence; with this sequence order the spacing between two consecutive arrivals is at least in the range of 4.5-5 NM (depending on wind conditions) for allowing a departure take-off between the two arrivals. This spacing of 4.5-5 NM is commonly equal or higher than wake turbulence separations applied with PWS-A and WDS-A as the traffic mix is mainly composed of Heavy-Medium or Medium-Medium pairs. Therefore, we consider that the main benefit in mixed mode is driven by the ORD (AO-0328) and that the effect of PWS-A (AO-0306) and WDS-A (AO-0310) is negligible in mixed mode compared to ORD (AO-0328).

Runway throughput reference scenario of mixed mode with ICAO (or RECAT-EU) wake separations without OR tool support, with RTS3a airport aircraft type mix and traffic pressure = 50.46 movements per hour

Runway throughput solution scenario of mixed mode with ICAO (or RECAT-EU) wake separations with **ORD (AO-0328) tool support**, with RTS3a airport aircraft type mix and traffic pressure = 54.9 movements per hour

RTS3a results for **ORD (AO-0328)** solution scenario showed an increase of 7.9% in throughput equivalent to additional 4.44 movements per hour, compared to reference scenario.

CAP3.2:
Several RTS and a one extensive FTS have been performed during the solution lifecycle. RTS are not the most appropriate method to measure capacity benefits, therefore the CAP3.2 results (segregated mode) are based on the more comprehensive set of results obtained by the FTS9 exercise.

Different traffic samples have been assessed in different wind conditions for the different solution scenarios and compared to the reference scenario (RECAT-EU TBS with FTD only).

The tables below summarize the minimum and maximum throughput % change obtained. The throughput of the solution scenarios compared to the reference scenario is also illustrated. Those throughput values are depending on the traffic sample that was providing the minimum or the maximum benefit.

Wind	low wind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU TBS with ORD (AO-0328)	1%	2.3%	0.8%	1.8%		
Throughput						
RECAT-EU TBS with ORD (AO-0328)	37.4	39.0	37.7	38.6	-	-
RECAT-EU TBS with FTD only	37.0	38.1	37.4	37.9		

Wind	low wind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU-PWS TBS with ORD (AO-0328 and AO-0306)	3.3 %	6.1%	5.3%	5.9%	-	-
Throughput						
RECAT-EU-PWS TBS with ORD (AO-0328 and AO-0306)	40.2	41.2	39.3	40.2	-	-
RECAT-EU TBS with FTD only	38.9	38.8	37.3	37.9		

Wind	low wind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU WDS with ORD (AO-0328 and AO-0310)	-	-	-	-	2.3%	7.5%
Throughput						
RECAT-EU WDS with ORD (AO-0328 and AO-0310)					39.9	40.4
RECAT-EU TBS with FTD only					39.0	37.6

Wind	low wind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU-PWS WDS with ORD (AO-0328, AO-0306 and AO-0310)	-	-	-	-	5.1%	9.8%
Throughput						
RECAT-EU-PWS WDS with ORD (AO-0328, AO-0306 and AO-0310)	-	-	-	-	40.2	42.1
RECAT-EU TBS with FTD only					38.2	38.3

In Table 14 is a recap of the maximum throughput in % for the different OIs and in different wind conditions.

Wind	low wind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU TBS with ORD (AO-0328)	1%	2.3%	0.8%	1.8%	-	-
RECAT-EU-PWS TBS with ORD (AO-0328 and AO-0306)	3.3%	6.1%	5.3%	5.9%	-	-
RECAT-EU WDS with ORD (AO-0328 and AO-0310)	-	-	-	-	2.3%	7.5%
RECAT-EU-PWS WDS with ORD (AO-0328, AO-0306 and AO-0310)	-	-	-	-	5.1%	9.8%

Table 14: Summary of the maximum throughput evolution for the different OIs, for different traffic samples and in different wind conditions

CAP4:

Assuming that the constrained airport has a single traffic peak of 1 hour during the day, the results of CAP3.2 are multiplied per the number of days in a year, to obtain a lower bound estimation of the benefit.

ORD (AO-0328) – 109.5-328.5 increase in flights/year

PWS-A (AO-0306) – 474-876 increase in flights/year

WDS-A (AO-0310) – 328.5-1022 increase in flights/year

KPIs / Pis	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
CAP3 Peak Runway Throughput (Mixed mode)	% and Flight per hour	% and also total number of movements per one runway per one hour for specific traffic mix and density (in mixed mode RWY operations). The percentage change is measured against the maximum observed throughput during peak demand hours in the mixed-mode RWY operations airports group.	YES	ORD (AO-0328) tool support for RECAT-EU TBS – **4.44 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) with ORD (AO-0328) tool support – **0.05**	ORD (AO-0328) tool support for RECAT-EU TBS – **7.9% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) with ORD (AO-0328) tool support – **0.01% increase** in movements per hour,

KPIs / Pis	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
				increase in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.05 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.01% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.
CAP3.1 Peak Departure throughput per hour (Segregated mode)	% and Flight per hour	% and also total number of departures per one runway per one hour for specific traffic mix and density (in segregated mode of operations). The percentage change is measured against the maximum observed throughput during peak demand hours in the segregated-mode RWY operations airports group.	YES	N/A	N/A
CAP3.2 Peak Arrival throughput per hour (Segregated mode)	% and Flight per hour	% and also total number of arrivals per one runway per one hour for specific traffic mix and density (in segregated mode of operations). The percentage change is measured against the maximum observed throughput during peak demand hours in the segregated-mode RWY operations airports group.	YES	ORD (AO-0328) tool support for RECAT-EU TBS– **0.3-0.9 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) with ORD (AO-0328) tool support – **1.3-2.4 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator	ORD (AO-0328) tool support for RECAT-EU TBS– **0.8%-2.3% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) with ORD (AO-0328) tool support – **3.3%-6.1% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for

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KPIs / Pis	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
				only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.9-2.8 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **2.3%-7.5% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.
CAP4 Un-accommodated traffic reduction	Flights/year	Reduction in the number of un-accommodated flights i.e. a flight that would have been scheduled if there were available slots at the origin/destination airports. NB: Supports CBA Inputs. NB: Relates to Airport Capacity because this is STATFOR computation. CBA calculate this based on the assessment of the runway throughput we provide with and without the solutions and STATFOR data.	YES For CBA.	ORD (AO-0328) tool support for RECAT-EU TBS– **109.5-328.5 increase** in flights per year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) with ORD (AO-0328) tool support – **474-876 increase** in flights per year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **328.5-1022 increase** in flights per year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	ORD (AO-0328) tool support for RECAT-EU TBS– **0.8%-2.3% increase** in flights per year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) with ORD (AO-0328) tool support – **3.3%-6.1% increase** in flights per year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **2.3%-7.5% increase** in flights per year, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.

Table 15: Airport Capacity for Mandatory KPIs /Pis

4.5.3 Extrapolation to ECAC wide

There is no ECAC wide extrapolation required for this KPI.

4.5.4 Discussion of Assessment Result

These results meet and exceed the performance targets defined from PJ.19 that was a 2.574% increase in capacity with the exception of ORD when deployed alone (where the best result of 2.3% capacity increase is very close to the validation target).

The confidence estimate in the results is moderate, they are based on generic characteristics that are common in other European airports. The benefits identified are an estimation applicable to very large, large and medium airports that are capacity constrained during traffic peaks because of the wake turbulence constraints and the separation delivery on approach.

For each local airports the exact benefits are depending on several factors including specific traffic mix, length of traffic peak, wind conditions (especially for WDS), applicable surveillance minima, runway occupancy time, glide length, type of approach, runway layout, airport infrastructure, etc..; these factors were taken into account in the FTS as fixed parameters (e.g. ROT) or dynamic parameters modified in each run (e.g. the traffic mix, wind conditions, …) to provide as many different cases as possible.

14 reference scenarios and 20 solution scenarios have been fast time simulated for each of the 4 traffic samples. Each traffic sample varies 7 times the traffic pressure, thus a comprehensive set of results has been obtained and for the PAR we provided a range of values.

4.5.5 Additional Comments and Notes

No additional comments.

4.5.6 Resilience (% Loss of Airport & Airspace Capacity Avoided)

4.5.7 Performance Mechanism

The arrivals OI are focused on reduction and optimising separations between aircraft during traffic peak. 2 OIs (WDS-A and PWS-A) further optimised the minimum wake separations to be applied between consecutive arrivals, the ORD OI further enhance the separation delivery tool that supports the ATCO in providing separations and spacing. By reducing separations and optimising spacing we obtain higher Resilience and loss of capacity can be avoided. See the BIM in the OSED for details.

4.5.8 Assessment Data (Exercises and Expectations)

For the resilience KPI, in the FTS9 exercise each solution run is compared to the reference scenario runs with the same traffic pressure, the number of go-around is then recorded. A go-around is equivalent to a loss of Airport Capacity, so a % reduction of the number of the go-around improves the airport resilience when adverse conditions (such as strong wind) are in place.

RES1

The following table summarizes the results in terms of fraction of go-around and number of movements (between brackets) for the solutions scenarios when compared to the reference scenario; a positive percentage indicates a reduction in the number of go-around in the solution scenarios.

Wind	low wind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU TBS with ORD (AO-0328)	0% (0)	0% (0)	0% (0)	0% (0)	-	-
RECAT-EU-PWS TBS with ORD (AO-0328 and AO-0306)	0% (0)	6% (3)	2% (1)	6% (3)	-	-
RECAT-EU WDS with ORD (AO-0328 and AO-0310)	-	-	-	-	0% (0)	4% (2)
RECAT-EU-PWS WDS with ORD (AO-0328, AO-0306 and AO-0310)	-	-	-	-	1% (1)	8% (4)

Depending from wind condition, traffic samples and OIs applied the benefit range for the solution is between 0%-8% movements and 0-4 go-arounds less.

RES1.1

In line with RES1, the following table shows the additional length of the runs due to the capacity disruption. A negative amount indicates the additional length of the run (in minutes) for the reference scenario compared to the solution scenarios runs.

Wind	low wind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU TBS with ORD (AO-0328)	-0.6	-0.6	-0.9	-0.9	-	-
RECAT-EU-PWS TBS with ORD (AO-0328 and AO-0306)	-0.6	-6.5	-2.65	-7.15	-	-
RECAT-EU WDS with ORD (AO-0328 and AO-0310)	-	-	-	-	-0.68	-4.8
RECAT-EU-PWS WDS with ORD (AO-0328, AO-0306 and AO-0310)	-	-	-	-	-2.7	-11.8

Depending from wind condition, traffic samples and OIs applied the benefit range for the solution is between -0.6-11.8 minutes to recover from disruption.

RES4

For this performance indicator results of the FTS9 are used. The reference scenario at the maximum traffic pressure for avoiding go-arounds is compared to the solution runs. The saved time spent flying in the TMA is recorded and used to quantify the benefit to reduce the delay due to the less time spent in holding, the amount time flying faster and the reduced separations in the TMA. A positive amount indicates a positive benefit for the solution run.

Wind	low wind		strong headwind		strong crosswind	
Separation scheme and mode	min	max	min	max	min	max
RECAT-EU TBS with ORD (AO-0328)	0.8	1	0.66	1	-	-
RECAT-EU-PWS TBS with ORD (AO-0328 and AO-0306)	2.48	7.83	2.48	7.83	-	-
RECAT-EU WDS with ORD (AO-0328 and AO-0310)	-	-	-	-	1	5.4
RECAT-EU-PWS WDS with ORD (AO-0328, AO-0306 and AO-0310)	-	-	-	-	2.1	10.68

Depending from wind condition, traffic samples and OIs applied the minutes of delay saved for the solution is between 0.66-10.68.

RES5 (Cancellation)

There aren't any differences between reference and solution scenarios, with 0 flights cancellation. This is because both scenarios rely on TBS OI from SESAR1. TBS has been deployed at Heathrow Airport in March 2015 and one of the main benefits was that tactical cancellations due to headwinds were reduced at 0 [9]. It is not expected that those OIs would be beneficial for cancellations due to other reasons.

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
RES1 Loss of Airport Capacity Avoided	% and Movements per hour	Loss of Airport Capacity with the concept divided by the loss of Airport Capacity without the concept.	YES	ORD (AO-0328) tool support for RECAT-EU TBS – **0 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0-3 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	ORD (AO-0328) tool support for RECAT-EU TBS – **0% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0-6% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
				WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support– **0-2 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	0328) tool support – **0-4% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.
RES 1.1 Airport time to recover from non-nominal to nominal condition	Minutes	Duration of Airport lost capacity from non-nominal to nominal condition.	YES for Airport OE Solutions	ORD (AO-0328) tool support for RECAT-EU TBS– **0.6-0.9 minutes gain**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0.6-7.15 minutes gain** in 1 hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.68-4.8 minutes gain** in 1 hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	ORD (AO-0328) tool support for RECAT-EU TBS– **1% minutes gain** in 1 hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **1%-12% minutes gain** in 1 hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0-8% minutes gain** in hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.
RES2 Loss of Airspace Capacity Avoided	% and Movements per hour	Loss of Airspace Capacity with the concept divided by the loss of Airspace Capacity without the concept	YES	ORD (AO-0328) tool support for RECAT-EU TBS– **0 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0-3 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for	ORD (AO-0328) tool support for RECAT-EU TBS– **0% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0-6% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
				RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0-2 increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0-4% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.
RES2.1 Airspace time to recover from non-nominal to nominal condition	Minutes	Duration of Airspace lost capacity compared to non-nominal to nominal condition.	YES for Airspace OE Solutions	*N/A*	*N/A*
RES4 Minutes of delays	Minutes	Impact on AUs measured through delays resulting from capacity degradation[4]. RES1 and RES2 KPIs drive this PI, though the PI may need to be measured on a condition-by-condition basis (e.g. fog, wind, system outage).	YES	ORD (AO-0328) tool support for RECAT-EU TBS– **0.8-1 minutes gain**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **2.48-7.83 minutes gain** in 1 hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **1-5.4 minutes gain** in 1 hour, compared to TBS (AO-0303) FTD	ORD (AO-0328) tool support for RECAT-EU TBS– **1% minutes gain** in 1 hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **4%-13% minutes gain** in 1 hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **1-9% minutes gain** in hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.

[4] Reactionary delay out of the scope since they could be due to many different reasons other than capacity degradation, in addition the cause of reactionary delay is not recorded in detail.

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
				Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	
RES5 Number of cancellations	Nb flights	Impact on AUs measured through Cancellations resulting from capacity degradation[5]. RES1 and RES2 KPIs drive this PI, though the PI may need to be measured on a condition-by-condition basis (e.g. fog, wind, system outage).	YES	ORD (AO-0328) tool support for RECAT-EU TBS– **0**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	ORD (AO-0328) tool support for RECAT-EU TBS– **0%**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0%**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0%**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.

Table 16: Resilience benefits for Mandatory KPIs /PIs

4.5.9 Extrapolation to ECAC wide

There is no ECAC wide extrapolation required for this KPI.

4.5.10 Discussion of Assessment Result

There is not a validation target associated to Resilience by PJ19.04. The confidence estimate in the results is low. The benefits identified are an estimation applicable to very large, large and medium airports that are capacity constrained during traffic peaks because of the wake turbulence constraints and the separation delivery on approach.

[5] Reactionary delay out of the scope since they could be due to many different reasons other than capacity degradation, in addition the cause of reactionary delay is not recorded in detail.

4.5.11Additional Comments and Notes

No additional comments.

4.6 Predictability

4.6.1 Performance Mechanism

The arrivals OI are focused on reduction and optimising separations between aircraft during traffic peak. Reduction of separations and spacing (e.g. takin in account a better estimation of wind conditions) will reduce the average delay per flight. See the BIM in the OSED for details.

4.6.2 Assessment Data (Exercises and Expectations)

PRD1

Predictability benefit for arrivals traffic in peak is measured using the results of the FTS9, where the time to land each aircraft was recorded and compared to the reference scenario. For these results only the scenarios where the traffic was coordinated in order to guarantee the maximum available traffic pressure without go-arounds were taken in account.

Predictability net benefit is measured using the standard deviation formula a, the results below provide the difference in standard deviation for each OIs, considering all runs with different traffic samples and wind conditions.

	Headwind	Crosswind
Separation scheme and mode	Standard Deviation (minutes)	
RECAT-EU TBS with ORD (AO-0328)	0.40	-
RECAT-EU-PWS TBS with ORD (AO-0328 and AO-0306)	0.62	-
RECAT-EU WDS with ORD (AO-0328 and AO-0310)	-	0.55
RECAT-EU-PWS WDS with ORD (AO-0328, AO-0306 and AO-0310)	-	0.57

4.6.3 Extrapolation to ECAC wide

The following PJ.19 common assumptions have been used:

- High density airports traffic contribution to total airport traffic = 59.5%
- Arrivals traffic contribution to total traffic = 50%
- TMA contribution to variability = 43%
- B2B variance = 49.0 mins^2

1. Current variance = 49 min^2 (B2B absolute variance) * 43% (B2B variance of the TMA arrival) = 21.07 min^2

2. Current variability = (21.07)1/2 = 4.59 min

PRD1 for AO-0328 (ORD):

1. Improved absolute variance (local) = 4.59 min -0.4 min = 4.19 min = 17.55 min^2
2. Absolute difference variance (local) = 17.55 – 21.07 = -3.5139 min^2
3. Arrival TMA predictability benefits at ECAC level -3.5139 min^2 (absolute difference variance (local)) *50% *59.5% (share of ECAC traffic) = -1.045min^2 = 2.13%

PRD1 for AO-0306 (PWS-A):

1. Improved absolute variance (local) = 4.59 min -0.62 min = 3.97 min = 15.761 min^2
2. Absolute difference variance (local) = 15.761 – 21.07 = -5.3091 min^2
3. Arrival TMA predictability benefits at ECAC level -5.3091 min^2 (absolute difference variance (local)) *50% *59.5% (share of ECAC traffic) = -1.579min^2 = 3.22%

PRD1 for AO-0310 (WDS-A):

1. Improved absolute variance (local) = 4.59 min -0.55 min = 4.04 min = 16.32 min^2
2. Absolute difference variance (local) = 16.32 – 21.07 = -4.748 min^2
3. Arrival TMA predictability benefits at ECAC level -4.748 min^2 (absolute difference variance (local)) *50% *59.5% (share of ECAC traffic) = -1.412min^2 = 2.88%

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
PRD1 Variance[6] of Difference in actual & Flight Plan or RBT durations	Minutes[2]	Variance of Difference in actual & Flight Plan or RBT durations	YES	ORD (AO-0328) tool support for RECAT-EU TBS – **1.045 min^2 reduction** (standard deviation) , compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) **1.579 min^2reduction** (standard deviation), compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support **1.412 min^2 reduction** (standard deviation) , compared to TBS (AO-0303) FTD	ORD (AO-0328) tool support for RECAT-EU TBS– **2.13% reduction** (standard deviation) , compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) **3.22% reduction** (standard deviation) , compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support **2.88% reduction** (standard deviation), compared to TBS (AO-0303) FTD Indicator only

[6] Standard Deviation is also accepted.

KPIs / PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
				Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	tool support for RECAT-EU TBS, with a Vienna airport traffic mix.

Table 17: Predictability benefits for Mandatory KPIs /PIs

Table 18 is showing the impact on flight phases (provided when it is possible).

	Taxi out	TMA departure	En-route	TMA arrival	Taxi in
PRD1 Variance[7] of Difference in actual & Flight Plan or RBT durations	N/A	N/A	N/A	ORD (AO-0328) tool support for RECAT-EU TBS– 1.045 min^2 reduction in flight duration, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – 1.579 min^2 reduction in flight duration, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – 1.412 min^2 reduction in flight duration, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	N/A

Table 18: Predictability benefit per flight phase

4.6.4 Discussion of Assessment Result

The performance target indicates 0.27%. The % expected performance benefits of 4-5-6 % exceed the performance target. The confidence in these results is low.

4.6.5 Additional Comments and Notes

No additional comments.

[7] Standard Deviation is also accepted.

4.7 Human Performance

4.7.1 HP arguments, activities and metrics

The HP Assessment performed for the Arrival concepts- as part of PJ.02-01-04 ensured that relevant HP aspects have been identified and considered for the operational and technical development of the Increased Runway and Airport Throughput concepts, based on the HP Assessment Process methodology.

The arrivals validation activities for PJ.02-01-04 focused on:

a) Arrival Wake Separation concepts:
   1. Static PairWise Separations (S-PWS) - Wake turbulence separations for arrivals based on static aircraft characteristics (AO-0306);
   2. Weather Dependent Separations (WDS) - weather dependant reductions of wake turbulence separations on the final approach (AO-0310);
   3. Optimised Runway Delivery (ORD) - a controller tool to support the application of static pairwise separations and weather dependent separations on the final approach (AO-0328).

All OIs have been analyses separately and the conclusions of the HP assessment are to be found in part IV of the OSED, where an HP log documents the conclusions for each OI separately. In the following sections of chapter 4.3.14 a separate input will be made for each of the OIs for arrivals.

PIs	Activities & Metrics	Second level indicators	Covered
HP1 Consistency of human role with respect to human capabilities and limitations	• **Stakeholder Workshop** • **Prototyping Sessions** • **Real Time Simulation**	**HP1.1** Clarity and completeness of role and responsibilities of human actors	(AO-0306) (AO-0310) (AO-0328)
		HP1.2 Adequacy of operating methods (procedures) in supporting human performance	(AO-0306) (AO-0310) (AO-0328)
		HP1.3 Capability of human actors to achieve their tasks in a timely manner, with limited error rate and acceptable workload level	(AO-0306) (AO-0310) (AO-0328)
HP2 Suitability of technical system in supporting the tasks of human actors	• **Stakeholder Workshop** • **Prototyping Sessions** • **Real Time Simulation**	**HP2.1** Adequacy of allocation of tasks between the human and the machine (i.e. level of automation).	(AO-0306) (AO-0310) (AO-0328)
		HP2.2 Adequacy of technical systems in supporting Human Performance with respect to timeliness of system responses and accuracy of information provided	(AO-0306) (AO-0310) (AO-0328)
		HP2.3 Adequacy of the human machine interface in supporting the human in carrying out their tasks.	(AO-0306) (AO-0310) (AO-0328)
HP3 Adequacy of team structure and team communication in	• **Stakeholder Workshop** • **Prototyping Sessions**	**HP3.1** Adequacy of team composition in terms of identified roles	**N/A**
		HP3.2 Adequacy of task allocation among human actors	(AO-0310) (AO-0328)

PIs	Activities & Metrics	Second level indicators	Covered
supporting the human actors	• **Real Time Simulation**	**HP3.3** Adequacy of team communication with regard to information type, technical enablers and impact on situation awareness/workload	(AO-0306) (AO-0310) (AO-0328)
HP4 Feasibility with regard to HP-related transition factors	• **Stakeholder Workshop** • **Prototyping Sessions** • **Real Time Simulation**	**HP4.1** User acceptability of the proposed solution	(AO-0306) (AO-0310) (AO-0328)
		HP4.2 Feasibility in relation to changes in competence requirements	(AO-0306) (AO-0310) (AO-0328)
		HP4.3 Feasibility in relation to changes in staffing levels, shift organization and workforce relocation.	N/A
		HP4.4 Feasibility in relation to changes in recruitment and selection requirements.	N/A
		HP4.5 Feasibility in terms of changes in training needs with regard to its contents, duration and modality.	(AO-0306) (AO-0310) (AO-0328)

Table 19: HP arguments, activities and metrics

4.7.2 Extrapolation to ECAC wide

There is no ECAC wide extrapolation required for this KPI.

4.7.3 Open HP issues/ recommendations and requirements

PIs	Number of open issues/ benefits	Number of recommendations	Number of requirements
HP1 Consistency of human role with respect to human capabilities and limitations	(AO-0306) - none (AO-0310) - none (AO-0328) - none	(AO-0306) – 0 (AO-0310) – 3 (AO-0328) – 4	(AO-0306) – 16 (AO-0310) – 23 (AO-0328) – 47
HP2 Suitability of technical system in supporting the tasks of human actors	(AO-0306) - none (AO-0310) - none (AO-0328) - none	(AO-0306) – 4 (AO-0310) – 3 (AO-0328) – 7	(AO-0306) – 5 (AO-0310) – 17 (AO-0328) – 81
HP3 Adequacy of team structure and team communication in supporting the human actors	(AO-0306) - none (AO-0310) - none (AO-0328) - none	(AO-0306) – 0 (AO-0310) – 2 (AO-0328) – 0	(AO-0306) – 0 (AO-0310) – 1 (AO-0328) – 3
HP4 Feasibility with regard to HP-related transition factors	(AO-0306) - none (AO-0310) - none (AO-0328) - none	(AO-0306) – 1 (AO-0310) – 3 (AO-0328) – 1	(AO-0306) – 6 (AO-0310) – 7 (AO-0328) – 16

Table 20: Open HP issues/ recommendations and requirements

4.7.4 Concept interaction

N/A

4.7.5 Most important HP issues

PIs	Most important issue of the solution	Most important issues due to solution interdependencies
HP1 Consistency of human role with respect to human capabilities and limitations	N/A	N/A
HP2 Suitability of technical system in supporting the tasks of human actors	N/A	N/A
HP3 Adequacy of team structure and team communication in supporting the human actors	N/A	N/A
HP4 Feasibility with regard to HP-related transition factors	N/A	N/A

Table 21: Most important HP issues

4.7.6 Additional Comments and Notes

No additional comments.

4.8 Gap Analysis

KPI	Validation Targets – Network Level (ECAC Wide)	Performance Benefits at Network Level (ECAC Wide or Local depending on the KPI)	Rationale[8]
FEFF1: Fuel Efficiency – Fuel burn per flight	26.7 kg	ORD (AO-0328) tool support for RECAT-EU TBS = **7.2-21.7 kg** compared to, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. AO-0306 (PWS-A) = **3-16 kg**, compared to TBS (AO-0303) FTD Indicator only tool support for	Arrivals (AO-0328, AO-0306, AO-0310) The performance target indicates a reduction of 26.7 kg per flight. The expected performance benefits (considering different traffic samples and wind conditions) are in this range with the performance target only with WDS-A (OI AO-0310). For ORD when deployed alone, the best result is 21 kg reduction, still close to the validation target.

[8] Discuss the outcome if, and only if, the gap indicates a different understanding of the contribution of the Solution (for example, the Solution is enabling other Solutions and therefore is not contributing a direct benefit).

		RECAT-EU TBS, with a Vienna airport traffic mix. AO-0310 (WDS-A) in the context of RECAT-EU TBS with ORD (AO-0328) tool support = **27.4-40.46 kg,** compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	For PWS-A the best result is 16 kg reduction, which is well below the target, The confidence in these results is low.
CAP3: Airport Capacity – Peak Runway Throughput (Mixed mode).	2.6%	ORD (AO-0328) tool support for RECAT-EU TBS – **7.9% increase** in movements per hour, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0.01% increase**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.01% increase**, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Arrivals (AO-0328, AO-0306, AO-0310) These results meet and exceed the performance targets defined from PJ.19 that was a 2.574% increase in capacity with the exception of ORD when deployed alone (where the best result of 2.3% capacity increase is very close to the validation target). The confidence estimate in the results is moderate, they are based on generic characteristics that are common in other European airports. The benefits identified are an estimation applicable to very large, large and medium airports that are capacity constrained during traffic peaks because of the wake turbulence constraints and the separation delivery on approach. For each local airports the exact benefits are depending on several factors including specific traffic mix, length of traffic peak, wind conditions (especially for WDS), applicable surveillance minima, runway occupancy time, glide length, type of approach, runway layout, airport infrastructure, etc..; these factors were taken into account in the FTS as fixed parameters (e.g. ROT) or dynamic parameters modified in each run (e.g. the traffic mix, wind conditions, …) to provide as many different cases as possible. 14 reference scenarios and 20 solution scenarios have been fast time simulated for each of the 4 traffic samples. Each traffic sample varies 7 times the traffic pressure, thus a comprehensive set of results has been obtained and for the PAR we provided a range of values.

PRD1: Predictability – Variance of Difference in actual & Flight Plan or RBT durations	0.27%[9]	ORD (AO-0328) tool support for RECAT-EU TBS– **0.40 minutes reduction** (4%) in flight duration, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. PWS-A (AO-0306) – **0.62 minutes reduction** (5%) in flight duration, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix. WDS-A (AO-0310) in the context of RECAT-EU TBS with ORD (AO-0328) tool support – **0.55 minutes reduction** (6%) in flight duration, compared to TBS (AO-0303) FTD Indicator only tool support for RECAT-EU TBS, with a Vienna airport traffic mix.	Arrivals (AO-0328, AO-0306, AO-0310) The performance target indicates 0.27%. The % expected performance benefits of 4-5-6 % exceed the performance target. The confidence in these results is low.

Table 22: Gap analysis Summary

[9] In Validation Targets [18] the unit for PRD1 is % Reduction in variance of block-to-block flight time.

5 References

This PAR complies with the requirements set out in the following documents:

[1] 08.01.03 D47: AIRM v4.1.0

[2] B05 Performance Assessment Methodology for Step 1 PJ19.04.01 Methodology for Performance Assessment Results Consolidation (2020)

[3] SESAR Performance Framework (2019), Edition 01.00.01, Dec 2019

https://stellar.sesarju.eu/?link=true&domainName=saas&redirectUrl=%2Fjsp%2Fproject%2Fproject.jsp%3FobjId%3Dxrn%3Adatabase%3Aondb%2Frecord%2F16414675

[4] Performance Assessment and Gap Analysis Report (2019), Edition 00.01.02, Dec 2019

[5] Methodology for the Performance Planning and Master Plan Maintenance, Edition 0.13, Dec 2017

[6] B.05 D72, Updated Performance Assessment in 2016

https://stellar.sesarju.eu/servlet/dl/ShowDocumentContent?doc_id=1669873.13&att=attachment&statEvent=Download

Content Integration

[7] SESAR ATM Lexicon

Performance Management

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[3] D1.1.01 – PJ.02-01-04 OSED-SPR-INTEROP (Final) Part II – 01.00.00

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10

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Appendix A Detailed Description and Issues of the OI Steps (PJ.02-01-04)

OI Step ID	Title	Consistency with latest Dataset
AO-0328	Optimised Runway Delivery on Final Approach	Full (DS20)
AO-0306	Wake Turbulence Separations (for Arrivals) based on static Aircraft Characteristics	Full (DS20)
AO-0310	Weather-Dependant Reductions of Wake Turbulence Separations for Final Approach	Full (DS20)

Table 23: OI Steps allocated to the Solution

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EUROPEAN PARTNERSHIP

Co-funded by the European Union