INDUSTRIAL RESEARCH

SESAR SOLUTION PJ02-01: COST BENEFIT ANALYSIS (CBA) FOR V3

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PJ02 EARTH

INCREASED RUNWAY AND AIRPORT THROUGHPUT

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Abstract

This document provides the Cost Benefit Analysis (CBA) at V3 level for SESAR Project PJ.02.01 - Wake turbulence separation optimisation. PJ.02-01 aims to optimize wake turbulence separation minima for arrivals and departures to enhance airport runway throughput introducing the use of a separation delivery tool with a more advanced wake turbulence separation scheme to maintain the separations between aircraft pair i.e. Static Pairwise Separation.

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1 Executive Summary

This report[1] provides the V3 Cost Benefit Analysis (CBA) for SESAR Project PJ.02 - Solution 01-Wake turbulence separation optimisation.

PJ.02-01 aims to optimize wake turbulence separation minima for arrivals and departures to enhance airport runway throughput introducing the use of a separation delivery tool with a more advanced wake turbulence separation scheme to maintain the separations between aircraft pair i.e. Static Pairwise Separation. The schemes used as a reference nowadays at European airports are the standard ones i.e. ICAO or RECAT-EU.

The development of multiple customisations of separation to apply will not be manageable by the Air Traffic Controller (ATCO) if not assisted by the System which will take into account the separations defined as a function of aircraft characteristics. ATC support tools such as Optimised Runway Delivery (ORD) for arrival and Optimised Separation Delivery (OSD) for departure are developed therefore, in order to mitigate the impact on ATCO workload and Human Performance, and to deliver cost efficiency targets (Appendix 5 – Solution Validation Targets).

PJ.02-01 contributes to Wake Turbulence Separation Optimisation through 4 concepts (8 Operational Improvements (OIs).

The CBA focusses only on two concepts i.e. Arrival and Departure covering 4 OIs:

1) Arrival Concept Solution
   - AO-0328 Optimised Runway Delivery on Final Approach
   - AO-0306 Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics
2) Departures Concept Solution
   - AO-0329 Optimised Separation Delivery for Departure
   - AO-0323 Wake Turbulence Separations (for departures) based on Static Aircraft Characteristics

The weather-dependent reduction of wake turbulence for arrival and departure (OIs AO-0304 and AO-0310) is not included in the CBA results because they provide limited benefits due to the limited applicability of the concepts; a specific part of the day during which a strong wind component is persistent for more than 30 minutes is a rare event. In addition, those weather conditions should happen at the same time when traffic peaks are experienced at the airport. The validation results have showed that there is a very limited additional benefit when Weather Dependent Separation (WDS) is deployed in addition to pairwise separations (which already reduces significantly the wake

[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.

separations); while the former may be used only for a part of the day, the latter can be used during the whole day.

Reduction of Wake Turbulence Risk through Wake Risk Monitoring (AO-0327) and Reduction of Wake Turbulence Risk considering Acceleration of Wake Vortex Decay (AO-0325) concepts are also out of CBA scope due to lack in maturity for the former and difficulty to quantify safety and capacity gains out of validation results for the latter.

For the above mentioned OIs - out of CBA scope - costs and benefits have been described qualitatively and quantitatively in this report presenting all the available information following validation exercises and PJ.02.01 partners' information.

The expected benefits from PJ.02-01 are mainly related to the impact of the optimised wake turbulence separations on **Time Efficiency** and the resulting increase in runway throughput and reduction in holding delay with the associated impact on **Fuel Efficiency**, **Predictability** and **Airport Capacity**.

The CBA is presented at ECAC level following an extrapolation of local benefits. The local analysis is conducted for capacity constrained Very Large and Large airports (following SESAR Classification Scheme) operating in segregated mode, using Fast Time Simulation exercise. The number of airports identified as candidate for this solution is 9 for Arrival and 14 for Departure concept.

The deployment of PJ.02-01 will require only ANSPs[2] to invest.

The CBA results are discounted at 8% between 2019 and 2040, with PJ.02-01 being deployed between 2021 and 2028 and with benefits starting to be realised in 2024. Combining both the Arrival and Departure CBA with overall costs of **150 M€** undiscounted (89 M€ discounted) PJ.02.01 would achieve a Net Present Value (NPV) of **637M€** by 2040 (571 M€ as the lowest value and 2 089 M€ as the highest value depending on the scenario of the sensitivity analysis following a change in either the discount rate or the airport capacity or the investment and annual operating costs of the tools). Looking at the concepts separately, the arrival concept would achieve a NPV of **294 M€ (994M€ undiscounted)** while the departure concept **343M€ (1 095M€ undiscounted)**.

It is recommended to present the outcome of the study and of this cost benefit analysis not only to ANSPs who may be interested in pursuing a similar concept solution to address their capacity and delays issue but also to airspace users and airports who are highly benefitting from this solution.

Although the CBA may seem negative from an ANSP point of view, delivering better services to airports and airspace users is a key benefit.[3]

[2] A simplifying assumption that airport systems are owned by the ANSPs has been taken; ANSPs are incurring also all the relevant upgrade costs of these systems.

2 Introduction

2.1 Purpose of the document

This document provides the Cost Benefit Analysis (CBA) for SESAR Project PJ.02 - Solution 01 - Wake turbulence separation optimisation that has been validated during validation exercises at v3 level. The CBA is required to assess the affordability of the solution PJ.02.01 with respect to its expected benefits.

According to SESAR Handbook, the final R&D CBA developed in V3 should include all the evidence gathered in terms of impacts, benefits and costs of a solution. By V3, the CBA should provide the NPV overall and per stakeholder group, a sensitivity analysis identifying most critical variables to the value of the project, the CBA model, report and recommendations.

2.2 Intended readership

The intended readership for this document includes:

- PJ.02-01 project members
- PJ.02 Increased Runway and Airport Throughput – Other Solution partners
- Project PJ.01 Enhanced Arrivals and Departures – Related Solutions' partners
- PJ.04 Total Airport Management – Related Solutions' partners
- PJ.09 Advanced Demand & Capacity Balancing – Related Solutions' partners
- PJ.19 – who provides inputs such as the assumptions and who will consolidate the CBA results (where required by PJ20).
- PJ.20, in its role of Master Plan Maintenance project
- PJ.22 - System Engineering Data Management Framework (SE-DMF)
- SESAR Programme Management
- Stakeholders (ANSPs and airports) interested in deploying this solution
- Airspace users

2.3 Structure of the document

This report is structured as follows:

- **Section 1 provides the executive summary;**
- **Section 2 provides the overall scope, time horizon, intended audience, structure of the document, background, glossary of terms and acronyms;**
- **Section 3 presents the objectives and scope of this CBA, provides a description of the PJ.02-01 Solution and the problem addressed by this Solution, identifies the main stakeholders impacted and describes the different scenarios compared in the CBA;**

- **Section 4 provides a view on the overall contribution to Key Performance Indicators (KPIs) and a description of the expected benefits per stakeholder group and the monetisation of the benefits**
- **Section 5 describes the cost approach and the main assumptions taken when assessing the cost elements of the Solution and presents the results of the cost assessment per stakeholder group;**
- **Section 6 provides a description of the CBA model and the sources of data used to build the CBA Model; the CBA Model will be provided as a supporting document.**
- Section 7 provides the CBA results;
- Section 8 includes sensitivity and risk analysis;
- **Section 9 includes recommendations and next steps;**
- **Section 10 includes the references and applicable documents.**
- **The appendices provides the list of targeted Airports by this CBA, the Operational Improvements (OIs) out of scope, the rational of the use of 8% discount rate and the mapping between ATM Master Plan Performance Ambition KPAs (Key Performance Areas) and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs.**

2.4 Background

This section provides information on previous activities related to the solution concepts. This background information covers mainly technical and regulatory aspects of the current operational improvements rather than providing cost assessment or economic appraisals related information.

1. An impact assessment of RECAT EU[4] (Non-SESAR R&D Solution) has been performed for Charles de Gaulle airport one year after RECAT EU Deployment at the airport. Results were presented in the Runway Throughput Symposium October 2018 at EUROCONTROL Experimental Centre.

   http://recat-project.eu/activities/runway-throughput-symposium-2018

2. Time Based Separation was introduced into full operational service at Heathrow Airport on 24 March 2015. To counteract the effect of wind on the landing rate and provide resilience for airport operations, Time Based Separation (TBS) replaces distance separations with time separations. Whilst TBS doesn't directly reduce the cost of ATM its introduction has delivered major benefits to Heathrow Airport, the airlines and the flying public at no additional cost. TBS is delivering a reduction in wind related ATFM delay of over 60%. This is achieved by an average increase in the landing rate of 1.2 arrivals per hour over distance-based separations across all wind conditions, increasing to an average of 2.9 arrivals per hour in winds over 20kts. As a result of this, there has been a marked reduction in weather related flight cancellations. TBS is mandated to be in operation at Europe's busiest airports by 2024.

   https://ec.europa.eu/transport/modes/air/ses/ses-award-2016/projects/time-based-separation-heathrow_en

3. In the context of SESAR Project 6.8.1 “Optimization of Runway Throughput”, EUROCONTROL investigated concepts for flexible and dynamic use of wake turbulence separations Study on separation delivery at six major European airports (Barcelona El Prat, London Gatwick, London Heathrow, Milan Malpensa, Paris Charles de Gaulle, and Vienna Schwechat). The results of this study were used by SESAR and EUROCONTROL in the development of a new ATC tool to predict aircraft speed performance. This Leading Optimised Runway Delivery (LORD) tool supports Air Traffic Controllers to optimize the separation buffer and more efficiently and easily deal with the compression effect on the last part of the final approach.

   http://www.atmseminarus.org/seminarContent/seminar11/papers/466-Van%20Baren_0126150311-Final-Paper-5-7-15.pdf

4. On wake risk monitoring previous work in Project P09.11 from SESAR 1 is relevant. The project focused on on-board prediction of wake turbulence encounters and also performed some preliminary work on detection of wake turbulence encounters based on air-to-air data exchange.

[4] European Wake Turbulence Categorisation and Separation Minima on Approach and Departure https://www.eurocontrol.int/publication/european-wake-turbulence-categorisation-and-separation-minima-approach-and-departure

5. On wake decay the plate line principle has been investigated within DLR internal projects employing different devices. Flight experiments were also conducted, with the DLR research aircraft HALO (Gulfstream G550) at special airport Oberpfaffenhofen where the vortex plate interaction was studied employing LiDAR measurements. The LiDAR measurement results indicate that the lifetime of the longest lived and thus potentially most hazardous vortex could be reduced by one third.

2.5 Glossary of terms

Term	Definition	Source of the definition
Benefit	A Benefit is the positive value of the return on investment to (some or all) stakeholders.	SESAR 16.06.06 - Methods to Assess Costs and Monetise Benefits for CBAs (D26, Edition 00.02.02, July 2016)
Benefit and Impact Mechanism	A Benefit and Impact Mechanisms a cause-effect description of the positive and negative impacts of the Solution proposed by the project	SESAR 16.06.06 – Guidelines for Producing benefit and Impact Mechanisms (D26_04, Edition 03.00.00)
Business Case	Quantitative and qualitative arguments (in addition to financial analysis) about performance and transversal activities to determine the value of a project so as to allow decision-makers to make a fully informed decision on whether funding should be provided and/or whether an investment should proceed.	PAGAR
Cash Flow	Cash flow is the difference between the cash inflows and outflows related to the project during the time horizon in which they occur.	SESAR 16.06.06 - ATM CBA for Beginners, D26-01, October 2014
Cost	A Cost is the monetary value of an investment used up to produce or acquire the benefit.	SESAR 16.06.06 - Methods to Assess Costs and Monetise Benefits for CBAs (D26, Edition 00.02.02, July 2016)
Cost Benefit Analysis	A Cost Benefit Analysis is a process of quantifying in economic terms the costs and benefits of a project or a program over a certain period, and those of its alternatives (within the same period), in order to have a single scale of comparison for unbiased evaluation. A CBA is a neutral financial tool that helps decision makers to compare an investment with other possible investments and/or to make a choice between different options / scenarios and to select the one that offers the best value for money while considering all the key criteria for the decision.	SESAR 1
Cost mechanisms	Cost mechanisms are a description of the	SESAR 16.06.06, ATM CBA

	potential costs of the project broken down into relevant cost categories (e.g. investment, operating).	for Beginners, D26-01, October 2014
Discount Rate	Discount Rate is a way to capture the time value of money. This is a percentage that represents the increase in the amount of money needed or estimated to keep the same value as one year ago.	SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014
Initial Operational Capability	Initial Operational Capability is the state archives when a capability is available in its minimum usefully deployable form. In other words, it identifies the start of benefits and the benefit ramp-up period.	16.06.06-D68-New CBA Model and Method 2015-Part1 of 2
Inflation	Inflation is a rise in the general level of prices of goods and services in an economy over a period of time.	SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014
Net Present Value (NPV)	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.	SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014
Sensitivity Analysis	Sensitivity refers to the impact one given input to the model has on the overall NPV.	SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014
Stakeholder	Stakeholders are organizations and entities who will have to pay for or will be impacted by the project directly or indirectly.	SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014
Time Horizon	Time horizon refers to a definite time period during which all cost and benefits related to a given project occur.	SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014
Time Value of Money	Time Value of Money means that the same (nominal) amount of money received at different points in time has different value	SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014
Wake Turbulence	Wake turbulence is a function of an aircraft producing lift, resulting in the formation of two counter-rotating vortices trailing behind the aircraft. Wake turbulence from generating aircraft can affect encountering aircraft due to the strength, duration, and direction of the vortices.	PJ.02.01 partners
Wake Vortex	Wake vortex is a circular pattern of rotating air	PJ.02.01 partners

	left behind a wing as it generates lift.	

2.6 List of Acronyms

Acronym	Definition
ACC	Area Control Centre
ATM	Air Traffic Management
ANS	Air navigation services
ANSP	Air Navigation Service Provider
APT	Airport
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
AU	Airspace User
CAP	Capacity
CAPEX[5]	Capital Expenditure
CBA	Cost Benefit Analysis
CCDF	Complementary Cumulative Distribution Function
CDG	Charles de Gaulle Airport
DS	Data Set
EATM	European ATM (Portal, database, dataset)
EATMA	European ATM Architecture
EC	European Commission
ECAC	European Civil Aviation Conference
EN	Enabler

[5] Note that the term CAPEX has been used in the CBA Report to indicate all the investments (pre-implementation and implementation costs).

ER	En-route
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
FEFF	Fuel Efficiency
FOC	Final Operating Capability
FTS	Fast Time Simulation
HC	High complexity (airport)
HP	Human Performance
ICAO	International Civil Aviation Organization
IGS	Increased Glide Slope
INTEROP	Interoperability
IOC	Initial Operating Capability
KPA	Key Performance Area
KPI	Key Performance Indicator
LC	Low complexity (airport)
LHR	London Heathrow airport
LiDAR	Light Detection And Ranging (or laser detection and ranging)
LORD	Leading Optimised Runway Delivery
MRAP	Multi Runway Aiming Points
MTOM	Maximum Take Off Mass
MTOW	Maximum Take Off Weight
NM	Network Manager
NPV	Net Present Value
OE	Operating Environment
OI	Operational Improvement
OPEX	Operating Expenditure (Considers Changes in Operating Costs)
ORD	Optimised Runway Delivery (Tool)
OSD	Optimised Separation Delivery (Tool)
OSED	Operational Service and Environment Definition
PAGAR	Performance Assessment And Gap Analysis Report
PANS-ATM 4	Procedures for Air Navigation Services — Air Traffic Management
PAR	Performance Assessment Report

PCP	Pilot Common Project
PJ	Project
PMP	Project Management Plan
PRD	Predictability
PWS	Pair Wise Separation
PWS-A	Pair Wise Separation for Approach
R&D	Research and Development
RECAT	Wake Turbulence Re-categorisation
RES	Resilience
ROT	Runway Occupancy Time
RTS	Real Time Simulation
RTS5	Real Time Simulation 5th Run (LHR Heathrow)
RWY	Runway
SAF	Safety
SDM	SESAR Deployment Manager
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking
SOL	Solution
S-PWS	Static Pair Wise Separation
SPR	Safety and Performance Requirements
TBS	Time Based Separation (Wake Turbulence)
TDIs	Target Distance Indicators
TMA	Terminal Manoeuvring Area
VT	Validation Target
VLD	Very Large Demonstration
WDS	Weather Dependent Separation
WDS-A	Weather Dependent Separation for Arrival
WP	Work Package

3 Objectives and scope of the CBA

3.1 Scope

The scope of this document is the V3 CBA for PJ.02-01.This CBA includes all costs and benefits generated by the OI Steps of the Solution and the associated list of required enablers.

The DS19 EATM Dataset was used as a Reference [10].

The CBA provides the costs and benefits of the PJ.02-01 Solution as if it would be deployed as a standalone Solution, independently from any other S2020 Solution.

3.1.1 Identification of stakeholders

CBA results are presented at the aggregated overall level and individually from the viewpoint of the impacted stakeholder groups, i.e. the stakeholders that will have to invest and will mainly benefit from the Solution:

- ANSPs (Approach and Tower reflected also as APP and AERODROME from an enabler point of view),
- Airspace Users,
- Airports.

3.1.2 Geographical Scope

According to the Operational Service and Environment Definition report (OSED)[13] and the Performance Assessment Report (PAR)[14] the solution is applicable to Very Large, Large and Medium airports which are capacity constrained during peak hours. The PAR assesses the achievement of the solution target at ECAC level based on the PJ19.04 common assumptions. Looking more specifically into EUROCONTROL NM arrival and departure data for August 2018 (busiest August in terms of IFR movements ever), only very large and some large airports seem to be capacity constrained during the day.

Although the approach followed remains the same as per the PAR this CBA enters in more depth considering traffic data for each single airport allowing a local assessment of the benefits if the solution is being put in place. The CBA is then conducted at ECAC level following an extrapolation of local benefits. This practically represents the effect of diluting specific locations' benefits into the network.

The extensive list of airports (local assumptions) considered for the purpose of this cost benefit analysis can be found in the Appendix 1 - List of PJ.02-01 targeted Airports of this document.

The solution is not considered to be attractive for non-capacity constrained airports therefore some very large, some large and all medium airports will be excluded from the current analysis as-from the NM data- traffic peaks leading to capacity constraints were not identified. Nevertheless, airports that are not included in the current local assumptions (i.e. not capacity constrained during August peaks) have the possibility of requesting a local CBA assessment based on the collection of relevant data and expected forecast growth.

Full set of candidate airport results per peak and per location are not disclosed for the purpose of this CBA due to sensitive data used and processed for this analysis.

3.1.3 CBA Timeline

The Solution and Reference Scenarios consider a 22-year period for the analysis of all potential costs and benefits, from 2019 to 2040. Deployment of most of the Operational Improvements of the Solution is not expected before 2023.

Any Net Present Values will be calculated back to 2019 (the end of Wave 1).

3.2 Problem addressed by the solution

The PJ.02.01 Solution addresses situations of over-demand on capacity-constrained airports related to wake turbulence separation minima, considering constraints such as weather, runway configuration, mode of operations and traffic mix, with a view to optimising traffic throughput with existing infrastructure, improving safety.

3.3 SESAR Solution description

PJ.02-01 aims to optimize wake turbulence separation minima for arrivals and departures to enhance airport runway throughput introducing the use of a separation delivery tool with a more advanced wake turbulence separation scheme to maintain the separations between aircraft pair i.e. Static Pairwise Separation. The schemes used as a reference nowadays at European airports are the standard ones i.e. ICAO or RECAT-EU.

The development of multiple customisations of separation to apply will not be manageable by the ATCO if not assisted by the system (tool) which will take into account the separations defined as a function of aircraft characteristics.

3.3.1 Arrival Concept Solution

The arrivals concepts solutions consist of Wake Turbulence Separations for Arrivals based on Static Aircraft Characteristics (AO-0306), Optimised Runway Delivery on Final Approach (AO-0328) and Weather-Dependent Reductions of Wake Turbulence Separations for Final Approach (AO-0310).

Existing ICAO wake vortex separation rules were implemented over 40 years ago and have in some respect become outdated, resulting in States introducing their own local amendments.

Today's ICAO separations are based on certified Maximum Take-Off Mass (MTOM) and it includes three categories (i.e. HEAVY, MEDIUM or LIGHT) allocating all aircraft into one of them. Arrival concept Static-Pairwise (S-PWS or PWS-A 96x96) provides a more precise definition of the minimum safe wake separation required for a pair of ICAO aircraft types.

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

To mitigate the impact on ATCO workload and human performance, and to deliver cost efficiency targets (Appendix 5 – Solution Validation Targets), ATC separation delivery support tools such as Optimised Runway Delivery (ORD) for arrival are also developed in the solution. These tools make use of Target Distance Indicators (TDIs) to enable consistent and efficient delivery of the required separation or spacing between arrival pairs on final approach up to the runway landing threshold.

Another concept for improving wake separation rules is the Weather Dependent Separations for Arrivals (WDS-A) which reduces (or even remove in some cases) the wake separation minima on final approach. This OI remains <u>out of CBA scope</u> due to limited applicability and specific wind conditions met for a very limited time in specific locations.

3.3.2 Departure Concept Solution

The departures concepts solutions consist of Wake Turbulence Separations for Departure based on Static Aircraft Characteristics (AO-0323), Optimised Separation Delivery for Departure (AO-0329) and Weather-Dependent Reductions of Wake Turbulence Separation for Departure (AO-0304).

The Optimised Separation Delivery for Departure is the controller tool support to facilitate the Tower Runway Controller to consistently and efficiently deliver to the more efficient wake turbulence separations that have been developed and are under approval by EASA through the re-categorisation programme by the RECAT-EU-PWS activities.

The Weather Dependent Reduction of Wake Turbulence Separation for Departure is the conditional reduction or suspension of the wake separation minima for departure operations, applicable under pre-defined wind conditions. 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 the initial departure path, or has decayed sufficiently to be acceptable to be encountered by the follower aircraft on the initial departure path. As for the WDS-A, this OI step remains out of CBA scope due to limited applicability of the concept.

3.3.3 Wake Risk Monitoring Concept Solution (out of CBA scope)

The Wake Risk Monitoring concept solution consists of Reduction of Wake Turbulence Risk through Wake Risk Monitoring (AO-0327).

To support the new arrival and departure concepts proposed by the solution, it includes a tool to identify wake turbulence encounters from operational aircraft data. This allows an improved monitoring of wake turbulence encounter occurrences, in particular after introduction of new wake turbulence separation rules.

This OI step will not reach V3 in SESAR2020 Wave 1.

3.3.4 Wake Decay Enhancing Concept Solution (out of CBA scope)

The Wake Decay Enhancing concept solution consists of Reduction of Wake Turbulence Risk considering the acceleration of wake vortex decay in ground proximity **(AO-0325).**

The highest risk of encountering wake vortices prevails during final approach in ground proximity, where the vortices cannot descend below the glide path but tend to rebound because of the interaction with the ground surface. This is aggravated by the fact that the possibilities of the pilot to recover from a vortex encounter are limited by the low flight altitude. A method is developed and demonstrated at an international airport that accelerates wake vortex decay in that critical height range. The installation of so-called plate lines beyond the runway tails may improve safety by reducing the number of wake vortex encounters and increase the efficiency of wake vortex advisory systems.

Wake decay enhancing devices concept (AO-0325) is not assessed in this CBA due to difficulties in benefit quantification.

More information can be found in 3.6.4 OIs out of CBA Scope (Not monetised).

3.3.5 OI Steps

For completeness, the following table provides the full list of OI Steps currently associated with PJ.02-01 (DS19). However, only AO-0306, AO-0328, AO-0323 and AO-0329 benefits have been

monetised in this version of the CBA. Further description of the benefits of the other OIs are described in the following sections.

SESAR Solution ID	OI Steps ref. (coming from the Integrated Roadmap)	OI Steps definition (coming from EATMA)
PJ.02-01 Wake Turbulence Separation Optimization	**AO-0306**	Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics
	AO-0310	Weather-dependent reductions of Wake Turbulence separations for final approach
	AO-0328	Optimised Runway Delivery on Final Approach
	AO-0323	Wake Turbulence Separations (for departures) based on Static Aircraft Characteristics
	AO-0304	Weather-dependent reductions of Wake Turbulence separations for departure
	AO-0329	Optimised Separation Delivery for Departure
	AO-0327	Reduction of Wake Turbulence Risk through Wake Risk Monitoring
	AO-0325	Reduction of Wake Turbulence Risk considering Acceleration of Wake Vortex Decay in Ground Proximity

Table 1: SESAR Solution PJ.02.01 Scope and related OI steps

The weather-dependent reduction of wake turbulence for arrival and departure (OIs AO-0304 and AO-0310) is not included in the CBA results because they provide limited benefits due to the limited applicability of the concepts; a specific part of the day during which a strong wind component is persistent for more than 30 minutes is a rare event. In addition, those weather conditions should happen at the same time when traffic peaks are experienced at the airport. The validation results have showed that there is a very limited additional benefit when WDS is deployed in addition to pairwise separations (which already reduces significantly the wake separations); while the former may be used only for a part of the day, the latter can be used during the whole day.

Reduction of Wake Turbulence Risk through Wake Risk Monitoring (AO-0327) and Reduction of Wake Turbulence Risk considering Acceleration of Wake Vortex Decay (AO-0325) concepts are also out of CBA scope due to lack in maturity for the former and difficulty to quantify safety and capacity gains out of validation results for the latter.

See Appendix 2 – Operational Improvements (OIs) out of CBA Scope for more information.

For the above mentioned OIs-out of CBA scope- costs and benefits have been described qualitatively and quantitatively in this report presenting all the available information following validation exercises and PJ.02.01 partners' information.

Description of OI Steps (as extracted from EATMA v.13 DS19)

AO-0304 Weather-Dependent Reductions of Wake Turbulence Separations for Departures

Optimization of the ICAO wake turbulence separation by use of weather-dependent separation (WDS) minima on departures for the initial common departure path from the runway, applicable under given wind conditions. This allows conditional reduction or suspension of separation minima for most aircraft pairs, enabling runway throughput increase compared to ICAO scheme, whilst maintaining acceptable levels of safety.

AO-0306 Wake Turbulence Separations (for Arrivals) based on Static Aircraft Characteristics

Optimization of the ICAO wake turbulence separation classes by use of longitudinal wake turbulence static pair-wise separation (S-PWS) minima on arrivals, applicable in all operating conditions. The specification is based on the comparison of wake generation and wake resistance between aircraft types, using aircraft type characteristics, to align on reference pairs considered as acceptable baseline. This allows reduction of separation minima for most aircraft pairs, enabling runway throughput increase compared to ICAO scheme, whilst maintaining acceptable levels of safety.

AO-0310 Weather-Dependent Reductions of Wake Turbulence Separations for Final Approach

Optimization of the ICAO wake turbulence separation by use of weather-dependent separation (WDS) minima on arrivals, applicable under given wind conditions. This allows conditional reduction or suspension of separation minima for most aircraft pairs, enabling runway throughput increase compared to ICAO scheme, whilst maintaining acceptable levels of safety.

AO-0323 Wake Turbulence Separations (for Departures) based on Static Aircraft Characteristics

Optimization of the ICAO wake turbulence separation classes by use of longitudinal wake turbulence static pair-wise separation (S-PWS) minima on departures for the initial common departure path from the runway, applicable in all operating conditions. The specification is based on the comparison of wake generation and wake resistance between aircraft types, to reference pairs considered as acceptable baseline for wake turbulence risk, and using aircraft type characteristics. This allows reduction of separation minima for most aircraft pairs, enabling runway throughput increase compared to ICAO scheme, whilst maintaining acceptable levels of safety.

AO-0328 Optimised Runway Delivery on Final Approach

The ATCO is able to efficiently deliver any separation (defined in time or distance) down to runway threshold, supported by the System which provides the following input:

1) the relevant separation to apply as a function of expected ROT, wake separation, aircraft type, approach procedures in place.

2) the required information for anticipating compression of separation buffers during the final approach phase (considering aircraft expected or measured performance [true air speed of leader and follower] and the glide slope wind conditions).

A better anticipation of the compression will allow for reducing buffer applied by ATCO on the glide and consequently increase the runway throughput.

AO-0329 Optimised Separation Delivery for Departure

"The ATCO is able to efficiently deliver airborne separation (defined in time or distance) after departure, supported by the System which provides the following information:

1) the relevant separation to apply as a function of expected rolling time, wake separation, aircraft type, departure procedures in place (SID)

2) the required information for anticipating catch-up of separation during initial climb phase. The system will consider aircraft expected or measured performance (true air speed of leader and follower) and wind conditions."

AO-0325 Reduction of Wake Turbulence Risk considering Acceleration of Wake Vortex Decay in Ground Proximity

Thanks to acceleration of wake vortex decay in ground proximity (e.g. with decay enhancing devices), the risk for a follower aircraft to a wake encounter generated by the lead aircraft is decreased. This may allow an increase in safety and may increase potential capacity gains of wake turbulence advisory systems (RECAT2 or WDS).

AO-0327 Reduction of Wake Turbulence Risk through Wake Risk Monitoring

In the cockpit, detection of wake encounters using on-board data and traffic positions broadcast by surrounding aircraft will increase safety by allowing to objectively characterise wake turbulence risk as a function of e.g. location, traffic mix or separation rules. Additional detection of wake turbulence using direct measurements from the ground (RADAR and/or LiDAR) may improve the monitoring at critical locations at ground level. This will provide additional objective information for monitoring of suitability of separations.

3.3.6 Enablers

The following table provides the full list of required Enablers currently associated with PJ.02-01 (DS19). However, only AO-0306, AO-0328, AO-0323 and AO-0329 required enablers' related costs have been monetised in the CBA. Further description of the costs of the other OIs are described in the following sections.

Enabler ref.[6]	Enabler definition	Applicable stakeholders	Comments on the Enabler / definition
AO-0306 [ARR] – Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics			
AERODROME-ATC-42a	Airport ATC Runway Usage Management sub-system enhanced for processing static wake-turbulence information	ANSPs [TMA] (Industry if not developed in house)	
APP ATC 118	ATC System to support static pair-wise wake separation (S-PWS) on approach	ANSPs[APP] (Industry if not developed in house)	
REG-0523	**Regulatory provisions (AMC) for static pair-wise wake separation minima (S-PWS)**	ANSP, AOs, AUs	
AO-0310 [ARR] – Weather-dependent reductions of Wake Turbulence Separations for final approach			
APP ATC 74	ATC System Support for Reduced, Weather-Dependent Separation Standards in Final Approach	ANSPs	
APP ATC 99	ATC System to use Real-Time Meteo Information Received From Met Systems	ANSPs	
REG-0522	Regulatory provisions for weather-dependent separation minima (WDS)	ANSP, AOs, AUs	
AO-0328 [ARR] – Optimised Runway Delivery on Final Approach			
AERODROME-ATC-68	ATC system to support optimised runway delivery on final approach	ANSPs [TMA]	
APP ATC 120	ATC system to support optimised runway delivery on final approach	ANSPs [APP]	
APP ATC 99	ATC System to use Real-Time Meteo Information Received From Met Systems	ANSPs, MET Office	
STD-093	EUROCONTROL Guidelines for Optimised Runway Delivery	ANSP, AOs, AUs	
AO-0323 [DEP] - Wake Turbulence Separations (for departures) based on Static Aircraft Characteristics			

[6] This includes System, Procedural, Human, Standardisation and Regulation Enablers

AERODROME-ATC-42b	Airport ATC tool to support static pair-wise wake separation (S-PWS) for departure operations	ANSPs [TMA] (Industry if not developed in house)	
REG-0523	Regulatory provisions (AMC) for static pair-wise wake separation minima (S-PWS)	ANSP, AOs, AUs	
AO-0304 [DEP] - Weather-dependent reductions of Wake Turbulence Separations for Departure			
AERODROME-ATC-19	Runway Usage Management sub-system capable of processing initial departure path wind conditions information		
REG-0522	Regulatory provisions for weather-dependent separation minima (WDS)		
AO-0329 [DEP] - Optimised Separation Delivery for Departure			
AERODROME-ATC-69 (R)	ATC system to support optimised departure separation	ANSPs [TMA] (Industry if not developed in house)	
AO-0327 [ARR/DEP] - Reduction of Wake Turbulence Risk through Wake Risk Monitoring			
A/C-30c	On-board detection of wake turbulences encounters	Flight Crew, Airlines, ANSP, ATCO, Aircraft Manufacturer, Regulator	This is the main Enabler of the OI Step, representing a detection of wake turbulence encounters by a ground-based tool analysing data collected on board the aircraft.
A/C-48a	Air broadcast of aircraft position/vector (ADS-B OUT) compliant with DO260B	Airlines	This Enabler is already mandated for introduction in the aircraft fleet and needs no further development.
AO-0325 [ARR] - Reduction of Wake Turbulence Risk considering Acceleration of Wake Vortex Decay in Ground Proximity			
AIRPORT-08	Decay Enhancing Devices	Airlines, Air Navigation Service Providers (ANSP), Airport Operators, Flight Crews, Authorities	Plate lines installed in front of the runway accelerate the decay of wake vortices near the ground and reduce the risk of wake encounters for subsequent approaches

Table 2: OI steps and related Enablers

3.4 Objectives of the CBA

The objective of the V3 CBA is to provide a consolidated assessment of the costs and benefits of deploying Solution PJ.02-01 in the airports that have been identified in the deployment scenario approach (see section 3.1.2).

This CBA will assess whether the benefits of the deployed Solution are expected to exceed the costs over the CBA time horizon. The V3 CBA includes all the evidence gathered in terms of impacts, benefits and costs of the solution. The output is the NPV overall, per concept (arrivals and departures) and per stakeholder group, sensitivity and risk analysis, CBA model report and recommendations.

The CBA aims also to capture the breakeven year (payback time) i.e. the year when benefits will start compensating for the costs incurred.

Airport capacity, flight efficiency, time savings and predictability benefits have been monetised in the CBA for ANSPs, Airspace Users and Airports, in full alignment with the Benefit Impact Mechanisms described in the OSED [13]. It was not possible to assess or monetise other potential benefits for other stakeholders (e.g. indirect benefit for NM) due to lack of evidence.

This V3 Cost Benefit Analysis will help in building an assessment of whether the PJ.02-01 Solution is worth deploying from an economic perspective for the involved stakeholders. It should also help in adjusting the deployment scenario approach and find the best option in terms of OIs/ENs implementation. To this aim, this V3 CBA provides high confidence results of expected benefits and costs for the stakeholders. The CBA results are intended to support the decision to move to deployment. To this aim the implementation of the two different concepts of PJ-02.01 solution (i.e. Arrivals and Departures) for different airports have been analysed separately to reflect a realistic implementation approach for the locations identified as candidate of each solution concept.

3.5 Stakeholders identification

Stakeholder	The type of stakeholder and/or applicable sub-OE	Type of Impact	Involvement in the CBA task	Quantitative results available in the current CBA version
ANSPs	ATCOs, TMA and Tower control Centres	Invest in the separation delivery tool development and the pairwise separation feature, operate and enjoy benefits from increase in runway throughput	NATS involved/ providing cost inputs for departures and reviewing cost items for arrivals/conducted real time simulation exercise for LHR (RTS5)	Costs and monetised benefits both available in this CBA

Airport Operators	**Very Large and Large Airports**	**Operate and enjoy benefits i.e. increase in runway throughput. Airports are not considered to pay for the PJ.02.01 investments since it has been assumed that systems and relevant upgrades in the airport are owned and paid by ANSPs**	**No involvement**	**Benefits monetised available in this CBA**
Network Manager	**En-Route ANS**	**Support operations**	**No involvement**	**Neither costs nor benefits monetised directly/Indirect impact**
Scheduled Airlines (Mainline and Regional)	**Flight Crew, Schedule Planner, Safety and Training Department**	**Operate and enjoy benefits from time efficiency, fuel efficiency and predictability**	**No involvement**	**Benefits monetised available in this CBA**
Regulation Authority	NSA/Ministry of Transport	**Approve new operations**	**No involvement**	**No costs for regulatory authorities. Costs for REG drafting taken into account on the ANSP costs.**
Weather Forecast service provider	MET Office (internal or external to the ANSP)	**Support Operations**	**No involvement**	**Not applicable because weather dependent separations out of CBA scope/very limited benefits for very limited applicability for a specific time of the day when strong crosswind component is persistent for more than 30 minutes**

Table 3: SESAR Solution PJ.02.01 CBA Stakeholders and impacts

3.6 CBA Scenarios and Assumptions

This section describes the scenarios that are compared in the CBA. The aim is to reflect the delta (difference) between the Reference scenario (where the Solution is not deployed - the orange box in Figure 1) and the Solution scenario (reflecting the proposed deployment of the Solution at applicable locations across ECAC - the green box in Figure 1).

Both scenarios encompass the same period of analysis, from 2019 to 2040.

The CBA uses a delta approach, i.e. the Solution Scenario identifies all the additional elements that will have to be put in place on top of what is assumed to be deployed in the Reference Scenario.

The role of SESAR R&D in this area is to demonstrate that tangible benefits can be obtained from implementing SESAR Solutions. Assumptions were made in this V3 maturity phase towards PJ.02-01 potential options in terms of deployment scenario and candidate Airports (with criteria) where PJ.02-01 Solution team identified OIs and ENs that could potentially bring benefits. However due to the expected update of PCP Regulation by 2024, the assumptions may need to be reviewed after that.

The PJ.02-01 Operational Improvements are not applicable everywhere. To answer the need for a scalable Solution, a common approach to PJ.02-01 was used to define a set of deployment assumptions and to identify the airports where the solution could be applicable and having the potential to bring benefits.

Defining the Reference Scenario has proven to be very challenging because of the assumptions that need to be made regarding the 'ongoing deployments' (blue arrow in Figure 1). To avoid being blocked by this issue this V3 CBA is currently based more on the difference between the current situation (2019) and the Solution Scenario; this is reflected in the following scenario descriptions.

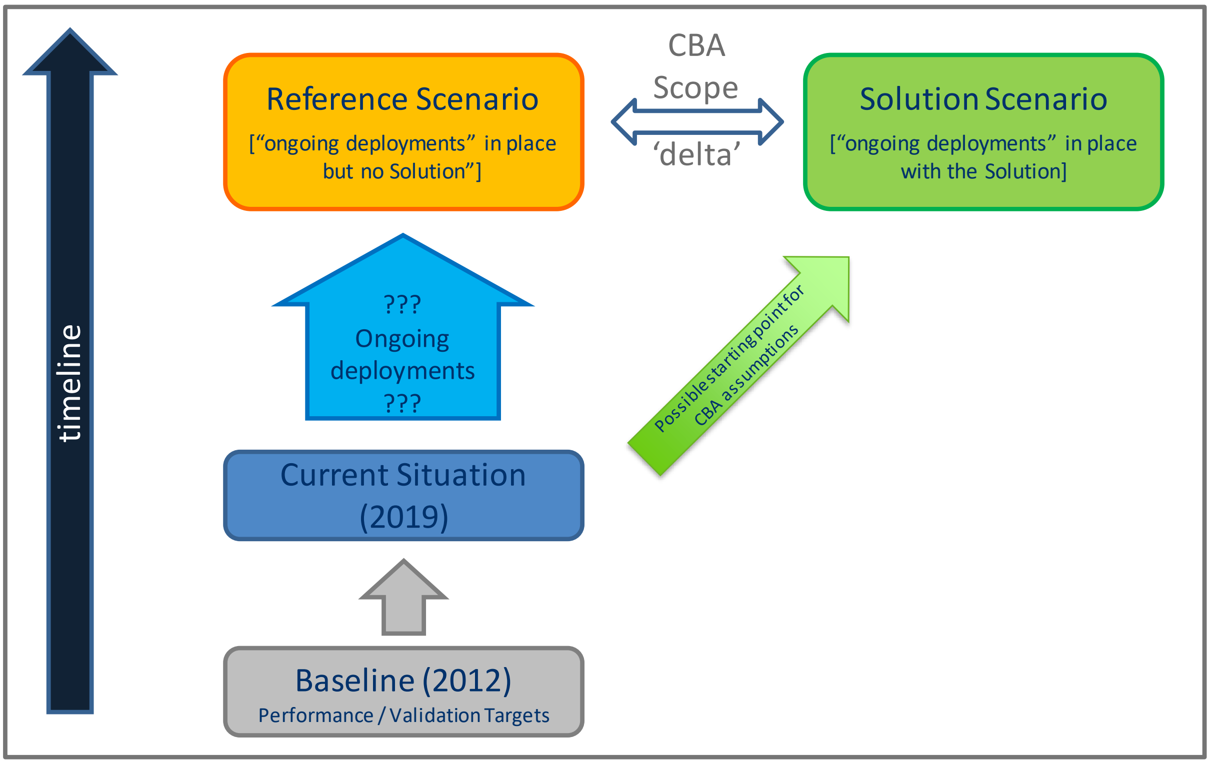

Figure 1: Scenario Overview

3.6.1 CBA Reference Scenario

The Reference Scenario is the scenario without implementing the S2020 PJ.02-01 Solution and correspond to today's situation (without the solution) and it is assumed that the situation does not change significantly during the CBA scope.

PJ.02.01 solution is focused on wake turbulence separation reductions. Currently two wake separation turbulence schemes are in place across European airports

- ICAO (3 categories +A380)
- RECAT-EU (6 categories)

With regards to the list of Large and Very Large airports, relevant to this CBA, RECAT-EU is deployed only in two airports for arrivals (Charles de Gaulle and London Heathrow) and for departures only at Heathrow airport. For these two airports RECAT-EU is considered as the reference scenario and the relevant benefits are compared against this baseline.

For the remaining airports reference scenario is considered to be the current operational environment which is ICAO (3 categories +A380) separation scheme.

Wake turbulence scheme choice should not be necessarily followed by a change in Minimum Radar Separation. There are airports operating in 2.5 NM MRS but still using ICAO.

3.6.2 CBA Solution Scenario

PJ.02-01 Solution aims to optimize wake turbulence separation minima for arrivals and departures to enhance airport runway throughput. The Solution scenario is developed based on these two operational concepts i.e. arrivals and departures. Each solution concept consists of Wake Turbulence Separations based on Static Aircraft Characteristics (PWS-A/PWS-D) together with a separation management supporting tool (ORD-OSD).

For Departure scenario, Real Time Simulation (RTS5) Heathrow local results have been used for the combined OSD+PWS-D 20-CAT scenario while for the rest of the airports, Fast Time Simulation (FTS) results on the basis of ICAO versus RECAT-PWS 7 CAT have been used.

It is important to note that RTS5 was departure concept solution only and the results used for the CBA concern the time based scenario TB PWS-D (96x96 Pairwise Matrix + 20-CAT Matrix) with OSD tool support (TB PWS-D+OSD)

The solution scenarios are described and summarised below:

- **The arrival concept solution scenario which consists of an Optimised Runway Delivery on Final Approach (AO-0328) and Wake Turbulence Separations for Arrivals based on Static Aircraft Characteristics (AO-0306) [ORD+ PWS-A] – see Table 4 and,**
- **The departure concept solution scenario which consists of an Optimised Separation Delivery for Departure (AO-0329) standalone scenario and an additional combined one with Wake Turbulence Separations for Departure based on Static Aircraft Characteristics (AO-0323) [OSD+ PWS-D] – see Table 5.**

Scenario Summary Tables

Reference Scenario	Solution Scenario
Arrivals	
CDG → RECAT-EU DBS HEATHROW → RECAT-EU TBS Other airports → ICAO DBS *(3 categories +A380)*	ORD+PWS-A (TBS with 0 wind)

Table 4: CBA Scenario Summary: Arrivals

Reference Scenario	Solution Scenario
Departures	
HEATHROW → RECAT-EU TBS without tool Other airports → ICAO TBS without tool	OSD+PWS-D (RECAT-PWS TBS 96X96 7CAT for all airports/ RECAT-PWS TBS 96X96 7CAT for Heathrow)

Table 5: CBA Scenario Summary: Departures

The table below lists the key dates used in the CBA and Figure 2 shows them over a timeline.

Dates	PJ.02-01
Start of deployment date: the start of investments for the first deployment location	**2021**
End of deployment date: the end of the investments for the final deployment location	**2028 (Same as FOC)**
Initial Operating Capability (IOC): the time when the first benefits occur following the *minimum deployment* necessary to provide them. Costs continue after this date as further deployment occurs at other locations.	**2024**
Final Operating Capability (FOC): Maximum benefits from the *full deployment*[7] of the Solution at applicable locations. Investment costs are considered to end[8] here although any operating cost impacts would continue.	**2028**

Table 6: CBA Investment and Benefit Dates

[7] Where ***full deployment*** means deploying the Solution in the all the locations where it makes sense to deploy it (i.e. it does not mean it has to be deployed everywhere)
[8] The basic assumption is that infrastructure does not need to be replaced during the CBA period

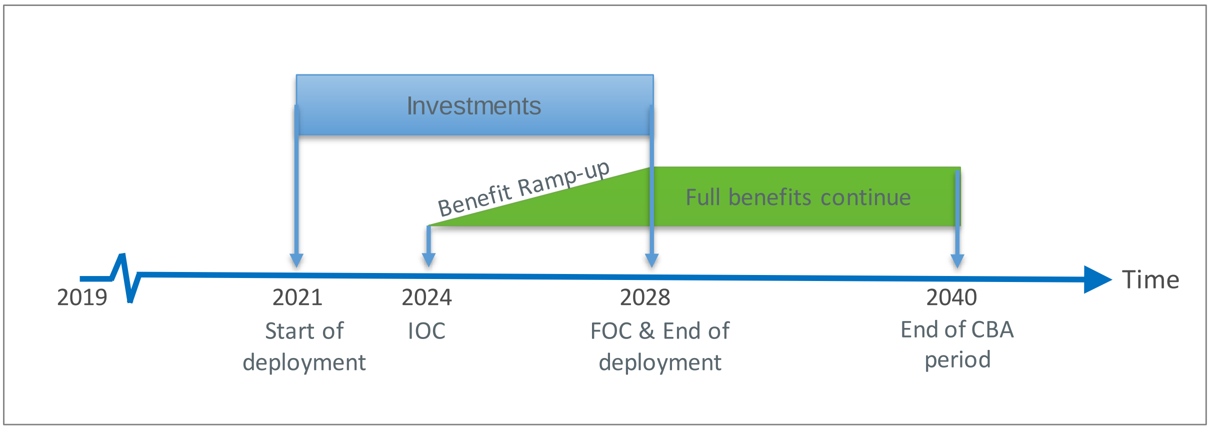

Figure 2: Overview of CBA Dates

Figure 2 shows that:

- **Investment costs are spread linearly between the Start and End of Deployment dates.**
- **Benefits ramp-up linearly between IOC and FOC and then continue up to the end of the CBA period.**
- **Operating cost impacts (increases or decreases) would also start at IOC and ramp-up linearly to FOC before continuing for the rest of the CBA duration.**

In line with PJ.19-04 guidance, the CBA model calculates the cash flows up to 2040 and then discounts the values back to 2019[9] to calculate the Net Present Value. The discount rate of 8% is used for all stakeholders.

3.6.3 Assumptions

Deployment Locations considered in the PJ.02.01 CBA correspond to Very Large and Large airports, in line with SESAR 2020 Airports' Classification Scheme (Airports' Group in 2018 according to SESAR 2020 Airports' Classification Scheme - PJ20 latest updated list – March 2019). For the extensive list please see Appendix 1 - List of PJ.02-01 targeted Airports.

Scenario feature	Year 2018	Year 2019	Year 2040	Source
ECAC traffic (M # flights) in line with [9]	11.4	14.0	19.5	STATFOR Long/Medium Term forecasts (2018)[21]
Equipage rate	N/A – no airborne equipage required for PJ.02-01			

[9] as specified in the PJ19.04 Common Assumptions [9]

Applicability: Number of locations where Solution is deployed (Number of airports)		Deployment location values are provided in the cost assessment section	PJ.02-01 Deployment Scenario based on PJ20 airport dataset
Impacted traffic, i.e. experiencing the benefits from the Solution(s)	'000 # IFR flights per year	Scheduled Airline traffic (≈89% of ECAC traffic) is considered for the Airspace User benefits	ECAC traffic above
	'000 # IFR flight hours per year	No benefits are based on flight hours	

Table 7: SESAR Solution PJ.02.01 CBA Solution Scenario

Costs and benefits have been computed using inputs from real-time (RTS5) and fast-time (FTS9) validation exercise results, partners' contribution and using average values taken from the PJ.19.04 Common Assumptions for further extrapolation at ECAC Level.

As it is not feasible to exactly identify ANSP costs for each airport separately, these have been estimated assuming that they would be of same order of implying that all targeted airports will support the same kind of costs.

Benefits taken into account have been estimated per airport and followed by an extrapolation at ECAC level.

3.6.4 OIs out of CBA Scope (Not monetised)

Weather Dependent Separation OIs

Weather Dependent Separation OIs (AO-0310 WDS-A and AO-0304 WDS-D) both for arrivals and departures were decided to be excluded from CBA scope because they provide limited benefits due to the limited applicability of the concepts; a specific part of the day during which a strong crosswind component is persistent for more than 30 minutes is rare and those weather conditions should happen at the same time when traffic peaks are experienced at the airport.

Wake Risk Monitoring

Benefit mechanisms have been identified for the Wake Risk Monitoring concept solution and are formalized in the Benefits and Impacts Mechanisms included in the OSED. Benefits are primarily related to Human Performance through the automation of processes formerly executed manually, and the improvement of the accuracy of the information available. However, a quantifiable benefit is not yet available for this concept solution.

Cost drivers have also been identified for this concept, but cannot be quantified yet for the V3 phase of the concept due to lack in maturity.

Wake Decay Enhancing Devices

Wake decay enhancing devices concept (AO-0325) is not assessed in this CBA due to difficulties in benefit quantification. Evidence from the Vienna airport validation exercise (LT10) shows that there is a reduction of long-lived vortices lifetime by 30%. The safety and capacity gains that can be achieved from these reductions will be quantified in the next project (VLD3). Therefore it was decided to present the identified costs and benefits qualitatively in the current CBA.

More information can be found in Appendix 2 – Operational Improvements (OIs) out of CBA Scope

4 Benefits

The benefits monetised in this CBA are related to Capacity, Predictability, Fuel and Time Efficiency for both arrivals and departures.

The CBA uses for arrivals the same fast time simulation platform that has been used to run the FTS9 exercise adapted in local conditions and local traffic mix. The FTS9 exercises assessed all the required KPIs according to SESAR Guidelines for different OIs in several scenarios (e.g. in different wind conditions). The analysis however has been performed with a limited number of traffic mix profiles. The CBA results are obtained using specific traffic mix for each local airport, considering a no-wind scenario only. A trade-off had to be made between the large amount of workload needed to prepare and run the platform and the resources available.

Real time simulation results have been considered only for London Heathrow airport (RTS5). To further characterize the CBA, a new traffic mix has been assessed looking in details at data from NM for all very large and large airports, for August 2018.

In particular for each airport the traffic peaks and related traffic mix have been identified in order to characterize better the benefits; PJ.02.01 OIs for Arrivals and Departures provide benefits when the runways are constrained at the airport. As results, out of the 30 airports only 12 are currently experiencing runway capacity constraints; out of these, 2 have been eliminated since they are operating Minimum Radar Separation (MRS) at 5NM and therefore they were considered as non-candidate airports. Istanbul Ataturk has also been eliminated from this analysis following the moving of operations in to the New Istanbul airport. Since New Istanbul airport had not started operations in August 2018, there is no traffic data for it.

While in the Performance Assessment Report (PAR)[14], results were obtained assuming specific traffic mix and traffic peaks of 1-2 hours, in reality airports experience different traffic peaks during the day and of different length. This has an impact when quantifying the benefit obtained, for example an airport can have 4.5% increase in runway throughput compared to 0.8% of a different one.

The source for the benefit calculation inputs is a combination of Performance Assessment Results from the PJ.02-01 PAR and separate calculations using inputs from FTS9.

Consequently, benefit results for each airport are very local. In the CBA each KPI is assessed at ECAC level. Therefore an average is used for quantifying the overall benefit for all the airports impacted currently which is then scaled at ECAC Level.

This way a better estimate of the current situation was provided compared to the PAR results where a range of results was used.

4.1 Benefit and Impact Mechanism

The benefit and impacts mechanism shown in Figures 3 and 4 are cause-effect description of the improvement proposed by the project. They show how benefits are delivered.

4.1.1 Benefit Description-Arrivals

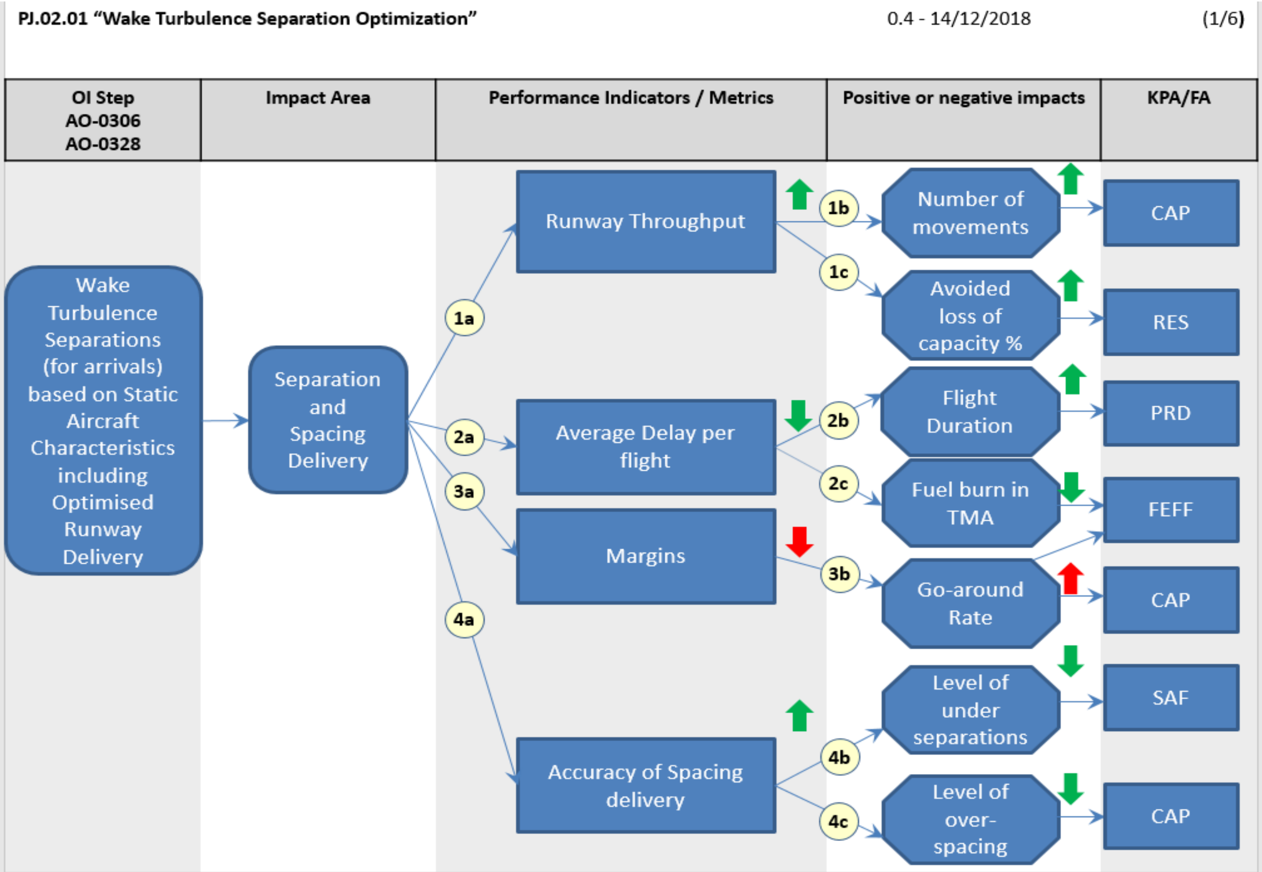

Figure 3: Benefit Mechanism (Arrival) from BIM [13]

The use of PWS-A (AO-0306) is expected to reduce wake separation between arrivals. The use of ORD (AO-0328) impacts the separation and spacing delivery between arrivals. The resulting optimised separation and spacing delivery increases the runway throughput, leading to a positive impact on Capacity.

Reduction of separations and spacing will reduce the average delay per flight and consequently the variance between the flight duration and its planned duration (without delays). This has a positive impact on Predictability.

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 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 Safety (not monetised) and Capacity.

Benefits have been calculated based on results of Fast Time (FTS9) and Real Time Simulation (RTS5).

FTS9 has been an enabler for CBA in order to assess ORD with PWS-A and OSD with PWS-D single Runway (RWY) in segregated mode.

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 is driven by the ORD (AO-0328) and that the effect of PWS-A (AO-0306) and WDS-A (AO-0310) is negligible compared to ORD (AO-0328).

Also the majority of airports use segregated mode for the runways, because mixed mode is more complex to operate and because they are not constrained by the number of runways (e.g. at least 2 are available in the majority of airports).

Once the benefits were identified and validation results became available extrapolation was applied producing results from local (validation exercise environment) to global (ECAC level) as required by the Performance Assessment and their further monetization. The unit for all benefits is euros.

The increase of arrival capacity is directly proportional to the proportion of wake-constrained pairs during peak hours on segregated arrival runway(s).

Capacity benefits for the Very Large and Large airports are calculated based on a combination of advanced processing of surveillance data and the results of the fast time simulations (FTS). It compares current operations (i.e. applying reference separation scheme (ICAO PANS-ATM 4 category scheme (3 categories + A380)) or RECAT-EU 6 Category scheme) to what could be achieved if applied the solution scheme (i.e. RECAT-EU-PWS defined wake minima for 96x96 aircraft pairs) and accounts for

- the observed traffic mix
- the observed traffic pressure (i.e. assuming that full benefits of the solution are only obtained if the traffic pressure is above 80% of the theoretical capacity when applying reference scheme)
- number of peaks during the day
- number of movements during each peak
- duration of the peak
- minimum radar separation (MRS)
- configuration of the runways

Loss in capacity avoided has been assumed to directly relate to the increase in throughput from each of the OI steps. It would be up to individual airports to decide whether to use the increase in throughput to increase airport capacity (schedule extra movements) or improve resilience (not schedule extra movements).

For airports with a declared maximum capacity that cannot benefit from any increase in runway and airport throughput, the benefits can be translated instead into reduction of flying time. For the purpose of this analysis the capacity benefits are shared between increase in airport capacity for the airport and reduction in flying time for the airspace users assuming that all these congested airports will not be able to allocate all the increase in airport capacity that the solution brings.

4.1.2 Benefit Description-Departures

PJ.02.01 "Wake Turbulence Separation Optimization" Final- 31/01/2020 (1/6)

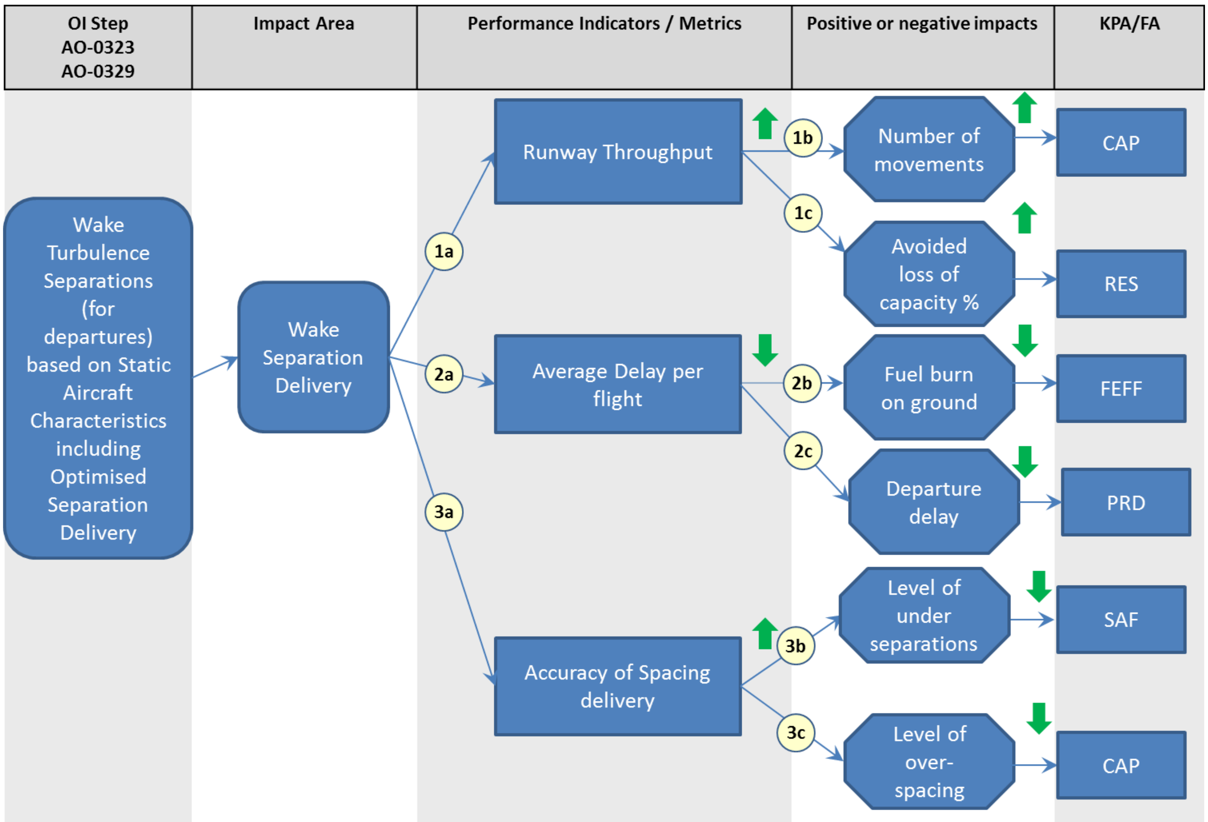

Figure 4: Benefit Mechanism (Departure) from BIM [13]

On the departure side, the use of PWS-D (AO-0323) is expected to reduce wake separation between departure aircraft. OSD (AO-0329) is expected to optimise the accuracy of the spacing delivered between departure aircraft. The reduced wake separations and optimised spacing delivery increases the runway throughput.

PWS-D reduces wake separation and OSD Optimised spacing delivery accuracy between departure aircraft has a positive impact on the runway throughput. The higher the departure aircraft throughput, the higher the number of departure aircraft movements, leading to a positive impact on Capacity.

The use of PWS-D reducing the wake departure aircraft separations will reduce the average ground delay per flight which leads to a reduced fuel burn on the ground. This has a positive impact on Fuel Efficiency.

This will also result in less variability between the planned and actual departure time and departures flying closer to their planned time will improve on-time operations. This has a positive impact on Predictability.

With the OSD system support, the accuracy of the spacing delivered between departure aircraft can be improved compared to what is achieved today.

Improved spacing delivery accuracy with the OSD system support can enable the improved separation delivery to the PWS-D rules, reducing the level of 'under separation delivery' compared to what is achieved today, thus enabling a safe reduction in the overall amount of wake separation that is required to be delivered, which links to Safety (not monetised) but also efficient reduction of the overall amount of wake separation that is required to be delivered, which links to Capacity (monetised).

For the departures the same analysis on traffic peak based on NM data is performed, to be noted that the traffic peaks for departures are different from arrivals and impacting a different number of airports (due to different layout, operations mode, …)

The increase of departure capacity for all the airports is directly proportional to the proportion of wake-constrained pairs on segregated departure runway(s).

Capacity benefits for the Very Large and Large airports are calculated based on advanced processing of surveillance data comparing current operations (i.e. applying reference separation scheme (ICAO PANS-ATM 4 category scheme (3 categories + A380))) to what could be achieved if applied the solution scheme (i.e. RECAT-EU 7 Category scheme). It accounts for:

- the observed traffic mix (also accounting for some possible optimization of the sequence to reduce separations)
- the observed traffic pressure (i.e. assuming that full benefits of the solution are only obtained if the traffic pressure is above 80% of the theoretical capacity when applying reference scheme)
- the minimum runway separation (MRS)
- the configuration of the runways

The configuration chosen for the purpose of the analysis may not correspond totally in the configuration used during the whole day by each airport but they are the most likely to be used by these airports according to available EUROCONTROL information; therefore assumptions on the preferred configuration have been made.

4.2 Benefit Monetisation Mechanism

4.2.1 Airport Capacity (CAP3)

CAP3 (ARR) Peak Runway Throughput	+0.11% (ECAC level)
CAP3 (DEP) Peak Runway Throughput	+0.16% (ECAC level)

Table 8: Airport Capacity Result

CAP 3 has been quantified taking into account the sum of additional number of movements for each peak is then compared to the sum of movements for each peak. The value is then divided by 2 as for each new movement is considered that half of the spacing saved is used to reduce delay and half to increase the capacity. This has been an assumption taken by the project team for all the airports since it would be quite impossible to predict each individual's airport decision. Taking into account that the current system is rather balanced between delays and capacity, a balanced 50% decision was taken for the distribution of capacity benefits.
ECAC level, benefits scaled by total number of movements for 9 airports for the arrivals and 14 airports for the departures, then divided by number of movements for all ECAC area.
For LHR (departures) results from RTS5 are used.

These values have been further monetised in terms of additional flights that can be operated per year at airports which are otherwise congested, multiplied by the reference values provided in EUROCONTROL Standard Inputs. This gives the economic value of additional airport capacity.

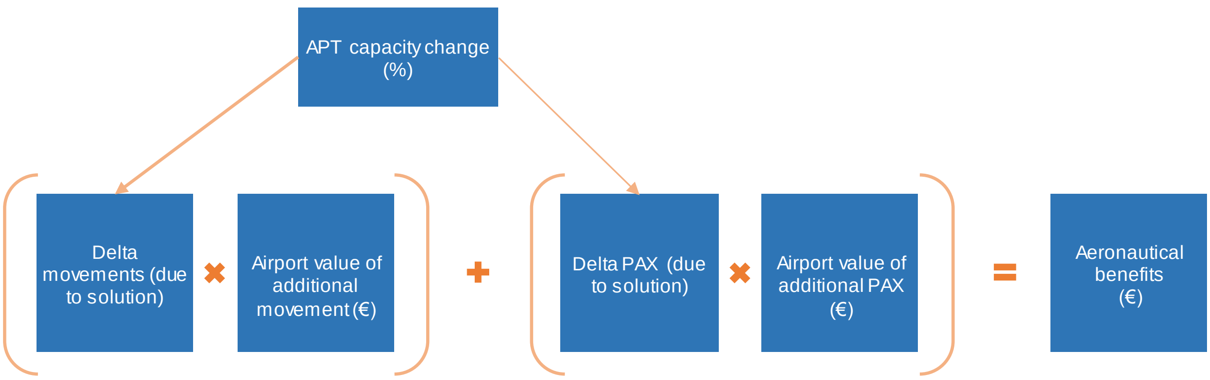

Figure 5: Airport Capacity Monetisation Mechanisms

4.2.2 Fuel Efficiency (FEFF1)

FEFF1 (ARR): Fuel Efficiency – Fuel burn per flight	-0.4 kg/flight (positive impact)
FEFF1 (DEP) Fuel Efficiency – Fuel burn per flight	-0.7 kg/flight (positive impact)

Table 9: Fuel Efficiency Result

The figure below shows the monetisation mechanisms used in the CBA model. The calculation is made in each year so the values includes the evolution of the number of flights and fuel price over the CBA period. The model automatically calculates the change in CO2 costs when there is a change in fuel burn.

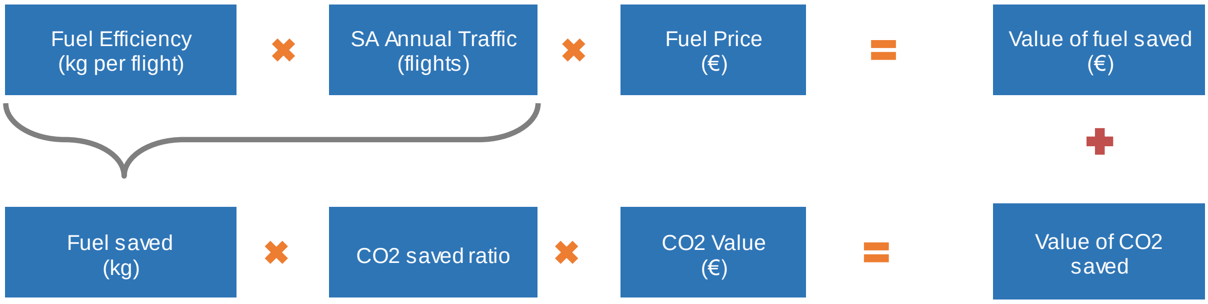

Figure 6: Fuel Efficiency and CO2 Monetisation Mechanisms

4.2.3 Predictability (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 as the difference in standard deviation for length of run when comparing solution scenarios to baseline. The value used for the predictability benefit in the CBA is in line with what has been quantified in the PAR, was then scaled by total number of movements for all airports and further extrapolated to ECAC.

PRD1 (ARR) Variance of Difference in actual & Flight Plan or RBT durations	2.9%
PRD1 (DEP) Variance of Difference in actual & Flight Plan or RBT durations	0.49%

Table 10: Predictability Result

These values have been further monetised through avoidance of strategic delay which is padded into airline schedules to recover from poor predictability. Reference values provided in EUROCONTROL Standard Inputs.

The improvements with SESAR can be calculated via their impact on the duration of the strategic buffer. When the variability in flight time reduces, the estimated buffer in order to achieve a given %, flights arriving on time will also reduce, using a normal distribution.

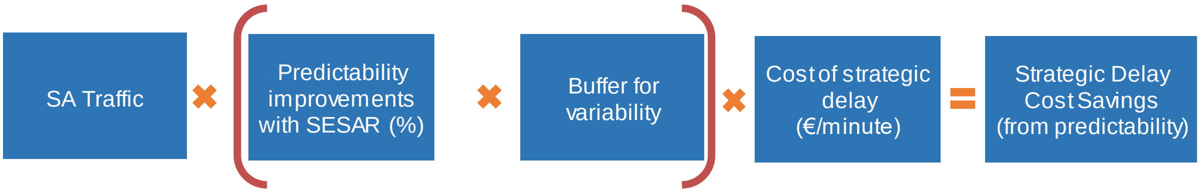

Figure 7: Predictability Monetisation Mechanisms

4.2.4 Time Efficiency (FEFF3)

Time savings are calculated as the average flying time saved in TMA (minutes /flight) for each aircraft in peak when the two arrival concept OIs are applied. The value is then divided by 2 as for each new movement is considered that half of the time saved is used to reduce delay and half to increase the capacity.

For departures the time savings correspond to the average time saved (minutes /flight) in the taxi-out phase for each aircraft in peak when two departure concept OIs are applied. As the FTS was not assessing the ground movements for LHR, RTS5 results have been used for this airport. are used for this airport and for the other airports a similar result is used.
Benefits have then been scaled by total number of movements for all airports and then divided by number of movements for all ECAC area.

FEFF3 (ARR) Reduction in average flight duration	0.3% (reduction in flying time in TMA)
FEFF3 (DEP) Reduction in average flight duration	0.7% (reduction in taxi out time)

Table 11: Time Efficiency Result

Figure 8: Time Efficiency Monetisation Mechanism

4.3 Benefit Monetisation of the Performance Framework KPI/PI

Performance Framework KPA[10]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Total benefits from IOC to 2040
Cost Efficiency	ANS Cost efficiency	**CEF2** Flights per ATCO-Hour on duty	Nb	ATCO employment Cost change	€/year	No Validation Target
				Support Staff Employment Cost Change	€/year	No Validation Target
				Non-staff Operating Costs Change	€/year	No Validation Target
		CEF3 Technology cost per flight	EUR / flight	G2G ANS cost changes related to technology and equipment	€/year	No Validation Target
	Airspace User Cost efficiency	**AUC3** Direct operating costs for an airspace user	EUR / flight	Impact on direct costs related to the aeroplane and passengers. Examples: fuel, staff expenses, passenger service costs, maintenance and repairs, navigation charges, strategic delay, landing fees, catering	€/year	No Validation Target

[10] For information, the mapping to the Performance Ambition KPAs (used in the ATM Master Plan) is available in the Appendix 1 - List of PJ.02-01 targeted Airports

Performance Framework KPA[10]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Total benefits from IOC to 2040
		AUC4 Indirect operating costs for an airspace user	EUR / flight	Impact on operating costs that don't relate to a specific flight. Examples: parking charges, crew and cabin salary, handling prices at Base Stations	€/year	No Validation Target
		AUC5 Overhead costs for an airspace user	EUR / flight	Impact on overhead costs. Examples: dispatchers, training, IT infrastructure, sales.	€/year	No Validation Target
Capacity	Airspace capacity	**CAP1** TMA throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	No validation target€
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	No Validation Target
		CAP2 En-route throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	No Validation Target
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	No Validation Target
	Airport capacity	**CAP3** Peak Runway Throughput	% and # movements	Value of additional flights	€	272 M€
	Resilience	**RES4a** Minutes of delays	Minutes	Tactical delay cost (avoided-; additional +)	€/year	No Validation Target

Performance Framework KPA[10]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Total benefits from IOC to 2040
		RES4b Cancellations	% and # movements	Cost of cancellations	€/year	No Validation Target
		Diversions	% and # movements	Cost of diversions	€/year	No Validation Target
Predictability and punctuality	Predictability	**PRD1** Variance of Difference in actual & Flight Plan or RBT durations	Minutes^2	Strategic delay cost (avoided-; additional +)	€	752 M€
	Punctuality	**PUN1** % Departures < +/- 3 mins vs. schedule due to ATM causes	% (and # movements)	Tactical delay cost (avoided-; additional +)	€/year	No Validation Target
Flexibility	ATM System & Airport ability to respond to changes in planned flights and mission	**FLX1** Average delay for scheduled civil/military flights with change request and non-scheduled / late flight plan request	Minutes	Tactical delay cost (avoided-; additional +)	€/year	No Validation Target No Validation Target
Environment	Time Efficiency	**FEFF3** Reduction in average flight duration	% and minutes	Strategic delay: airborne: direct cost to an airline <u>excl. Fuel</u> (avoided-; additional +)	€	991 M€
	Fuel Efficiency	**FEFF1** Average fuel burn per flight	Kg fuel per movement	Fuel Costs	€	15 M€

Performance Framework KPA[10]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Total benefits from IOC to 2040
	Fuel Efficiency	**FEFF2** CO2 Emissions	Kg CO2 per movement	CO2 Costs	€	210 M€
Civil-Military Cooperation & Coordination	Civil-Military Cooperation & Coordination	**CMC2.1a** Fuel saving (for GAT operations)	Kg fuel per movement	Fuel Costs	€/year	
		CMC2.1b Distance saving (for GAT operations)	NM per movement	Time Costs	€/year	

Table 12: Results of the benefits monetisation per KPA

5 Cost assessment

5.1 Overall costs approach and main assumptions

Costs were estimated based on expert judgement and are in line with other PJ.02 solutions using the same separation delivery tool (ORD) as optional or required enabler (reflected as a different enabler in the other solutions due to additional adaptations relevant to each OI). Costs for this solution are entirely borne by the ANSPs (APP and TWR) assuming that airport system costs and relevant maintenance is entirely occurred by the ANSPs for ECAC area. Some additional costs for the airports in this CBA represent some induced investment that the airports would have to do following the additional passengers that the increase in capacity brings.

5.2 ANSPs costs

5.2.1 ANSPs cost approach

A bottom-up approach was used to estimate the ANSPs implementation and operating costs. The scope of each enabler was analysed, discussed, reviewed and challenged within the CBA team as well as with other operational and technical experts in the PJ-02.01. With the support of the Solution leader and the partners it was possible to associate a cost to each enabler. Inputs for enabler costs were then aggregated at OI level.

Implementation costs include all type of costs: development of the system, specific adaptation and functionalities, additional inputs of static information, integration costs and regulatory costs.

5.2.2 ANSPs cost assumptions

- The following cost assumptions have been made for **arrival concept:**

AO-0328 costs are limited to the enablers of AERODROME-ATC-68 ATC system to support optimised runway delivery on final approach and APP ATC 120 ATC system to support optimised runway delivery on final approach, with STD-093 AMC on Optimised Runway/Separation Delivery and with STD-093 EUROCONTROL Guidelines for Optimised Runway Delivery for supporting ICAO DBS.

Development and deployment of the ORD Tool supporting:

AO-0306 costs are limited to the enablers of AERODROME-ATC-42a Airport ATC tool to support static pair-wise wake separation (S-PWS) in final approach and APP ATC 118 ATC System to support static pair-wise wake separation (S-PWS) on approach, with REG-0523 Regulatory provisions (AMC) for static pair-wise wake separation minima (S-PWS).

The core ORD tool costs are principally APPROACH enabler costs with respect to tracking the arrival aircraft through the intermediate and final approach phases of flight, the provision and update of the final approach sequence order, the modelling of anticipated trajectory behaviour on the straight-in final approach path, the provision of the glideslope wind conditions service, the calculation of the FTD and the calculation of the anticipated compression distance and the ITD, and the provision of the ITD and FTD Indicator information to the Approach and Tower CWP Systems for displaying to the Approach and Tower Controller respectively.

The ORD Tool integration costs are principally those associated with the APPROACH enabler related systems and services; the approach surveillance service, the AMAN system, the approach CWP operational radar display system, and other electronic HMI elements of the approach CWP environment. Cost elements relating to training, validation, safety and customisation have also been taken into account.

The ORD Tool integration costs with the TOWER enabler related systems and services are principally those associated with supporting the displaying the FTD and ITD Indicators on the Tower ATM display. Dependent on the trajectory modelling in the algorithm calculating the anticipated distance spacing compression this may also include the provision of the runway surface wind conditions and support for the provision of the glideslope wind conditions service.

As a result of the above, the split between APPROACH enabler costs and TOWER (AERODROME) enabler costs is estimated at around 75% to 25%.

- The following cost assumptions have been made for **departure concept**:

Cost estimates taken into account for the departures (AO-0329 OSD/AO-0323 PWS-D) are with respect to the “Airborne Time” procedures variant of the tool without any support for distance based separations. Note also that it is assumed that if there is a need for management of catch-up due to speed differences between the preceding and follower aircraft types along the SID route, this would be applied through the SID time separation rules and associated Speed Group related to time separation adjustments.

Support for distance based separations related costs have not been taken into account for the OSD tool.

Costs estimated for OSD include pre-implementation, implementation and operating cost items such as project definition, additional validation (if needed during project definition), demonstrator, simulator staffing, concept and validation expertise, implementation, installation and commission, support and maintenance. User implementation validation, safety assurance and training implementation management are also taken into account.

With respect to on-going support and maintenance the costs include post operational performance monitoring and maintaining the OSD tool with new aircraft types (PWS-D aircraft type pairwise separations).

5.2.3 Number of investment instances (units)

Due to sensitive information used with regard actual traffic, traffic mix, traffic peak information, runway configuration, MRS etc. information on the specific locations identified as target airports are considered as confidential and therefore are not included in this report.

Number of congested airports identified as benefitting from this solution i.e. number of investment instances is 9 for arrivals and 14 for departures.

5.2.4 Cost per unit

Average unit cost for arrivals results in around 10.7 M€ investment costs and 180K€ annual operating costs. Below you may find a breakdown at enabler level.

OI Step	Enabler	Required vs Optional	Enabler Title	Development Costs (M€)-ANSPs	Operating costs (M€/year)-ANSPs
AO-0328 Optimised Runway Delivery on Final Approach	AERODROME-ATC-68	required	ATC system to support optimised runway delivery on final approach	2.50	0.05
	APP ATC 120	Required	ATC system to support optimised runway delivery on final approach	7.50	0.05
	APP ATC 99	Required	ATC System to use Real-Time Meteo Information Received From Met Systems	0.50	0.05
	STD-093	Required	EUROCONTROL Guidelines for Optimised Runway Delivery	-	-
AO-0306 Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics	AERODROME-ATC-42a	Required	Airport ATC tool to support static pair-wise wake separation (S-PWS) in final approach	0.15	0.02
	REG-0523	Required	Regulatory provisions (AMC) for static pair-wise wake separation minima (S-PWS)	0.05	-
	APP ATC 118	Required	ATC System to support static pair-wise wake separation (S-PWS) on approach	0.02	0.02
Total				**10.7 M€**	**0.18 M€**

Table 13: Cost per Unit – ANSP for Arrivals

Average unit cost for departures results in around 2.61 M€ investment costs and 50K€ annual operating costs. Below you may find a breakdown at enabler level.

OI Step	Enabler	Required vs Optional	Enabler Title	Development Costs (M€)-ANSPs	Operating costs (M€/year)-ANSPs
AO-0329 Optimised Separation Delivery for Departure	AERODROME-ATC-69	Required	ATC system to support optimised departure separation	2.26	0.02
AO-0323 Wake Turbulence Separations (for departures) based on Static Aircraft Characteristics	AERODROME-ATC-42b	Required	Airport ATC tool to support static pair-wise wake separation (S-PWS) for departure operations	0.30	0.03
	REG-0523	Required	Regulatory provisions (AMC) for static pair-wise wake separation minima (S-PWS)	0.05	-
Total				2.61 M€	0.05 M€

Table 14: Cost per Unit – ANSP for Departures

6 CBA Model

The model used to calculate the CBA results is Single Solution CBA model developed by PJ.19. This CBA Model has been developed in Excel and aims at calculating the costs and benefits of the implementation of PJ.02-01 Solution based on the Deployment Scenario approach that has been defined in the context of the CBA task.

The PJ.02-01 V3 CBA Model (xlsx file) is also attached as a supporting document of the CBA report.

PJ02-01-v3-CBA
Model_for review.xls

It must be pointed out that all costs are analysed in the form of a "delta", this is the difference between a reference scenario where current operations continue "as usual" and a solution scenario, where PJ.02-01 is adopted by the stakeholders considered and implemented.

CBA model provides an overview of the costs for ANSPs and a view on the expected benefits for Airport Operators and Airspace Users.

This model is built to support strategic decision-making and although it does not aim to achieve 100% accuracy, it aims to be a good tool to model the problem and obtain results that should be close to the real characteristics of the solution.

6.1 Data sources

Cost Inputs

Since the cost inputs provided from some partners were not fully reflecting all functionalities of the different enablers, the cost items considered are a combination of different inputs from relevant PJ.02-01 partners.

Benefit Inputs

The source for the benefit calculation inputs is a combination of Performance Assessment Results from the PJ.02-01 Performance Assessment Report (PAR)[14] and separate calculations using inputs from FTS9. More information on the calculation of these benefits is available in the Benefit section.

Other Inputs Parameters

The data sources for the non-Solution specific CBA Model parameters are referenced in the various inputs sheets of the CBA Model with details provided in the sheet 'Source of Reference'. These are all part of the PJ.19.04 Common Assumptions.

7 CBA Results

The following section provides the results of the PJ.02-01 CBA at V3 Level.

PJ.02-01 contributes to Wake Turbulence Separation Optimisation through 4 concepts (8 OIs).

The CBA focusses only on Arrival and Departure concept covering 4 OIs i.e. ORD+PWS-A and OSD+PWS-D without covering the weather dependent separation aspects (due to limited applicability). Wake decay is not covered due to difficulties in quantifying safety and capacity benefits from current validation results. Finally wake monitoring is not covered due to lack of maturity.

The results presented are already consolidated and can be considered as conclusive. The CBA has been built gathering the following information:

- The Investments costs (pre-implementation and implementation costs) and Operating Costs have been identified for the main stakeholders impacted: ANSPs. Other costs for other stakeholders have been considered as negligible.
- The impact of PJ.02-01 on the Capital Expenditures (CAPEX) has been analysed and only the costs on top of what could be expected in the Reference Scenario have been estimated in the cost assessment and integrated in the CBA Model.
- Benefits (flight efficiency, airport capacity, predictability) have been estimated and monetised in the CBA Model for Airspace Users (Scheduled Airlines operating in Large and Very Large Airports) and Airport Operators. Inputs used have been a combination of results from PJ.02-01 Performance Assessment Report (PAR)[14], Validation Report (VALR)[15] and calculations based on NM actual data and potential improvement using results mainly from Fast Time Simulation and Real Time Simulation.
- No benefits are provided for Medium Airport and airport operating in mixed mode due to lack of peaks and limitations in the FTS modelling tool of the FTS.

A CBA can always be improved or refined, even if this is a CBA at V3 level. Further investigation could improve some areas. This is the case of the cost model which could be refined if more data was available. Recommendations are provided in Section 9 Recommendations and next steps.

All the analysis in this Chapter presents the delta between the Solution Scenario (with PJ.02-01) and the Reference Scenario (without PJ.02-01).

The V3 CBA allows calculating the Payback year as the NPV of the Solution changes from negative to positive in the early years of implementation. This is due to the fact that costs are higher than benefits (which are zero or partial) at the beginning.

7.1 PJ.02-01 results

The PJ.02-01 **CBA results**[11] are visible in the CBA model (see section 6) by selecting Scenario 1 for arrivals and Scenario 2 for departures.

Costs and Benefits are estimated at ECAC level considering the targeted list of airports where the PJ.02-01 Solution is expected to be deployed according to the Solution Scenario i.e. 9 airports for arrival concept and 14 airports for departure concept.

Combining both the Arrival and Departure CBA results give the following overall figures:

3) **Overall costs** for the period total **150 M€** undiscounted (89 M€ discounted at 8% discount rate).
4) **Total benefits** expected reach **2 240 M€** undiscounted (**725 M€ discounted**). As a reminder these benefits include Airport and AUs benefits.
5) The Net Result anticipated for PJ.02-01 would be a **positive NPV of 2 089M€** undiscounted **or 637 M€** with an 8% discount rate.

This section is structured in the following way:

- 7.1.1 provides the PJ.02-01 CBA Arrival discounted values
- 7.1.2 provides the PJ.02-01 CBA Arrival undiscounted values
- 7.1.3 provides the PJ.02-01 CBA Departure discounted values
- 7.1.4 provides the PJ.02-01 CBA Departure undiscounted values

7.1.1 Discounted Values - Arrivals

This section provides the discounted CBA results for arrival concept. The values shown in table 14 below are discounted to account for the time value of money[12]. Undiscounted values are shown in the next section.

The Net Present Value (NPV) for PJ.02-01 Arrivals is **294 M€**. This is calculated with an 8% discount rate over the period 2019 to 2040.

The payback year is 2026 as shown in Figure 9 where the discounted cumulative net benefits line crosses back over the x-axis.

[11] Any differences in totals are due to rounding errors

[12] **The time value of money reflects the idea that 1€ received today has more value than 1€ received in 2040 because it could be invested and earn interest over that period.**

PJ.02-01-Arrivals 2019-2040 Discounted				
in M€	NPV	Costs	Benefits	Discount rate
ANSP	-68	59	-8	8%
Airports	45	3	48	8%
Scheduled Airlines	316	0	316	8%
Overall	**294**	**62**	**356**	

Table 15: PJ.02-01 (Arrivals) Discounted CBA results (per stakeholder and overall)

Based on the current assumptions and inputs, the expected benefits offset the overall costs.

The sensitivity analysis in section 8 explores these results in more detail to see the impact on the NPV of changing some of the assumptions.

Figure 9 shows these discounted values on a year-by-year basis. The net benefits are the benefit value per year minus the cost value for that year; these are then shown cumulatively as a line in the figure.

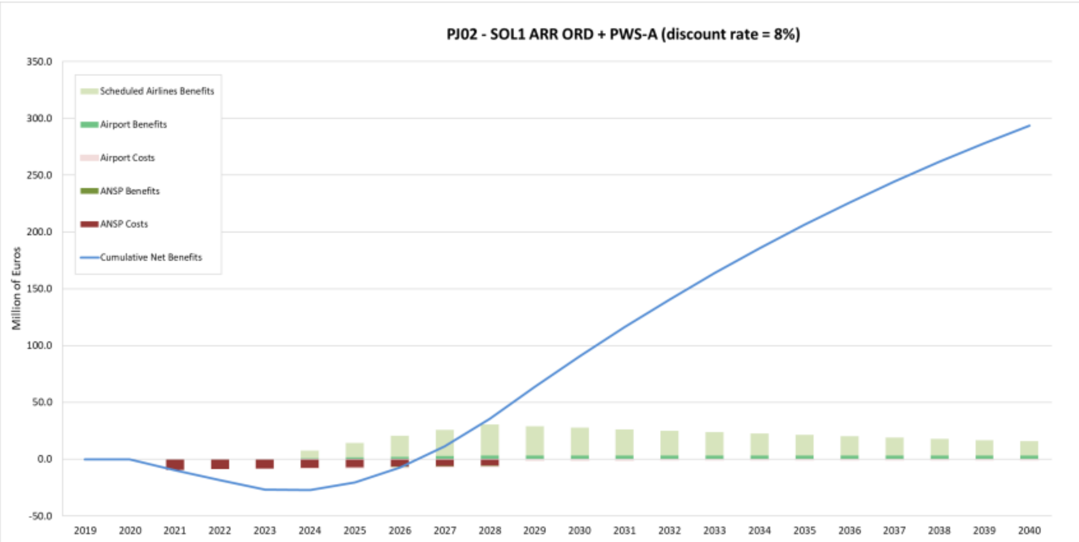

Figure 9: PJ.02-01 (Arrival) Annual Investment Levels and Benefits (discounted)

Figure 10 shows the cost and benefit data without the cumulative net benefits line so that the scale of the costs and benefits per stakeholder are easier to read.

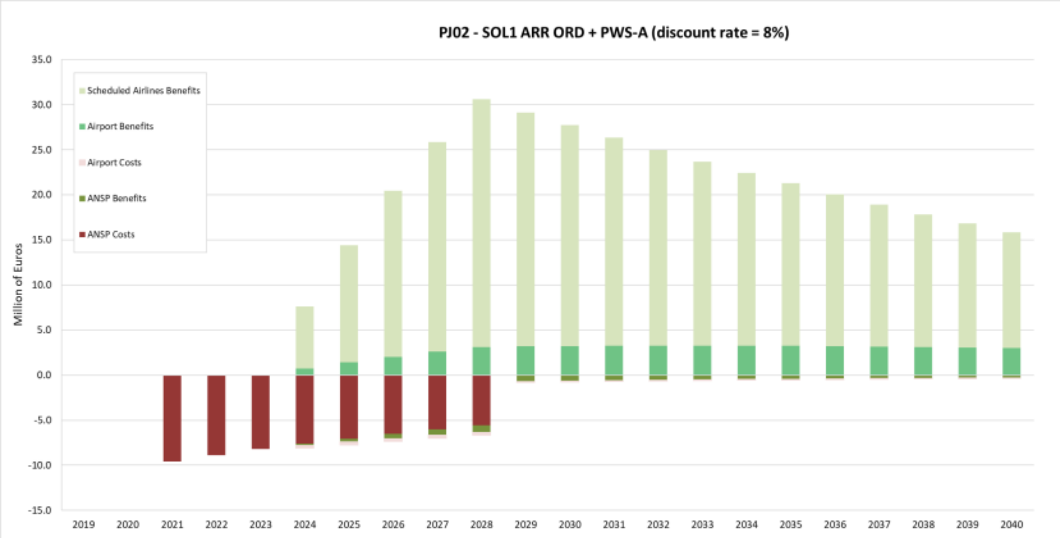

Figure 10: PJ.02-01 (Arrival) Annual Investment Levels and Benefits expanded (discounted)

7.1.2 Undiscounted Values –Arrivals

The values shown in this section do not consider the time value of money, so one unit of currency spent or received in 2040 is considered to have the same value as one unit of currency spent or received today.

Table 16 contains the undiscounted values, which show that without discounting, i.e. doing the CBA calculation with a discount rate of 0%, the overall net benefits are 994 M€.

PJ.02-01-Arrivals 2019-2040 Undiscounted			
in M€	Net Benefits	Costs	Benefits
ANSP	-121	96	-24
Airports	152	7	159
Scheduled Airlines	963	0	963
Overall	**994**	**104**	**1.098**

Table 16: PJ.02-01 (Arrival) Undiscounted CBA results (per stakeholder and overall)

Figure 11 shows the undiscounted costs and benefits over each year. The undiscounted cumulative net benefits line is not included to avoid readers considering the point it crosses the x-axis as the payback year.

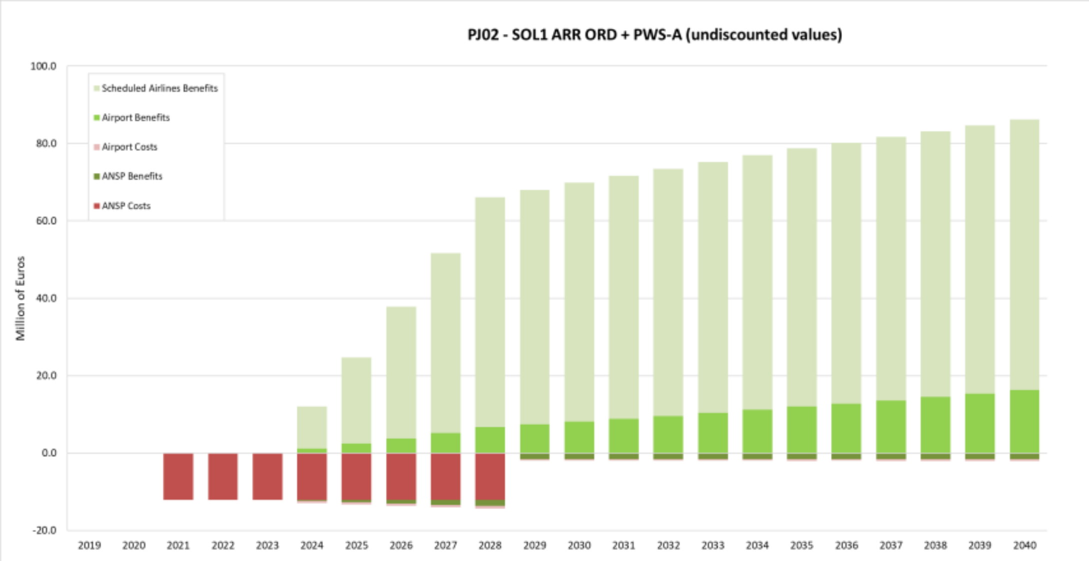

Figure 11: PJ.02-01 (Arrival) Annual Investment Levels and Benefits (undiscounted)

The undiscounted values are useful, especially for the costs, as they provide an idea of the overall investments that will be required. For example, based on these results, the stakeholders will need to invest 104 M€ to deploy this Solution over the deployment period. The 62 M€ discounted cost value, Table 15, simply reflects the present value of those investments in 2019.

7.1.3 Discounted Values - Departures

This section provides the discounted CBA results for Departure concept. The values shown in table 16 below are discounted to account for the time value of money[13]. Undiscounted values are shown in the next section.

The Net Present Value (NPV) for PJ.02-01 Departures is **343 M€**. This is calculated with an 8% discount rate over the period 2019 to 2040.

The payback year is 2025 as shown in Figure 13 where the discounted cumulative net benefits line crosses back over the x-axis.

[13] The time value of money reflects the idea that 1€ received today has more value than 1€ received in 2040 because it could be invested an earn interest over that period.

PJ.02-01-Departures 2019-2040 Discounted				
in M€	NPV	Costs	Benefits	Discount rate
ANSP	-26	23	-3	8%
Airports	62	4	66	8%
Scheduled Airlines	306	0	306	8%
Overall	**343**	**26**	**369**	

Table 17: PJ.02-01 (Departure) Discounted CBA results (per stakeholder and overall)

Based on the current assumptions and inputs, the expected benefits offset the overall costs.

The Sensitivity analysis explores these results in more detail to see the impact on the NPV of changing some of the assumptions.

Figure 12 shows these discounted values on a year-by-year basis. The net benefits are the benefit value per year minus the cost value for that year; these are then shown cumulatively as a line in the figure.

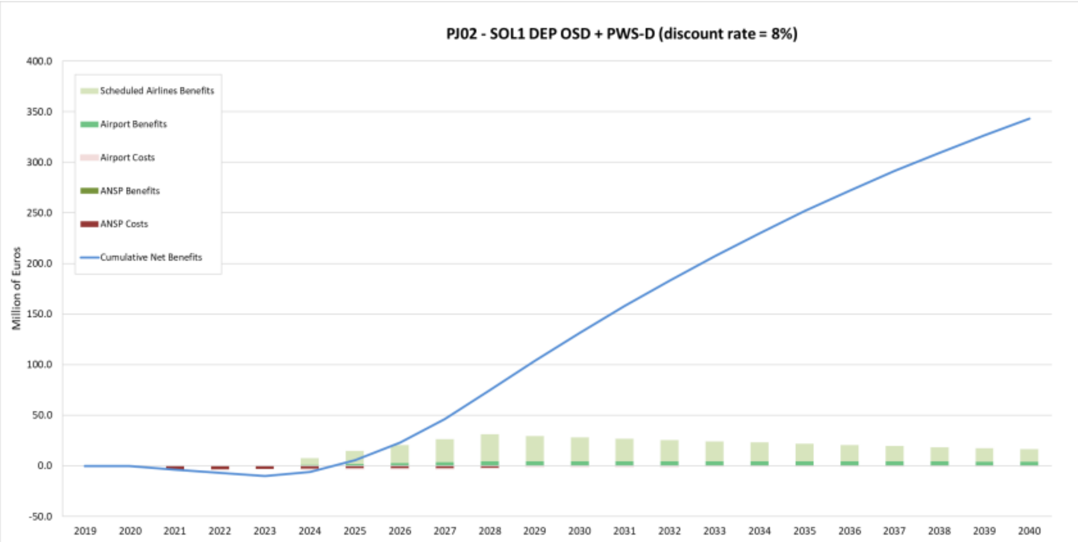

Figure 12: PJ.02-01 (Departure) Annual Investment Levels and Benefits (discounted)

Figure 13 shows the cost and benefit data without the cumulative net benefits line so that the scale of the costs and benefits per stakeholder are easier to read.

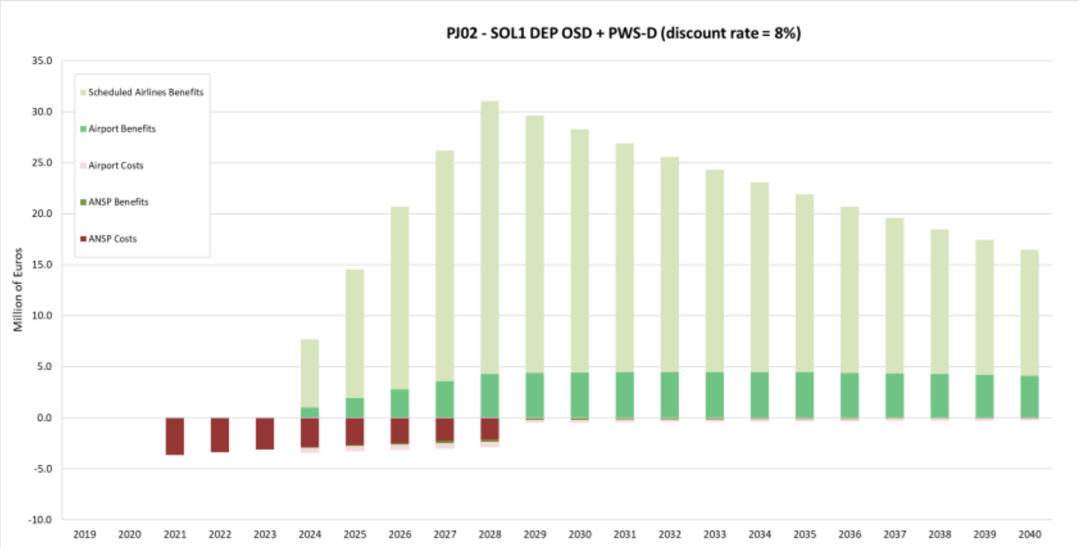

Figure 13: PJ.02-01 (Departure) Annual Investment Levels and Benefits expanded (discounted)

7.1.4 Undiscounted Values – Departures

The values shown in this section do not consider the time value of money, so one unit of currency spent or received in 2040 is considered to have the same value as one unit of currency spent or received today.

Table 17 contains the undiscounted values, which show that without discounting, i.e. doing the CBA calculation with a discount rate of 0%, the overall net benefits are 1 095 M€.

PJ.02-01-Departures 2019-2040 Undiscounted			
in M€	Net Benefits	Costs	Benefits
ANSP	-46	37	-9
Airports	209	10	219
Scheduled Airlines	932	0	932
Overall	**1.095**	**47**	**1.142**

Table 18: PJ.02-01 (Departure) Undiscounted CBA results (per stakeholder and overall)

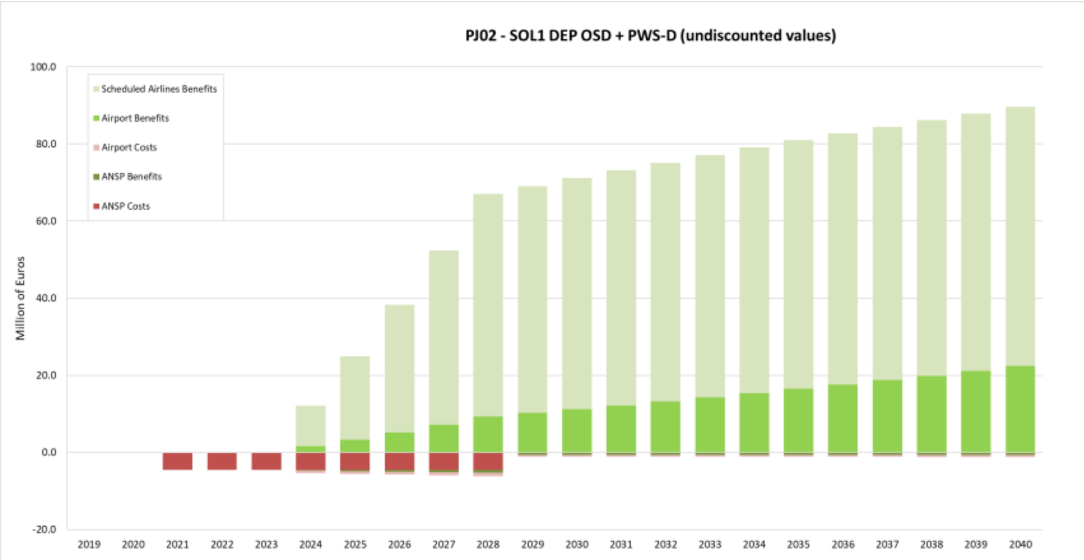

Figure 14: PJ.02-01 (DEP) Annual Investment Levels and Benefits (undiscounted)

The undiscounted values are useful, especially for the costs, as they provide an idea of the overall investments that will be required. For example, based on these results, the stakeholders will need to invest 47 M€ to deploy this Solution over the deployment period. The 26 M€ discounted cost value, Table 17, simply reflects the present value of those investments in 2019.

8 Sensitivity analysis

This section[14] only considers the PJ.02-01 CBA for arrivals and for departures.

The results shown here explore a set of what-ifs to see how sensitive the CBA results are to changes in the input values. The 'base' values, which produce the discounted results in section 7, are shown with a green background.

The following sub-sections look at these questions:

8.1) What-if we use a lower discount rate?

8.2) What-if we increase or reduce the ANSP investment and operating cost values?

8.3) What-if we increase or reduce airport capacity benefit?

Each of the what-ifs is considered separately, i.e. only the mentioned values are changed and all other inputs are set at their 'base' values.

8.1 Discount Rate

The discount rate is used to reflect the time value of money[15] so reducing the discount rate reduces the difference between the value of money today and its value in the future.

Table 19 and Table 20 shows that using a lower discount rate increases the NPV.

Discount Rate	Change compared to base case	NPV (M€)		Change compared to base case
8%	0%	**294**	As shown in Table 15	0%
6%	-25%	393		46%
4%	-50%	530		111%
2%	-75%	722		205%
0% (undiscounted)	-100%	994	As shown in Table 16	342%

[14] Risk Analysis has not been performed for this V3 CBA due to non-availability of an appropriate tool / Excel. Risk Analysis uses Monte Carlo simulation techniques to calculate the NPV results for thousands of scenarios where different combinations of the input values (taken from probability distributions) are used in each.

[15] The time value of money reflects the idea that 1€ received today has more value than 1€ received in 2040 because it could be invested an earn interest over that period.

Table 19: Sensitivity Analysis (Arrival) – Discount Rate

Discount Rate	Change compared to base case	NPV (M€)		Change compared to base case
8%	0%	343	As shown in Table 17	0%
6%	-25%	451		46%
4%	-50%	599		111%
2%	-75%	805		205%
0% (undiscounted)	-100%	1 095	As shown in Table 18	342%

Table 20: Sensitivity Analysis (Departure) – Discount Rate

8.2 Sensitivity to the Investment and Operating Costs

Table 21 shows that reducing/increasing the ANSP costs by 20% and 40% only increased/reduces the NPV by around 5% and 9% respectively.

ANSP costs		Change compared to base case	NPV (M€)	Change compared to base case
CAPEX	OPEX			
58	1.0	-40%	321	9%
77	1.3	-20%	307	5%
96	1.6	0%	294	0%
118	1.9	20%	280	-5%
137	2.3	40%	267	-9%

Table 21: Sensitivity Analysis – ANSP Costs (Arrival)

Table 22 shows that reducing/increasing the ANSP costs by 20% and 40% only increased/reduces the NPV by around 1% and 3% respectively.

ANSP costs		Change compared to base case	NPV (M€)	Change compared to base case
CAPEX	OPEX			
22	0.4	-40%	353	3%
29	0.5	-20%	348	1%

ANSP costs		Change compared to base case	NPV (M€)	Change compared to base case
CAPEX	OPEX			
37	0.6	0%	343	0%
44	0.8	20%	338	-1%
51	0.9	40%	333	-3%

Table 22: Sensitivity Analysis – ANSP Costs (Departure)

8.3 Sensitivity to the Airport Capacity Benefit

Table 23 and Table 24 show that the impact of the airport capacity on the results.

Airport CAP	Change compared to base case	NPV (M€)	Change compared to base case
0.03%	-40%	266	-21%
0.1%	0%	294	0%
0.2%	40%	322	21%

Table 23: Sensitivity Analysis – Airport Capacity (Arrival)

Airport CAP	Change compared to base case	NPV (M€)	Change compared to base case
0.04%	-40%	305	-11%
0.16%	0%	343	0%
0.3%	40%	381	11%

Table 24: Sensitivity Analysis – Airport Capacity (Departure)

9 Recommendations and next steps

This report has identified that the effective implementation of PJ.02-01 would have a significant positive impact for European ATM. It would be a broad contributor to future improved operational performance in terms of airport capacity, flight efficiency, time efficiency and predictability compared to a situation without implementation of PJ.02-01.

A wider European-level implementation of PJ.02-01 would extend the economic benefits, as well as the operational performance, to the wider ANSP community.

The deployment of PJ.02-01 would achieve a positive global business case with the deployment phase estimated to kick off as from 2021. The net present value of such initiative could reach higher NPVs after 2040, since only OPEX remains and full benefits are accounted. Additionally, if more Airports/ANSPs adopt such a stance the benefits will also be higher.

The expected benefits from PJ.02-01 are mainly related to the impact of the optimised wake turbulence separations on **Time Efficiency** and the resulting increase in runway throughput and reduction in holding delay with the associated impact on **Fuel Efficiency, Predictability and Airport Capacity**.

CBA is presented at ECAC level following an extrapolation of local benefits. The local analysis is conducted for capacity constrained Very Large and Large airports (following SESAR Classification Scheme) operating in segregated mode, using Fast Time Simulation exercise. The number of airports identified as candidate for this solution is 9 for Arrival and 14 for Departure concept.

The deployment of PJ.02-01 will require only ANSPs[16] to invest. The CBA results are discounted at 8% between 2019 and 2040, with PJ.02-01 being deployed between 2021 and 2028 and with benefits starting to be realised in 2024. Combining both the Arrival and Departure CBA with overall costs of **150 M€** undiscounted (89 M€ discounted) PJ.02.01 would achieve a net present value of **637M€** by 2040 (571 M€ as the lowest value and 2 089 M€ as the highest value depending on the scenario of the sensitivity analysis following a change in either the discount rate or the airport capacity or the investment and annual operating costs of the tools). Looking the concepts separately, the arrival concept would achieve a Net Present Value (NPV) of **294 M€ (994M€ undiscounted)** while the departure concept **343M€ (1 095M€ undiscounted)**.

It is recommended to present the outcome of the study and of this cost benefit analysis not only to ANSPs who may be interested in pursuing a similar concept solution to address their capacity and delays issue but also to airspace users and airports who are highly benefitting from this solution. Although the CBA may seem negative from an ANSP point of view, delivering better services to airports and airspace users is a key benefit.[17]

[16] A simplifying assumption that airport systems are owned by the ANSPs has been taken; ANSPs are incurring also all the relevant upgrade costs of these systems.

10 References and Applicable Documents

10.1 Applicable Documents

[1] **SESAR 2020 Project Handbook, edition 01.00.01, 06 June 2017**

[2] **SESAR 16.06.06-D26_04, Guidelines for Producing Benefit and Impact Mechanisms, Ed. 03.00.01**

[3] **SESAR 16.06.06-D26_03, Methods to Assess Costs and Monetise Benefits for CBAs, Ed. 00.02.02**

[4] **Method to assess cost of European ATM improvements and technologies, v1.0, 28 July 2014**

[5] **Cost-Benefit Analyses – Model and Methods – Part I, edition 00.01.01, 30 April 2017**

[6] **Cost-Benefit Analyses – Model and Methods – Part II, edition 00.01.01, 30 April 2017**

[7] **SESAR 16.06.06-D51 SESAR 1 Business Case 2016, Edition 00.01.01, 13 July 2016**

[8] **SESAR 16.06.06-D68-New CBA Models and Methods 2015-Part 1 of 2-00_01_01 (1_0).docx**

10.2 Reference Documents

The following documents were used to provide input / guidance / further information / other:

[9] **SESAR 2020, PJ19, D4.0.30 S2020 Common Assumptions (2019), Edition 01.00.00**

[10] **European ATM Master Plan Portal 2019, https://www.atmmasterplan.eu/**

[11] **SESAR C.02-D110, Updated D02 after MP Campaign, Edition 00.01.00**

[12] **SESAR 2020 D4.7, Performance Framework (2019), Edition 01.00.01**

[13] **SESAR 2020 PJ.02-01 V3 SPR-INTEROP/OSED - Part I, Deliverable ID D1.1.021, Edition 00.00.14**

[14] **SESAR 2020 PJ.02-01 V3 SPR-INTEROP/OSED - Part V, Performance Assessment Report Deliverable D1.1.021, Edition 00.01.02, 23 October 2019**

[15] **SESAR 2020 PJ.02-01 VALR (V3), Edition 00.00.06, 31 October 2019**

[16] **EUROCONTROL - CODA Digest 2017 report (Edition CDA_2017_004 - 31/05/2018)**

[17] **EUROCONTROL - European Aviation in 2040 – Challenges of Growth. Edition 2.**

[18] **Standard Inputs for EUROCONTROL Cost-Benefit Analyses. Edition 8.0, January 2018.**

[19] **EUROCONTROL – Performance Review Report 2011 (PRR 2011, Final Report - PRC, May 2012)**

[20] **SESAR 2020 PJ20 Classification of APTs (SESAR 2018 list)**

[21] **STATFOR traffic forecast data (2019) – Regulation & growth scenario**

[22] **Performance Review Unit - ATM Cost-Effectiveness (ACE) 2016 Benchmarking Report with 2017-2021 outlook**

Appendix 1 - List of PJ.02-01 targeted Airports

The table below presents the list of targeted APTs as defined by WP2.2 (PJ20). Complexity is forecasted for 31/12/2026 mainly according the traffic growth (IFR movements).

These are the very large and large airports in 2018. Between 2018 and 2040 it is expected that many more airports will become capacity constrained and would need arrival and departure concepts of PJ.02.01.

ICAO Code	Full Name of Airport	State Name	Airports' Group in 2018 according to SESAR 2020 Airports' Classification Scheme
EDDF	Flughafen Frankfurt/Main	Germany	Very large
EHAM	Amsterdam Airport	Netherlands	Very large
LFPG	Aéroport de Paris-Charles de Gaulle	France	Very large
EGLL	Heathrow Airport	United Kingdom	Very large
LTBA	Atatürk International Airport	Turkey	Very large
EDDM	Munich Airport	Germany	Very large
LEMD	Aeropuerto de Adolfo Suárez Madrid-Barajas	Spain	Very large
LEBL	Aeropuerto de Barcelona-El Prat	Spain	Very large
LIRF	Aeroporto di Roma-Fiumicino	Italy	Very large
EGKK	Gatwick Airport	United Kingdom	Very large
LSZH	Flughafen Zürich	Switzerland	Very large
EKCH	Copenhagen Airport	Denmark	Very large
ENGM	Oslo-Garnemoen Airport	Norway	Very large
LOWW	Vienna International Airport	Austria	Very large
ESSA	Stockholm-Arlanda Airport	Sweden	Large
EIDW	Dublin Airport	Ireland	Large
LFPO	Aéroport de Paris-Orly	France	Large
EBBR	Brussels Airport	Belgium	Large
LTFJ	Sabiha Gökçen International Airport	Turkey	Large
LEPA	Aeropuerto de Palma de Mallorca	Spain	Large
EDDL	Düsseldorf International Airport	Germany	Large
LPPT	Lisbon Airport	Portugal (Madeira and Azores)	Large
LGAV	Athens International Airport	Greece	Large
EGCC	Manchester Airport	United Kingdom	Large
EGSS	Stansted Airport	United Kingdom	Large
LIMC	Milano Malpensa	Italy	Large
EFHK	Helsinki-Vantaa Airport	Finland	Large
EPWA	Warsaw Frederic Chopin Airport	Poland	Large
LTAI	Antalya International Airport	Turkey	Large

ICAO Code	**Full Name of Airport**	**State Name**	Airports' Group in 2018 according to SESAR 2020 Airports' Classification Scheme
EDDT	Tegel Airport	Germany	Large
LSGG	Genève Aéroport	Switzerland	Large
LKPR	Prague Airport	Czech Republic	Large

Appendix 2 – Operational Improvements (OIs) out of CBA Scope

A.2.1 WDS-A Analysis of applicability at 2 very large airports

For Weather Dependent Separation on Approach (WDS-A), in order to provide benefits by reducing the wake separation the crosswind measured on the ground and over the glide shall be in the order of the 10 knots as a minimum and it shall be persistent for an extended amount of time in order to allow several aircraft in the TMA to land with reduced wake separations.

An analysis has been made on the first criteria (10 knots crosswind) by using 1 year and 6 months of weather data (Anemometer and Sodar) of two different airports in Europe belonging to the very large category. The weather data were cross-checked with the runway configurations used the most. The result was that the 10 knots crosswind at the ground is only satisfied the 9% and 13% of the time respectively at the two airports.

Results for Very Large Airport #1

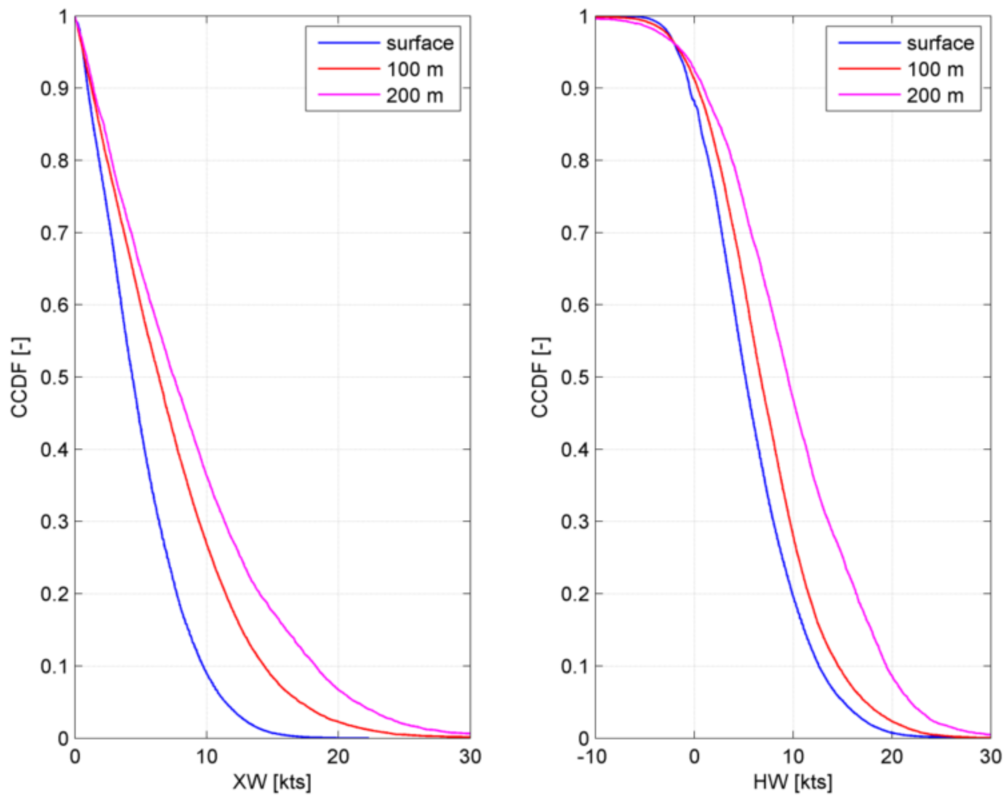

Figure 15: Crosswind (Left) and Headwind (Right) for a Very Large Airport #1 measured at different altitudes.

In the figure above we see how the crosswind at 200m altitude for airport #1 was above 10 knots more than 30% of the measurements, however at the ground this is only the 9% reducing

drastically the time the concept could be used. As we said before the crosswind shall also be persistent for a sufficient amount of time and it shall apply at the same time of the traffic peaks, so the 9% can be seen as a maximum threshold if we also assume that the other two conditions are satisfied.

Results for Very Large Airport #2

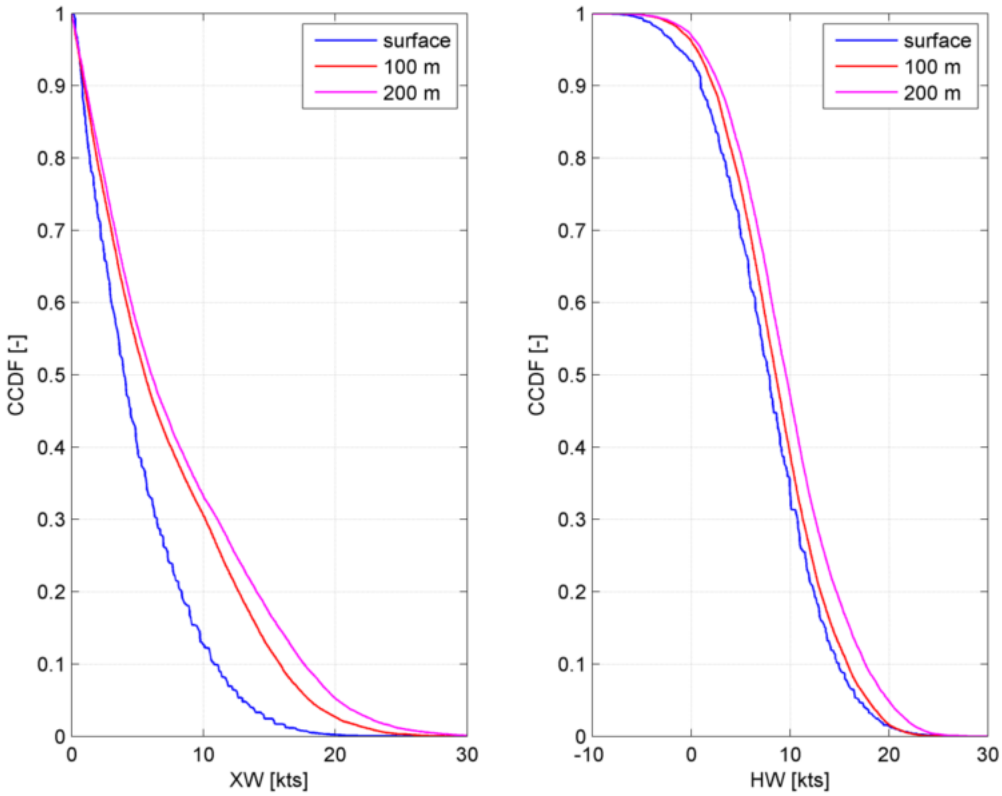

Figure 16: Crosswind (Left) and Headwind (Right) for Very Large Airport #2 measured at different altitudes.

For the Airport #2 the same trend is confirmed, the wind is stronger at altitude, crosswind can be above 10 knots more than the 30% of the time at 100 and 200m altitude but only 13% of the time is above 10 knots at the ground.

The Performance Assessment Report [14] assesses the benefits for these two OIs and presents the quantified benefits on the KPIs for the solution. The results show that there is a very limited additional benefit when WDS is deployed in addition to pairwise separations (which already reduces significantly the wake separations); while the former may be used only for a part of the day, the latter can be used during the whole day.

Costs have been estimated at 0.66M€ for an investment cost for both WDS-A and WDS-D reflecting the costs for ATC system support and system to use real-time meteo on the arrival side as well as the costs for runway usage management sub-system capable of processing initial departure path wind conditions information. Annual operating costs have been estimated at 100K€ and 50K€ respectively for the two concepts.

WDS concepts also require technological solutions able to create the requested wind profiles which are not available for the moment. That does not mean that WDS-A is not viable and cannot provide any benefits, there might be airports that have higher exposure to cross-wind conditions and could benefit from the concept. For the purpose is recommended to make a local assessment with the wind conditions being one of the main factor.

A.2.2 WDS-D Analysis

From D1.1.019 - PJ.02-01 OSED-SPR-INTEROP 9th Draft - Part II - 00.01.02 –Appendix K4

For a WDS-D reduced wake separation of 90s there is a need to factor in the time separation evolution, headwind transport and the provision for under separation delivery when considering the amount of time for wake transport

- **These may reduce the time separation for wake transport towards 70s**

For a 70s time separation for wake transport, depending on the core size of the wake vortices (5m or ½ wing span modelled) the minimum time for wake transport appears to be 7 knots or 8 knots at the runway surface and 8 knots or 9 knots aloft.

When allowing for the provision for the wind conditions changing of 2 knots this results in a GO to NOGO transition of 9 knots or 10 knots at the runway surface and 10 knots or 11 knots aloft.

When allowing for provision for some instability of the wind conditions to provide for a stable NOGO to GO transition of either 2 knots or 3 knots this results in a NOGO to GO transition of 11/12 knots or 12/13 knots at the runway surface and 12/13 knots or 13/14 knots aloft.

Crosswind conditions above 10 knots only occurred 8% of the time and above 12 knots only occurred 3% of the time at the runway surface at Heathrow during 2016. There is a need to reduce the crosswind criteria towards 7 knots for the proportion of the time to increase to above 20%. This will mean assessing the necessity for outlier behaviour to be mitigated by the crosswind transport.

A.2.3 Wake Enhancing Devices

Below you may find a qualitative description of costs and benefits identified for Wake Enhancing devices.

Costs

Costs for the wake decay enhancing concept solution arise mainly from purchase and installation of the required plate lines underneath the glide path. The validation exercise at Vienna International Airport has shown that two plate lines are sufficient for each landing direction.

During the validation exercise, two temporary plate lines where installed in the approach corridor of one runway at Vienna airport. A first design for the permanent installation assumes aluminium lattice masts grounded with prefab concrete foundations and covered with truck tarpaulin. The costs for the purchase and installation of plate lines are estimated to be between 100.000 and 360.000 Euros for each landing direction. Because plate lines are robust and passive devices, maintenance costs are expected to be less than 10.000 Euros per airport per year.

Benefits

Plate lines accelerate the decay of wake vortices in ground proximity. On average, the lifetime of long-lived and potentially most hazardous wake vortices is reduced by 30%.

Reduced wake vortex lifetimes lead to a lower wake vortex encounter risk for aircraft on final approach, which is the flight phase with most wake encounters. Thus, plate lines reduce wake encounter frequency corresponding to an improved safety. Furthermore, the rate of vortex-related go-arounds is reduced which improves fuel efficiency and leads to a modest increase in runway capacity. In extreme cases, potential accidents can also be avoided.

Further monetary benefits can be achieved in combination with regulations and systems optimizing aircraft separations. Reduced vortex lifetimes in the bottleneck phase of flight can be exploited to allow for smaller wake separations between arrivals, potentially reducing the average delay per flight and increasing runway throughput. An assessment indicates a possible reduction of tactical delay costs on the order of a million Euros per year for a large airport. The achievable increase in runway throughput shall be quantified in VLD3.

Because of the fact that the installation of plate lines requires no change in ATM procedures and no further systems usage, this concept provides a highly efficient method for wake-vortex decay acceleration without raising any additional workload for the air traffic controllers. Furthermore, the applicability to basically any airport environment offers a high degree of interoperability due to the flexibility in terms of plate line design and amount of plate lines and single plate elements.

Appendix 3 – Discount rate

This note explains the choice of 8% for the discount rate in the SESAR CBAs.

The discount rate is used to reflect the Time Value of Money (i.e. money received today has more value than money that will be received in 10 years because money received today can be invested to get some income.)

The discount rate used to calculate the Net Present Value (NPV) can be interpreted as the interest on invested money (from a project or a savings account) or as the interest charged on borrowing money (to fund an investment).

The 8% discount rate used in the SESAR CBA model to calculate the NPV reflects the higher end of the range of Cost of Capital values faced by the partners involved in PJ.20 sWP2.6 (Business Cases) to acquire the funds necessary to invest. This value is used by some partners in their local CBAs.

If a Solution has a positive NPV at 8% then it will be more positive at lower discount rates. However, a positive NPV with a lower rate, e.g. 4%, may be negative at an 8% discount rate. Therefore 8% is a conservative value, which can also be considered to include a risk premium to cover the uncertainties associated with such broad CBAs. The undiscounted values (i.e. a discount rate of 0%) are also provided to allow a comparison.

In addition, the SESAR CBAs do not consider inflation (i.e. the discount rate is the real rate and not the nominal rate). This is because it would be necessary to make many, many assumptions about how inflation rates evolve over the CBA period and how they would differ in the different states and how they would apply to the costs and benefits in each state.

Appendix 4 – Mapping between ATM Master Plan Performance ambitions and framework

Mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs

ATM Master Plan SESAR Performance Ambition KPA	ATM Master Plan SESAR Performance Ambition KPI	Performance Framework KPA	Focus Area	#KPI / (#PI) / <Design goal>	KPI definition
Cost efficiency	PA1 - 30-40% reduction in ANS costs per flight	Cost efficiency	ANS Cost efficiency	CEF2	Flights per ATCO hour on duty
				CEF3	Technology Cost per flight
Capacity	PA7 - System able to handle 80-100% more traffic	Capacity	Airspace capacity	CAP1	TMA throughput, in challenging airspace, per unit time
				CAP2	En-route throughput, in challenging airspace, per unit time
	PA6 - 5-10% additional flights at congested airports		Airport capacity	CAP3	Peak Runway Throughput (Mixed Mode)
			Capacity resilience	<RES1>	% Loss of airport capacity avoided
				<RES2>	% Loss of airspace capacity avoided
	PA4 - 10-30% reduction in departure delays	Predictability and punctuality	Departure punctuality	PUN1	% of Flights departing (Actual Off-Block Time) within +/- 3 minutes of Scheduled Off-Block Time after accounting for ATM and weather related delay causes

ATM Master Plan SESAR Performance Ambition KPA	ATM Master Plan SESAR Performance Ambition KPI	Performance Framework KPA	Focus Area	#KPI / (#PI) / <Design goal>	KPI definition
Operational Efficiency	PA5 - Arrival predictability: 2 minute time window for 70% of flights actually arriving at gate		Variance of actual and reference business trajectories	PRD1	Variance of differences between actual and flight plan or Reference Business Trajectory (RBT) durations
	PA2 - 3-6% reduction in flight time	Environment	Fuel efficiency	(FEFF3)	Reduction in average flight duration
	PA3 - 5-10% reduction in fuel burn			FEFF1	Average fuel burn per flight
Environment	PA8 - 5-10% reduction in CO2 emissions			(FEFF2)	CO2 Emissions
Safety	PA9 - Safety improvement by a factor 3-4	Safety	Accidents/incidents with ATM contribution	<SAF1>	Total number of fatal accidents and incidents
Security	PA10 - No increase in ATM related security incidents resulting in traffic disruptions	Security	Self- Protection of the ATM System / Collaborative Support	(SEC1)	Personnel (safety) risk after mitigation
				(SEC2)	Capacity risk after mitigation
				(SEC3)	Economic risk after mitigation
				(SEC4)	Military mission effectiveness risk after mitigation

Table 25: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPI

Appendix 5 – Solution Validation Targets

KPA/KPI	Solution Validation Target	TMA Very High Complexity	TMA High Complexity	TMA Medium Complexity	TMA Low Complexity	APT Very Large	APT Large	APT Medium
FEFF	30,8550	6,844	3,366	5,386	-	5,049	4,151	6,059
APT CAP	2.574%	-	-	-	-	2.574%	2.574%	2.574%
PRD1	0,531%	0,213%	0,105%	0,168%	0,045%	-	-	-

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