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AART

AIRPORT AIRSIDE AND RUNWAY THROUGHPUT

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

Abstract

This document provides the Cost Benefit Analysis (CBA) at V3 level for **PJ.02-W2-14.5 – Increased Glide Slope to a Second Runway Aiming Point (IGS-to-SRAP)**, which is an Enhanced Arrival Procedure (EAP). The associated OI Step is AO-0331: Enhanced approach operations using an increased glide slope to a second runway aiming point (IGS-to-SRAP).

This deliverable includes the quantification and monetisation of costs and benefits associated with the implementation of the IGS-to-SRAP procedure at relevant airports across ECAC.

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1 Executive Summary

This report[1] provides the V3 Cost Benefit Analysis (CBA) for SESAR Solution **PJ.02-W2-14.5 Increased Glide Slope to a Second Runway Aiming Point** (IGS-to-SRAP), which is an Enhanced Arrival Procedure (EAP) that uses two active thresholds on a single runway with a steeper glide slope to the second threshold.

Solution PJ.02-W2-14.5 has validated to V3 level the Operational Improvement Step (OI Step) AO-0331: Enhanced approach operations using an increased glide slope to a second runway aiming point (IGS-to-SRAP). The CBA focuses on the **deployment** of the Solution at ECAC[2]-level and is not limited to the scope of the validation activities.

Benefits

The expected IGS-to-SRAP **benefits** that are monetised in the CBA are:

- Reduced environmental impact from **Noise Reduction** below the final approach in peak and non-peak periods for aircraft using the IGS-to-SRAP. These benefits are based on the change in size of the noise contours around the airport areas, which reflects a reduction in aircraft noise for impacted residents.
- Increases in **Airport Capacity** during capacity-constrained peak periods when both runway aiming points are used to optimise wake turbulence separations for specific combinations of leader/follower aircraft pairs
- Improvements in **Fuel Efficiency** and **Time Efficiency** in peak and non-peak periods where the optimised wake separations can help optimise flight profiles and the airport layout allows a reduction in runway occupancy time and taxi-in time for aircraft using the SRAP

An airport will choose to deploy a second runway aiming point with an increased glide slope based on their operational needs, such as, optimising wake turbulence separations, optimising taxi-in times and reducing the impact of noise.

The CBA is presented at the ECAC-level following an extrapolation of local benefits from the validation activities. Deployment covers five[3] capacity-constrained airports for the airport capacity benefits, these airports come from the Very Large and Large operating environment categories (SESAR 2020 Airport Classification Scheme) and are operating in segregated mode. In addition, all 32 Very Large and Large airports are assumed to deploy the solution for the noise related benefits. Other airports, such as those in the Medium category could also deploy the solution and benefit from the noise reduction aspects, however, the associated costs and benefits are not included in this CBA.

CBA Results

The Net Present Value (NPV) of 1320 M€ reflects that the benefits from deploying this Solution are expected to exceed the costs of deploying and operating it. Confidence in the airport capacity, fuel and time efficiency benefits is medium as they are based on Fast Time Simulation results. Confidence in the noise results is low to medium as they generalise the benefits calculated from the noise simulations produced in the Wave 1 Solution PJ.02-02 'Enhanced Arrival Procedures'.

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[1] The opinions expressed herein reflect the authors' view only. Under no circumstances shall the SESAR 3 Joint Undertaking be responsible for any use that may be made of the information contained herein.

[2] European Civil Aviation Conference

[3] The airport names are not provided as they were chosen based on criteria and have made no commitment to deploy.

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The NPV has been calculated with an 8% discount rate over the period 2022 to 2043, with PJ.02-W2-14.5 being deployed between 2025 and 2030 and with benefits starting to be realised from late 2026. The payback year is 2027, which reflects when the cumulative net benefits will exceed the costs.

The sensitivity analysis shows that even if the costs doubled and the benefits halved, the deployment, as described in the CBA Solution Scenario, would still have a positive NPV of 460 M€.

Costs

On the cost side the deployment of IGS-to-SRAP will require ANSPs[4], Airport Operators and Airspace Users to invest.

- ANSP costs are based on a controller tool to support final approach operations and a controller separation support tool (enhanced Optimised Runway Delivery tool, eORD[5]) to support the use of IGS-to-SRAP as well as training for both.
- Airport Operator costs relate to runway markings, lighting and PAPI (precision approach path indicator) for each second runway aiming point with an increased glide slope.
- Airspace User costs relate to pilot training requirements. There are no airborne or flight operation centre investments required.

Some of the enablers required for this Solution will also enable other Solutions, however, the full enabler cost has been included in this CBA as a conservative approach.

While not included in the CBA, approach guidance is required for the operation of IGS-to-SRAP. This can be RNP (Required Navigation Performance), SBAS (Satellite Based Augmentation System) or GBAS (Ground Based Augmentation System). RNAV (Required Vertical Navigation Performance) guidance is also considered because it is anticipated that in 2025 most aircraft will be able to follow RNAV procedures, whereas only 25% of the fleet is expected to be GBAS-equipped.

Recommendations and next steps

PJ.02-W2-14.5 is a Solution that an airport could choose to deploy if they face capacity-constraints and noise issues around the airport. However, each airport needs to assess if this Solution is the best way to meet their operational needs and they should develop their own CBA based on their specific infrastructure, operations, layout, etc. to assess the scale of their potential benefits. They should also review related solutions, such as PJ.02-W2-14.2 Second Runway Aiming Point and PJ.02-W2-14.3 Increased Second Glide Slope, to ensure they deploy the most appropriate solution for their needs.

[4] It is assumed that air traffic control (ATC) systems located at airports are owned by the ANSPs that provide the service; ANSPs are therefore assigned the relevant upgrade costs of these systems in the CBA. In reality the situation will differ across airports as some airports may own the systems.

[5] The eORD is included in this CBA although only for the 5 airports targeting airport capacity benefits, the tool is optional for airports with lower traffic levels that would focus solely on the noise benefits

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2 Introduction

2.1 Purpose of the document

This document provides the Cost Benefit Analysis (CBA) for SESAR Solution **PJ.02-W2-14.5 Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP)**, which is an Enhanced Arrival Procedure (EAP) that has been validated to V3 level. The CBA looks at the **affordability of deploying IGS-to-SRAP solution** with respect to its expected benefits.

This V3 CBA considers the impacts, benefits and costs of deploying the Solution at ECAC-level. It includes the Net Present Value (NPV) for the Solution and per impacted stakeholder group, as well as a sensitivity analysis to identify the most critical variables to the value of the project.

2.2 Scope

Deploying IGS-to-SRAP will result in two active thresholds on a single runway with a steeper glide slope to the second threshold. This is expected to provide benefits in terms of:

- Reduced environmental impact from **Noise Reduction** below the final approach in peak and non-peak periods for aircraft using the IGS-to-SRAP. These benefits are based on the change in size of the noise contours around the airport areas, which reflects a reduction in aircraft noise for impacted residents.
- Increases in **Airport Capacity** during capacity-constrained peak periods when both runway aiming points are used to optimise wake turbulence separations for specific combinations of leader/follower aircraft pairs
- Improvements in **Fuel Efficiency** (reduced fuel burn and CO_2 emissions) and **Time Efficiency** in peak and non-peak periods where the optimised wake separations can help optimise flight profiles and the airport layout allows a reduction in runway occupancy time and taxi-in time for aircraft using IGS-to-SRAP

This PJ.02-W2-14.5 V3 CBA provides the costs and benefits of the IGS-to-SRAP Solution Operational Improvement Step (OI Step AO-0331) and associated enablers; see section 3.2. It considers the standalone deployment of the Solution, i.e. independently from any other SESAR Solution(s). This means that the costs of any enablers that also enable other solutions are fully included here.

The CBA covers the period from 2022 to 2043. The Solution is assumed to be available to deploy from 2025, with initial benefits starting in late 2026 and full benefits from 2030. The CBA includes the 32 airports, from the Very Large and Large categories [10], which have been identified as candidates for deployment. Five are assumed to deploy for the airport capacity benefits, while all of them receive the noise reduction benefits. Airports in other categories, especially Medium, could also benefit from noise reduction although the scale of an airport’s benefits will depend on the population density of the area surrounding it. The associated costs and benefits for these other airports are not included in this CBA.

2.3 Intended readership

The intended readership for this document includes:

- PJ.02-W2-14.5 solution members
- PJ.02 Increased Runway and Airport Throughput – Other project partners

- PJ.19 – in its Content Integration role
- PJ.20 - in its role of Master Plan Maintenance project
- SESAR Programme Management
- Stakeholders (ANSPs and airports) interested in deploying this Solution
- Airspace Users (Scheduled Airlines, Business Aviation) interested in the deployment of this Solution

2.4 Structure of the document

This report is structured as follows:

- Section 1 provides the Executive Summary
- Section 2 provides the scope, intended readership, structure, background, glossary of terms and acronyms
- Section 3 presents the objectives and scope of this CBA, provides a description of the PJ.02-W2-14.5 IGS-to-SRAP Solution, information on the main stakeholders and descriptions of the CBA scenarios
- Section 4 described the benefits and how they are monetised as well as a view on the overall contribution to the Key Performance Indicators (KPIs)
- Section 5 details the costs along with the cost approach per stakeholder group and the associated assumptions
- Section 6 includes the CBA model and information on the sources of data used to feed it
- Section 7 provides the CBA results
- Section 8 includes the sensitivity analysis
- Section 9 includes recommendations and next steps
- Section 10 includes the references and applicable documents
- The appendices provide a visual representation of the solution concept, the rationale for using an 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.

2.5 Background

The PJ.02-W2-14.5 IGS-to-SRAP Solution builds on the PJ.02-02 Solution "Enhanced Arrival Procedures" from SESAR 2020 Wave 1. PJ.02-02 considered a group of five Enhanced Arrival Procedures (EAP). In Wave 2 each EAP has been defined as a separate Solution:

- **PJ.02-W2-14.1** (AO-0308) Closely Spaced Parallel Runways optimised operations using Staggered Thresholds (CSPR-ST) – *frozen in Wave 2*
- **PJ.02-W2-14.2** (AO-0319) Enhanced Arrival procedures using Second Runway Aiming Points (SRAP)
- **PJ.02-W2-14.3** (AO-0320) Enhanced Arrival procedures using Increased Glide Slope (ISGS)
- **PJ.02-W2-14.4** (AO-0321) Enhanced Arrival procedures using Adaptive Increased Glide Slope (A-IGS) - *frozen in Wave 2*

- **PJ.02-W2-14.5** (AO-0331) Enhanced Arrival Procedure using an Increased Second Glide Slope to a Second Runway Aiming Point (IGS-to-SRAP) – focus of this CBA

As each Solution is separate, they each have a stand-alone CBA (PJ.02-W2-14.2 SRAP, PJ.02-W2-14.3 ISGS and PJ.02-W2-14.5 ISGS-to-SRAP) developed from the PJ.02-02 CBA deliverable [20] from Wave 1 that included a consolidated analysis for the five EAP concepts. The CBA is based on nominal conditions and so the non-nominal validation exercises performed in SESAR 2020 Wave 2 have not provided additional inputs for this CBA.

The PJ.02-02 Solution built on validation work produced during SESAR 1 for projects:

- P06.08.08 D07 – Enhanced Arrival Procedures Enabled by GBAS - OSED Consolidation [15] and,
- P06.08.05 D04 – Operational Service and Environment Definition (OSED) Displaced Thresholds [16].

2.6 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.	SESAR 16.06.06 – Guidelines for Producing benefit and Impact Mechanisms (D26_04, Edition 03.00.00)
Business Case	A Business Case is a tool for decision-makers, it aims to provide them with the information they need to make a fully informed decision on whether funding should be provided and/or whether an investment should proceed. A Business Case is much more than just a financial analysis as it also includes quantitative and qualitative arguments on performance and transversal activities that are key to determining the value of the project.	SESAR 16.06.06, SESAR 1 Business Case 2016, D51, Edition 00.01.01, 13/07/16
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	SESAR 16.06.06, SESAR 1 Business Case 2016, D51, Edition 00.01.01, 13/07/16

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Term	Definition	Source of the definition
	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.	
Cost mechanisms	Cost mechanisms are a description of the potential costs of the project broken down into relevant cost categories (e.g. investment, operating).	SESAR 16.06.06, ATM CBA 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 achieved 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
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
Stakeholders	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 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 left behind a wing as it generates lift.	PJ.02-01 partners

306 **Table 1: Glossary of terms**

307 2.7 List of Acronyms

Acronym	Definition
AART	Airport Airside and Runway Throughput
ACC	Area Control Centre
AERO	Aerodrome

Acronym	Definition
A-IGS	Adaptive Increased Glide Slope
ANS	Air navigation services
ANSP	Air Navigation Service Provider
AO	Airport Operator
APP	Approach Centre
APT	Airport
APV-Baro	Approach Procedures with Vertical Guidance (using barometric altitude info)
APV-SBAS	Approach Procedures with Vertical Guidance (using SBAS altitude info)
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
AU	Airspace User
AUC	Airspace User Costs
BA	Business Aviation
BIM	Benefit and Impact Mechanisms
CAP	Capacity
CAPEX[6]	Capital Expenditure
CBA	Cost Benefit Analysis
CEF	Cost Effectiveness
CMC	Civil Military Coordination
CO_2	Carbon dioxide
CP1	Common Project 1
CSPR-ST	Closely Spaced Parallel Runways - Staggered Thresholds
db	decibel
DS	Data Set
EAO	Enhanced Arrival Operations
EAP	Enhanced Arrival Procedures
EATM	European ATM (Portal, database, dataset)
EATMA	European ATM Architecture
EC	European Commission
ECAC	European Civil Aviation Conference
EN	Enabler

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

Acronym	Definition
ENV	Environment (KPA)
eORD	Enhanced Optimised Runway Delivery (Tool)
ER	En-route
EU	European Union
EUR	Euro
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAP	Final Approach Point
FEFF	Fuel Efficiency
FLX	Flexibility
FOC	Final Operating Capability / Flight Operations Centre
FTS	Fast Time Simulation
G2G	Gate to Gate
GAT	General Air Traffic
GBAS	Ground-Based Augmentation System
GLS	GNSS (Global Navigation Satellite System) Landing System
H	High complexity (En-route/Terminal Airspace classification)
H2020	Horizon 2020
HC	High complexity (airport)
HP	Human Performance
HUM	Human (enabler)
ICAO	International Civil Aviation Organization
IGS	Increased Glide Slope
IGS-to-SRAP	Increased Glide Slope to a Second Runway Aiming Point
ILS	Instrument Landing System
INTEROP	Interoperability
IOC	Initial Operating Capability
IR	Industrial Research
IT	Information Technology
KG (kg)	Kilogram
KM	Kilometre
KPA	Key Performance Area
KPI	Key Performance Indicator
L	Large (Airport classification) / Low complexity (En-route/Terminal Airspace classification)
LC	Low complexity (airport)
Lden	Day-evening-night noise level

Acronym	Definition
M	Medium (Airport classification) / Medium complexity (En-route/Terminal Airspace classification)
M€	Millions of euros
NM	Network Manager / Nautical Mile
NOI	Noise
NPV	Net Present Value
NSA	National Supervisory Authority
O	Optional (enabler)
OE	Operating Environment
OI	Operational Improvement
OPEX	Operating Expenditure (Considers Changes in Operating Costs)
ORD	Optimised Runway Delivery (Tool)
OSED	Operational Service and Environment Definition
PAPI	Precision Approach Path Indicator
PAR	Performance Assessment Report
PAX	Passengers
PBN	Performance Based Navigation
PCP	Pilot Common Project
PI	Performance Indicator
PJ	Project
PMP	Project Management Plan
PRD	Predictability
PUN	Punctuality
R	Required (enabler)
R&D	Research and Development
RECAT	Wake Turbulence Re-categorisation
REG	Regulation (enabler)
RES	Resilience
RET	Rapid Exit Taxiway
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP APCH	Required Navigation Performance Approach
ROT	Runway Occupancy Time
RTS	Real Time Simulation
RWY	Runway
S	Small (Airport classification)

Acronym	Definition
S3JU	SESAR3 Joint Undertaking
SA	Scheduled Aviation
SAF	Safety
SBAS	Satellite-based Augmentation Systems
SEC	Security
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking
SOL	Solution
SPR	Safety and Performance Requirements
SRAP	Second Runway Aiming Point (SRAP)
STD	Standardisation (enabler)
sWP	Sub-Work Package
TEFF	Time Efficiency (KPA)
TMA	Terminal Manoeuvring Area
V3	Pre-industrial development and integration stage of the Concept Lifecycle Model (E-OCVM)
VASI	Visual Approach Slope Indicator
VH	Very High complexity (En-route/Terminal Airspace classification)
VL	Very Large (Airport classification)
VLD	Very Large Demonstration
W1	SESAR 2020 Wave 1
W2	SESAR 2020 Wave 2
WHO	World Health Organisation
WP	Work Package

Table 2: List of acronyms

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3 Objectives and scope of the CBA

3.1 Problem addressed by the solution

Some airports face the following two problems, which could be improved by deploying an Increased Glide Slope to a Second Runway Aiming Point (IGS-to-SRAP):

1) Managing arrival traffic during high-demand periods when there is a mix of aircraft sizes. The number of aircraft in the heavy category is increasing at major airports, and also at secondary airports where such aircraft types were rare in the past. At these airports, it is becoming more and more difficult to manage the cohabitation of large aircraft with the much smaller aircraft that have historically operated from secondary airports or that are interested in establishing new business jet connections with major airports. The difficulty in managing wake vortex separations can lead airports to not accept smaller aircraft during peak hours.
2) The noise impact of aircraft flying ILS (Instrument Landing System) approaches, especially during the night. This noise impact is a major limitation that constrains the operations at some airports because most airports provide straight-in ILS precision approaches on a standard 3-degree glide slope that obliges aircraft to fly low over built-up, often residential, areas. The aircraft are not always able to follow trajectories that allow optimum flap settings and engine thrust for both fuel consumption and noise.

IGS-to-SRAP will help airports meet their operational needs to optimize wake turbulence separations between arrivals while reducing the noise below the final approach.

3.2 SESAR Solution description

The Solution description in EATMA (DS23 draft) is:

> This Solution introduces the Increased Glide Slope to a Second Runway Aiming Point (IGS-to-SRAP) as a new concept of enhanced approach operation. The distance between the second threshold and the nominal one is at least of 1100m.
>
> IGS-to-SRAP increases runway performance by using two active thresholds on a single runway and an increased glide slope to the second one.
>
> By doing so, the environmental impact (e.g. noise, fuel) should be reduced. In addition, runway throughput may be increased (e.g. via optimization of runway occupancy time (ROT) and/or wake turbulence separations).

The following description is based on the Solution description from the OSED, section 3.1 (version 00.01.00, dated 27/09/22) [24].

IGS-to-SRAP is an enhanced approach operation (EAO) that will apply an Increased Glide Slope (above the angle in use to the nominal runway threshold and up to 4.49°) to a Second Runway Aiming Point further down the runway threshold (as specified in the published chart). The distance between the second threshold and the nominal one is at least 1100m. The IGS-to-SRAP procedure would be published as an alternate final procedure which can be captured at any time during the approach phase before the Final Approach Point (FAP).

Using IGS-to-SRAP will enable inbound aircraft to reduce their noise footprint (environmental benefit) and possibly reduce runway occupancy time and/or taxi-in time depending on local runway/taxiway layout. The airport capacity related benefits will be realised at capacity-constrained airports in periods of over-demand related to wake turbulence separation minima. Constraints such as weather, runway configuration, mode of operations and traffic mix will need to be considered.

The aim is to optimise traffic throughput with the existing infrastructure, while improving safety. Using an increased glide slope to a second runway aiming point could also serve as an enabler for reducing the wake vortex encounter risk, therefore potentially bringing a secondary benefit in reducing wake vortex separation minima for specific combination of leader/follower aircraft pairs. For example, IGS-to-SRAP permits 'light wake' category aircraft to fly a final approach above the approach profile of heavier aircraft flying to the primary runway threshold; this enables the smaller aircraft to avoid the wake vortex of the larger aircraft, and results in an increase in runway throughput.

Approach guidance is required for the operation of IGS-to-SRAP. This can be RNP (Required Navigation Performance), SBAS (Satellite Based Augmentation System) or GBAS (Ground Based Augmentation System). RNAV (Required Vertical Navigation Performance) guidance is also considered because it is anticipated that in 2025 most aircraft will be able to follow RNAV procedures, whereas only 25% of the fleet is expected to be GBAS-equipped.

The IGS-to-SRAP function aims at being compatible with any approach with vertical guidance: ILS, GLS (GBAS), APV-Baro or APV-SBAS based approaches.

Table 3 provides the definition of the PJ.02-W2-14.5 OI Step.

SESAR Solution ID	OI Steps ref.	OI Steps definition
PJ.02-W2-14.5	**AO-0331**	Enhanced approach operations using an increased glide slope to a second runway aiming point (IGS-to-SRAP)

Table 3: SESAR Solution PJ.02-W2-14.5 OI step

Costs and benefits are both calculated on the assumption that all required enablers are deployed by the relevant stakeholders. In addition, as the validation simulations made use of the separation delivery tool (eORD), the optional enablers corresponding to the tool have also been included for the 5 airports targeting airport capacity benefits. The other Optional enablers are not included in the cost assessment.

Table 4 lists the Required and Optional enablers, while Table 5 lists the institutional enablers.

Enabler [7] ref.	Enabler definition	Applicable stakeholders
AERODROME-ATC-102 (R)	Aerodrome ATC system to support final approach operations (distinguish approach procedures)	Air Navigation Service Provider - Civil ATS Aerodrome Service Provider - Military ATS Aerodrome Service Provider
AIRPORT-56 (R)	Runway marking, lighting and PAPI for SRAP/IGS-to-SRAP approach procedures	Airport Operator - Civil APT operator - Military APT operator
APP ATC 170 (R)	Approach ATC system upgraded to support approach procedure assignment	Air Navigation Service Provider - Civil ATS Approach Service Provider - Military ATS Approach Service Provider
HUM-024 (R)	Flight Crew new role for handling IGS-to-SRAP approach	Airspace User - Civil Scheduled Aviation - Civil Business Aviation-Fixed Wing

[7] This includes System, Procedural and Human Enablers

Enabler [7] ref.	Enabler definition	Applicable stakeholders
		- Civil General Aviation - Military Transport - Military Fighter - Military Light Aircraft
HUM-033 (R)	ATC new role for handling IGS-to-SRAP approach	Air Navigation Service Provider - Civil ATS Aerodrome Service Provider - Civil ATS Approach Service Provider - Military ATS Aerodrome Service Provider - Military ATS Approach Service Provider
A/C-86 (O)	On-board assistance to aircraft energy management	Airspace User - Civil Scheduled Aviation - Civil Business Aviation-Fixed Wing - Civil General Aviation - Military Transport - Military Fighter - Military Light Aircraft
A/C-87 (O)	On-board assistance to flare	Airspace User - Civil Scheduled Aviation - Civil Business Aviation-Fixed Wing - Civil General Aviation - Military Transport - Military Fighter - Military Light Aircraft
AERODROME-ATC-94 (O)	Aerodrome ATC System to support IGS-to-SRAP operations (separation delivery)	Air Navigation Service Provider - Civil ATS Aerodrome Service Provider - Military ATS Aerodrome Service Provider
APP ATC 163 (O)	Approach ATC System to support IGS-to-SRAP operations (separation delivery)	Air Navigation Service Provider - Civil ATS Approach Service Provider - Military ATS Approach Service Provider

374 **Table 4: AO-0331 related Enablers**

375 The institutional enablers, REG-0533 and STD-112, listed in the Wave 1 PJ.02-02 CBA, have been
376 allocated to system and human enablers in more recent datasets. They are listed in Table 5 to give a
377 link to the Wave 1 PJ02-02 CBA. Section 5 explains how they are considered in the cost assessment.

Enabler ref.	Enabler definition	Applicable stakeholders
REG-0533 Allocated to AERODROME-ATC-94 (O), APP ATC 163 (O)	Regulatory provisions for Increased Glide Slope to Second Runway Aiming Point operations (IGS-to-SRAP)	Institutional enabler - unassigned in DS23 draft
STD-112 Allocated to HUM-024 (R), AIRPORT-56 (R)	Update of EASA and ICAO regulatory frameworks for new visual ground aids (SRAP)	Institutional enabler - unassigned in DS23 draft

378 **Table 5: AO-0331 Institutional Enablers**

379 3.3 Objectives of the CBA

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This V3 Cost Benefit Analysis helps to build an assessment of whether PJ.02-W2-14.5 is worth deploying from an economic perspective for the involved stakeholders.

The objective is to provide an assessment of the costs and benefits of deploying an increased glide slope to a second runway aiming points (IGS-to-SRAP) at the 32 Very Large and Large airports that have been included in the ECAC-level CBA Solution Scenario. Five of the airports target the airport capacity benefits while all of them receive the noise benefits. The airports are not named in the CBA to avoid the implication that those airports have made any commitment to deploy PJ.02-W2-14.5.

This CBA assesses whether the benefits of the deployed Solution are expected to exceed the costs over the CBA time horizon (up to 2043). It does this using discounted cash flow analysis which provides the Net Present Value (NPV) for the Solution and per stakeholder group. As there is a positive NPV, the break-even year and payback period are provided; respectively, these are the year from which the benefits will cover the costs incurred and the number of years from the start of the project before this occurs.

The CBA results are also explored through a sensitivity analysis to assess the impact on the NPV of changes to the input values, e.g. a doubling of the costs and a halving of the benefits.

As the CBA provides results at ECAC-level it does not provide sufficient detail to support individual deployment decisions that must take into account the local environment/situation (e.g. current operational systems, their lifespan(s), replacement timing, etc.). However, interested parties can take the mechanisms and inputs used here and refine them for their local CBAs, if appropriate.

Note that the key inputs for the PJ.02-W2-14.5 CBA come from SESAR 2020 Wave 1 PJ.02-02 as no additional performance data will be produced by the PJ.02-W2-14.5 Wave 2 validation activities. Cost data was originally provided by PJ.02-01 and PJ.02-02 members and has been reviewed in Wave 2 with Airport Operator costs being updated.

3.4 Stakeholders[8] identification

The CBA results are presented at solution level and individually from the viewpoint of each impacted stakeholder group, i.e. those that need to invest and those who will receive benefits from the Solution.

- ANSPs providing approach (APP) and tower (AERO) services at the deploying airports
- Airport Operators at the deploying airports
- Airspace Users[9] who operate at the deploying airports
- Society focused on the inhabitants living around the deploying airports

Table 6 describes how each stakeholder is impacted by the IGS-to-SRAP solution in terms of costs and benefits.

Stakeholder	Type of stakeholder and/or applicable sub-OE	Type of Impact	Involvement in the CBA task	Quantitative results available in the CBA

[8] Note that the terminology used to describe AU stakeholders in the CBA differs from that associated with Enablers in the dataset. This is due to costing being provided for different types of aircraft regardless of the operations they perform.

[9] Note that the terminology used to describe AU stakeholders in the CBA differs from that associated with Enablers in the dataset. This is due to costing being provided for different types of aircraft regardless of the operations they perform.

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ANSPs	ATCOs, TMA (APP) and Tower (Aerodrome) control Centres	Benefits: ANS charges from the additional movements Costs: implementation of tools and functionalities (assigning and identifying the approach procedures and separate delivery, where needed) to allow the ATCO to handle arrivals using two glide slopes to separate runway aiming points	PJ.02 partners providing cost inputs	Costs and monetised benefits
Airport Operators	Very Large and Large Airports	Benefits: • Noise reduction in the areas close to the airport could reduce capacity restrictions due to noise allowing an improved quality of service to AUs • Runway Occupancy Time reduction, leading to potential increase in runway capacity Costs: investments are needed for the runway (lighting, marking) and PAPI (Precision Approach Path Indicator)	No involvement	Costs and monetised benefits
Network Manager	Network	Benefits: no direct benefits for NM although the network will benefit from additional runway capacity during relevant airport capacity-constrained periods Costs: no costs as there are no changes to NM systems or operations	No involvement	No costs or benefits included
Scheduled Airlines (Mainline and Regional) / Business Aviation	Flight Crew, Schedule Planner, Safety and Training Departments	Benefits: time efficiency and fuel efficiency associated with improved flight profiles, reduced runway occupancy time and shorter taxi routes, where applicable, when using the IGS-to-SRAP. AU will also benefit from the increase of runway capacity during peak periods which can enable additional flights (reduce unaccommodated demand). Costs: investments are needed for flight crew training (pilot) for IGS-to-SRAP procedures	No involvement	Costs and monetised benefits
Regulation Authority	National Supervisory Authority (NSA) / Ministry of Transport	New operations need to be approved before they can become operational and provide the stakeholder benefits mentioned in this table. Benefits: no benefits Costs: no costs for regulatory authorities, the cost for regulation	No involvement	No costs or benefits

		drafting are taken into account in the ANSP costs		
Society	Communities around airports and passengers	Benefits: Communities around airports are interested in environmental benefits, especially noise reduction, coming from the implementation of the IGS-to-SRAP solution Passengers will indirectly benefit from SRAP through the increase in runway capacity, which could result, for example, in an increase in available destinations and the avoidance of diversions due to missing curfews.	No involvement	Societal benefits have been monetised following the reduction in noise contours around the airports. The other mentioned passenger benefits are not included in the CBA.

Table 6: SESAR PJ.02-W2-14.5 solution CBA Stakeholders and impacts

3.5 CBA Scenarios and Assumptions

This section describes the scenarios that are compared in the CBA. The comparison is between the CBA 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). The CBA uses a delta approach where the focus is on the costs and benefits associated with the ECAC-level deployment of the solution, i.e. with the changes from the CBA Reference Scenario.

Defining the CBA Reference Scenario has proven to be very challenging for many Solutions 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 (2022) and the Solution Scenario.

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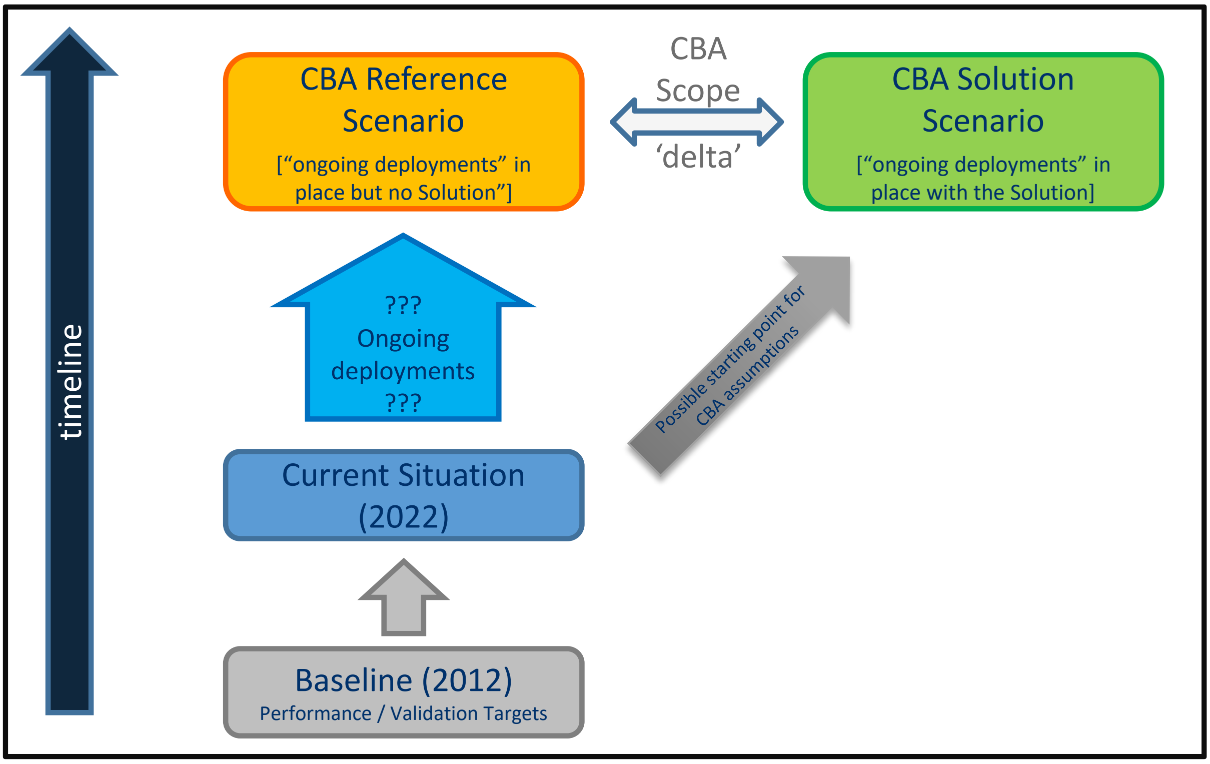

Figure 1: Scenario Overview

3.5.1 CBA Reference Scenario

The CBA Reference Scenario reflects the future situation where PJ.02-W2-14.5 is not deployed.

It is assumed that any relevant Common Project 1 (CP1) elements have been deployed at applicable airports in line with the SESAR Deployment Programme planning.

For the wake turbulence schemes, the current operational environment is assumed in the CBA Reference Scenario i.e. RECAT-EU[10] and ICAO[11] (3 categories+A380). Relevant benefits are assessed from this starting point.

3.5.2 CBA Solution Scenario

The deployment of the Solution involves the implementation of the enablers listed in section 3.2, which include:

- The runway markings, lighting and PAPI for each second runway aiming point (Airport-56 (R)); the CBA includes one implementation per airport, the costs of deploying on additional runways are not included in this CBA

- A controller tool to support final approach operations (Aerodrome-ATC-102 (R), APP ATC 170 (R))

[10] RECAT-EU: European Wake Turbulence Categorisation and Separation Minima on Approach and Departure (applicable scheme at Charles de Gaulle and London Heathrow)
[11] ICAO Wake Turbulence Scheme https://www.skybrary.aero/index.php/ICAO_Wake_Turbulence_Category (applicable scheme at all other airports)

- A controller separation support tool (eORD) to support the use of IGS-to-SRAP (optional for lower traffic levels where the focus is on the noise benefits) (Aerodrome-ATC-94 (O), APP ATC 163 (O))
- ATCO training (HUM-033 (R))
- Flight crew training (HUM-024 (R))

The 32 airports included in the CBA Scenario are assumed to deploy IGS-to-SRAP to achieve the noise benefits. The airports all come from the Very Large and Large airport categories [11]. Five of those airports are considered to target the airport capacity benefits and will deploy the optional separation tool as they have significant periods of capacity-constrained peak traffic. The airports are not named to avoid the implication that those airports have made any commitment to deploy PJ.02-W2-14.5. Medium or smaller airports may also choose to deploy the solution to gain the noise reduction benefits, however, such deployments are not included in the CBA.

The capacity benefits will depend on the percentage of Medium aircraft that are able to use the IGS-to-SRAP and on the distance between the two thresholds. As mentioned above, the CBA includes capacity benefits for 5 airports. However, it is expected that both the number of airports with capacity-constrained peaks and the duration of peaks will increase over time, which could result in additional capacity benefits in the future.

For each airport the exact benefits will depend on several factors including specific traffic mix, length of traffic peak, wind conditions, applicable surveillance minima, glide parameters, fraction of aircraft type operating on the IGS-to-SRAP, runway occupancy time, glide length, runway layout, airport infrastructure, etc.

The key criteria that identify an airport as a candidate deployment location for IGS-to-SRAP are:

1) Final Spacing

IGS-to-SRAP is assumed to be compatible with both current and future separation schemes such as Time Based Spacing. It is however worth noting that Enhanced separation minima, based on legacy ICAO wake turbulence categories or on RECAT-EU categories, are specified as a function of which approach the lead and follower aircraft are flying, the EAO glideslope angle and the distance between the conventional landing threshold and the displaced one. This, for example, may allow a safe separation minima reduction of up to 1.5 NM for some pairs like Lower Medium behind Upper Heavies, compared to the standard in-trail separation.

2) Airport layout

IGS-to-SRAP is applicable to any airport layout from single to multiple runways with simple or complex taxiway structures. However, the overall airport layout along with airport neighbourhood topography may bring constraints that will be determine if implementation is feasible and will bring the intended benefits, (e.g. the runway length which needs to be long enough to accommodate the second threshold, the availability or lack of rapid runway exits (RET) at appropriate positions, the impact on runway occupancy time).

3) Runway operating mode

IGS-to-SRAP is applicable to both dependent and independent runways in both mixed and segregated mode operations.

4) En-Route/TMA Operations

IGS-to-SRAP is applicable to any arrival traffic management operations (radar vectoring, PBN route structure, vertical instructions, Continuous Descent Operations, speed instructions, etc.)

5) Traffic Mix

IGS-to-SRAP is applicable to airports serving both IGS-to-SRAP capable and non-capable aircraft. Any aircraft wake category mix can be serviced. However, it is worth noting that, as anticipated in the near to medium term horizon, only part of the traffic will be equipped with advanced satellite-based approach capability (e.g. GBAS or SBAS), some aircraft types from the Medium or Light category groups will need to remain on the conventional approach if RNP APCH types are needed. In order to apply the adequate separation minima for an arrival pair, the Approach and Tower ATCOs need to know which aircraft types are eligible to use the IGS-to-SRAP.

6) Weather

Wind has an impact on increased glide slope operations due to more challenging aircraft energy management under tailwind conditions. Thus, a reduced use of IGS-to-SRAP operations can be expected under such conditions.

7) Runway conditions

IGS-to-SRAP is applicable regardless of the runway conditions.

8) Airspace consideration

IGS-to-SRAP is compatible with both high traffic density and low traffic density situations, although the realised benefits will differ. IGS-to-SRAP will be conducted only in controlled airspace where separation is ensured (classes A, B, C, D and E, according to ICAO classification of airspaces).

CBA timeline

The CBA covers the period from 2022 to 2043 as defined by PJ19.04; this mean that Net Present Value is calculated by discounting the cash-flows back to 2022 (the end of Wave 2).

Table 7 lists the key dates used in the CBA and Figure 2 shows them over a timeline.

Dates	PJ.02-W2-14.5
Start of deployment date: the start of investments for the first deployment location	**2025**
End of deployment date: the end of the investments for the final deployment location, same as FOC	**2030**
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.	**Late 2026**
Final Operating Capability (FOC): Maximum benefits from the *full deployment*[12] of the Solution at applicable locations. Investment costs are considered to end[13] here although any operating cost impacts would continue.	**2030**

Table 7: CBA Investment and Benefit Dates

[12] 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)

[13] The basic assumption is that infrastructure does not need to be replaced during the CBA period

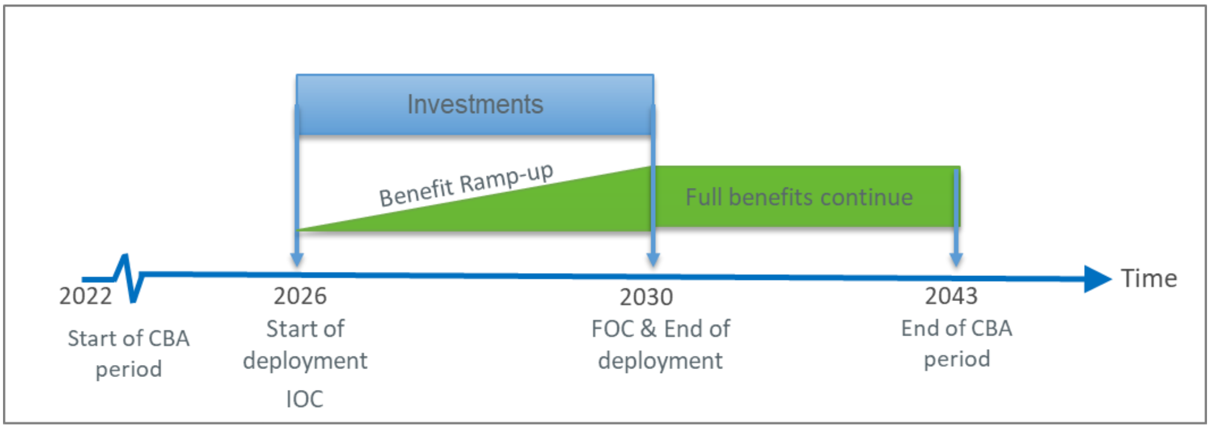

Figure 2: Overview of CBA Dates

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.

3.5.3 Assumptions

Costs and benefits have been computed from fast-time validation exercise results, partners' contributions and average values taken from the PJ.19.04 Common Assumptions for extrapolation to ECAC-Level.

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

4 Benefits

The main objective of solution PJ.02-W2-14.5 IGS-to-SRAP is to **reduce the environmental impact** (mainly the noise footprint) during the arrival procedure to airports while **increasing airport capacity** when possible.

The solution Performance Assessment Report (PAR[14], [25]) shows that the solution improves fuel efficiency (FEFF1), time efficiency (TEFF1), airport noise (NOI2), airport capacity (CAP3.2), and ATCO productivity (CEF2). The PAR extrapolates the local performance gains (calculated based on a fast-time simulations in Wave 1) to ECAC level assuming that the solution will impact all the traffic occurring at "high-density airports" (SESAR 1 airport classification [11]).

This CBA re-calculates the extrapolation, introducing the following changes in comparison with the PAR:

- The CBA assumes implementation in Very Large and Large airports (SESAR2020 Wave 2 Classification [11]), instead of "high-density airports"
- The CBA considers that the solution works during peak and off-peak hours so that the fuel savings, flight time savings, and noise reduction benefits are present the whole day
- The CBA only considers peak periods to extrapolate the airport capacity gain (& ATCO productivity). Therefore, the CBA only monetises the extra runway throughput when there is demand for it (i.e. in capacity-constrained peak periods).
- As per section 3.5.2, fuel & flight time savings and airport capacity gain only applies to five (5) airports, whereas the noise reduction applies to all the thirty-two (32) VL and L airports. This is a conservative approach to avoid over-estimating the benefits, as any flight using the IGS-to-SRAP may receive the fuel and flight time saving benefits depending on the airport and its layout.

Table 8 shows the local benefits the CBA applies to the Very Large and Large airports, as per the bullets listed above. The average value in each case is used to calculate the benefits.

Performance gain	KPI	Low value[15]	High value
Fuel savings	FEFF1	-9.08 kg fuel per arrival	-186.76 kg fuel per arrival
Flight time savings	TEFF1	-0.25 minutes per arrival	-3.16 minutes per arrival
Airport capacity gain	CAP3.2	-1.8%	+7.7%
ATCO productivity gain	CEF2	-1.8%	+7.7%
Noise reduction	NOI2 – 55dB contour	+0.92 km^2 per airport	-2.73 km^2 per airport

[14] Note that the PJ.02-W2-14.5 PAR [25] inputs are taken from the SESAR 2020 Wave 1 PJ.02-02 PAR [18] as no additional performance data will be produced by the PJ.02-W2-14.5 Wave 2 validation activities as they only focus on non-nominal situations.

[15] Note that for the Low value, the airport capacity, ATCO productivity and noise reduction are negatively impacted so the airport capacity is reduced and the noise contour actually increases. These results are due to the specific traffic and assumptions used in the fast time simulations to explore the limits of the concept, see the Validation Report [26] for more details.

	NOI2 – 65dB contour	-0.50 km^2 per airport	-0.57 km^2 per airport
	NOI2 – 75dB contour	-0.07 km^2 per airport	-0.14 km^2 per airport

Table 8: Solution PJ.02-W2-14.5 ISGS-to-SRAP local benefits [25]

4.1 Benefit Monetisation Mechanisms

4.1.1 Extrapolation assumptions

Table 9 shows the SESAR Common Assumptions [12] that the CBA uses to extrapolate IGS-to-SRAP local benefits to the Very Large and Large airports.

Item	ID	Value	Unit
Contribution to total En-Route traffic from Very Large airports	APT-VL-2035	0.71	Movements per ECAC flight[16]
Contribution to total En-Route traffic from Large airports	APT-L-2035	0.21	Movements per ECAC flight
Contribution to total En-Route traffic from Very Large airports during peak traffic	APT-PC-VL-2035	0.47	Movements per ECAC flight
Contribution to total En-Route traffic from Large airports during peak traffic	APT-PC-L-2035	0.15	Movements per ECAC flight
Percentage of arrivals per TMA movement	M-0012	50%	%
Average ECAC flight time	T-0010	1.7	hours
Average fuel burn per flight	F-0001	5,280	Kg per flight

Table 9: SESAR Common Assumptions (Annex 1, v5, 17-10-2019)

The percentage of ECAC traffic that benefits from the solution are calculated as follows:

- Traffic at VL and L airports: $0.71 + 0.21 = 0.92$ movements per ECAC flight
- Arrivals at VL and L airports: $0.92 \cdot 50\% = 46\%$ of the ECAC flights
- Arrivals at 5 VL and L airports: $\frac{5}{32} \cdot 46\% = 7.2\%$ of the ECAC flights

Therefore, the FEFF1 and TEFF1 local benefits are multiplied by 7.2% to calculate the ECAC-wide performance gain. The NOI2 benefit calculation follows a different approach (see section 4.1.6).

[16] For Airports the traffic contribution to total traffic handled per sub-OE category is the sum of annual movements at each specific sub-OE within the same category divided by the annual IFR ECAC flights, because the volume of arrival and departure traffic is best considered in number of movements. The sum of all sub-OE traffic contributions of the TMA and airport OEs, respectively, is less than 2 movements per flight because of flights departing to or arriving from outside ECAC.

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The CAP3.2 (and CEF2) benefits are multiplied by 4.9% instead, to monetise airport capacity benefits only during peak hours:

- Peak traffic at VL and L airports: $0.47 + 0.15 = 0.62$ movements per ECAC flight
- Peak arrivals at VL and L airports: $0.62 \cdot 50\% = 31\%$ of the ECAC flights
- Peak arrivals at 5 VL and L airports: $\frac{5}{32} \cdot 31\% = 4.9\%$ of the ECAC flights

4.1.2 Fuel Efficiency (FEFF1)

The CBA considers the average local performance gain to calculate the FEFF1 extrapolation to the ECAC:

- Average local FEFF1 gain: -97.92 kg per arrival
- ECAC FEFF1 gain (absolute): $-97.92 \text{ kg per arrival} \cdot 7.2\% = -7.07 \text{ kg per flight}$
- ECAC FEFF1 gain (relative): $-7.07\text{kg} \ / \ 5280\text{kg} = -0.13\%$

The CBA monetise the Fuel Efficiency as the value of the savings in fuel (FEFF1) and, consequently, in CO_2 (ENV1). Figure 3 shows the CBA monetisation mechanism for Fuel Efficiency.

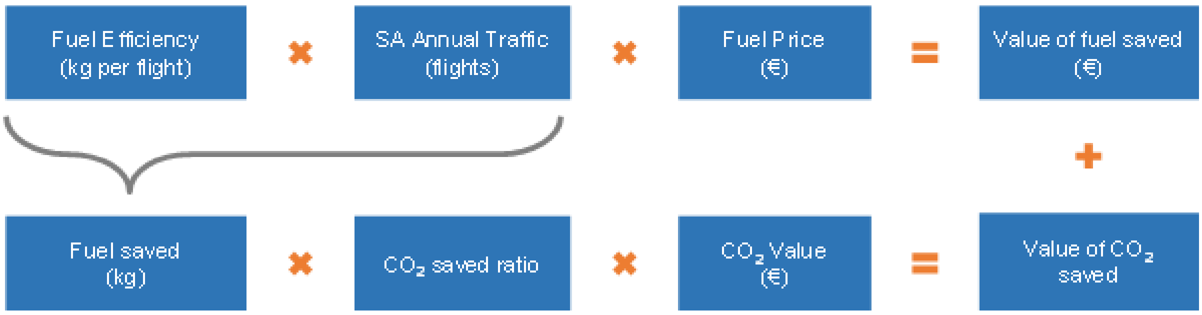

Figure 3: Fuel Efficiency and CO2 Monetisation Mechanisms

4.1.3 Time Efficiency (TEFF1)

The Time Efficiency savings refer to a reduction in the average flight time (minutes/flight) for each aircraft. Again, the CBA considers the average local performance gain to calculate the TEFF1 extrapolation to the ECAC:

- Average local TEFF1 gain: -1.71 minutes per arrival
- ECAC TEFF1 gain (absolute): $-1.71 \text{ minutes per arrival} \cdot 7.2\% = -0.12 \text{ minutes per flight}$
- ECAC TEFF1 gain (relative): $-0.12 \text{ min} \ / \ (1.7 \text{ hours} \cdot 60 \text{ min}) = -0.12\%$

The CBA model monetises time efficiency only as strategic delay savings, see Figure 4, to avoid double counting benefits with the flight efficiency gain (fuel and emissions).

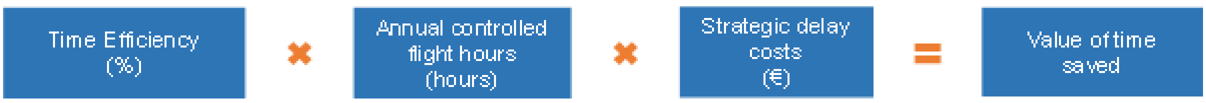

Figure 4: Time Efficiency Monetisation Mechanism

4.1.4 Airport Capacity (CAP3.2)

The CBA only monetises the airport capacity gain during the peak periods at the implementing airports, reflecting when there is unaccommodated demand that would benefit from the extra runway throughput. Once again, the CBA considers the average local performance gain to calculate the CAP3.2 extrapolation to the ECAC:

- Average local CAP3.2 gain: +3.0% arrivals
- ECAC CAP3.2 gain (relative): $+3.0\%\ \text{arrivals} \cdot 4.9\% = +0.15\%$

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

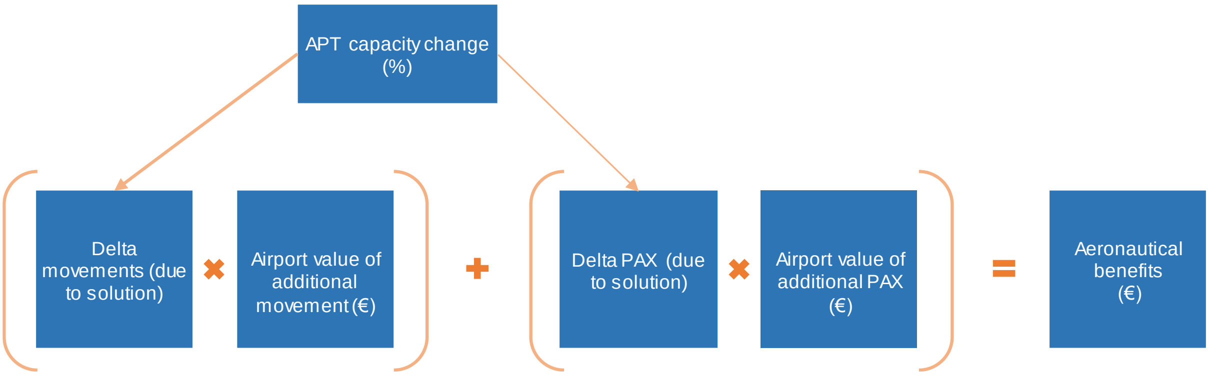

Figure 5: Airport Capacity Monetisation Mechanisms

4.1.5 ATCO Productivity (CEF2)

The PAR [25] also claims an ATCO Productivity change (CEF2) based on the additional runway throughput (i.e., the same number of APP-TWR ATCOs will handle more movements during the airports' peak periods).

- ECAC CEF2 gain (relative): $= +0.15\%$

The mechanisms in the CBA model are based ATCO Productivity, as shown in Figure 6, which come from the ATM Cost Effectiveness (ACE) benchmarking report [21].

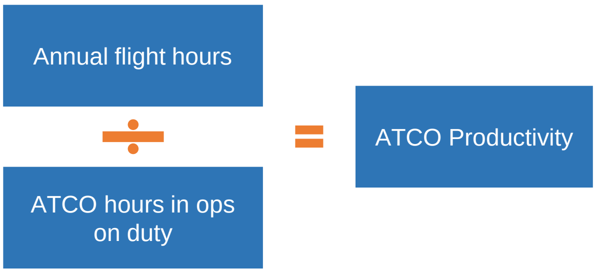

Figure 6: ATCO Productivity

4.1.6 Noise Reduction (NOI2)

Whilst the increase in traffic volume results in higher noise levels, the increase in urbanisation results in a higher number of people experiencing disutility due to noise. Communities around airports are interested in environmental benefits, especially noise, coming from the implementation of the IGS-to-SRAP solution. In general, noise can be defined as unwanted sounds of varying duration, intensity or other quality that cause physical or psychological harm to humans.

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The PAR [25] calculates the noise benefits as the reduction in the size of the noise contours (NOI2) around the airport area when the IGS-to-SRAP solution is applied. The CBA considers the average reduction in this noise contour and then multiplies it by (i) the average population density and (ii) the value of noise per person.

Since the PAR calculates the change in noise contour area per decibel band, the CBA estimates the cost of noise per decibel band too.

The population density is the average of the cities where the Very Large and Large airports are located, which results in 4,788 inhabitants per square kilometre[17].

The cost of noise (EU28 averages) is extracted from the Handbook[18] on the external costs of transport Version 2019 [22], which takes into account only health and annoyance costs. Section 7 refers to these benefits as Societal Benefits.

Noise (Lden)	Annoyance	Health	Total	Unit
50-54 dB(A)	34	5	39	EUR per dB per person per year
55-59 dB(A)	68	6	74	
60-64 dB(A)	68	9	77	
65-69 dB(A)	129	12	141	
70-74 dB(A)	129	16	145	
≥75 dB(A)	129	21	150	

Table 10: Environmental price of traffic noise for EU28
(CE Delft- Handbook on the external costs of transport Version 2019)

Annoyance represents the disturbance individuals experience when they are exposed to traffic noise. It can hinder people from performing certain activities, which may lead to a variety of negative responses, including irritation, disappointment, anxiety, exhaustion and sleep disturbance (WHO, 2011). Sleep disturbance is not considered a separate component in this value to avoid potential double counting. If one is asked about their annoyance they are inclined to also take into account the effects of sleep disturbance; therefore sleep disturbance is assumed to be included in the annoyance.

Concerning *health*, exposure to noise results in several health endpoints due to prolonged and frequent exposure to transport noise. According to the CE Delft report, "t*hese health endpoints can take a multitude of forms. Health endpoints for which significant evidence is available are ischaemic heart disease, stroke, dementia and hypertension. For health endpoints not mentioned in the list above, e.g. breast cancer and depression, only fragmented evidence is available. Therefore, these costs are not included in the noise costs estimated in this study. For the same reason, productivity losses (e.g. loss of concentration) and environmental impacts of traffic noise (e.g. harmful effects on wildlife) are not covered. Finally, direct material damages as a result of vibrations are not included in the costs of noise in this study, as the vibrations are not necessarily an effect of noise, but rather an external effect on its own.*"

Further benefits related to reduced noise taxes have not been included in this CBA due to limited, thus non-exhaustive, information concerning noise taxation around the ECAC area airports.

The following tables translate the solution noise benefit (NOI2) into avoided "cost of noise" for the population[19] living in the airports' cities.

Noise (Lden)	Area reduction (km^2)	Population density (hab/km^2)	Population reduction (inhabitants)

[17] European Commission, Urban Centre Database UCDB R2019A, Population density value in 2015.
[18] CE Delft (on behalf of the European Commission).
[19] Differences are due to rounding

75 dB(A)	0.11	4,788	503
65 dB(A)	0.54	4,788	2,562
55 dB(A)	0.91	4,788	4,333

Table 11: Reduction in population impacted by noise per airport

Noise (Lden)	Population reduction (inhabitants)	Noise cost (EUR per person per year)[20]	Noise cost (EUR per year)
75 dB(A)	503	150	75,414
65 dB(A)	2,562	141	361,199
55 dB(A)	4,333	74	320,667
		Total	**757,281**

Table 12: Avoided cost of noise per airport

The CBA considers that 32 Very Large and Large airports benefit from the IGS-to-SRAP procedures in terms of reduction of noise. Therefore:

- Noise cost savings (ECAC): $€757{,}281 \text{ per airport} \cdot 32 \text{ airports} = 24.2 \text{ M€ per year}$

Finally, Figure 7 shows the noise monetisation mechanism applied in the CBA model.

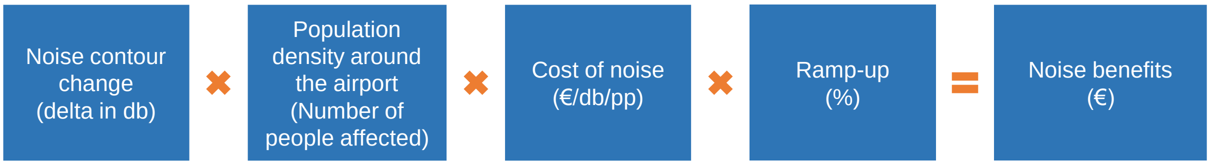

Figure 7: Noise reduction Monetisation Mechanism

4.1.7 Summary of benefits

Table 13 summarises the benefit inputs for the CBA model, which have been calculated based on the solution Performance Assessment Report (PAR, [25]) and updated as described in section 4:

Performance gain	KPI	CBA input (ECAC)
Fuel savings	**FEFF1** *(ENV1)*	**-7.07kg of fuel per flight** *(-22.26kg of CO_2 per flight)*
Flight time savings	**TEFF1**	**-0.12%** *(-0.12min per flight)*
Airport capacity	**CAP3.2**	**+0.15%**
ATCO productivity	**CEF2**	**+0.15%**
Noise reduction	**NOI2**	**€24.2m per year** *(aggregated benefit for 32 Very Large and Large airports)*

Table 13: Solution PJ.02-W2-14.5 IGS-to-SRAP ECAC-wide benefits

[20] Considering only 1dB reduction per person. This is a conservative assumption since the PAR provides the noise footprints every 10dB.

660 ## 4.2 Benefit Monetisation of the Performance Framework KPI/PI

Performance Framework KPA[21]	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	€	0 M€ The additional traffic is handled with the same ATCO-hours
				Support Staff Employment Cost Change	€	
				Non-staff Operating Costs Change	€	
		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
		AUC4 Indirect operating costs for an airspace user	EUR / flight	Impact on operating costs that do not 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**	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	No validation target€

[21] For information, the mapping to the Performance Ambition KPAs (used in the ATM Master Plan) is available in the Appendix C

Performance Framework KPA[21]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Total benefits from IOC to 2040
		TMA throughput, in challenging airspace, per unit time	% 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	€	1,308 M€
	Resilience	**RES4a** Minutes of delays	Minutes	Tactical delay cost (avoided-; additional +)	€/year	No Validation Target
		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 +)	€	No Validation Target
	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	**FLX1** Average delay for scheduled civil/military flights with change request and non-	Minutes	Tactical delay cost (avoided-; additional +)	€/year	No Validation Target

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Performance Framework KPA[21]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Total benefits from IOC to 2040
	planned flights and mission	scheduled / late flight plan request				
Environment	Time Efficiency	**TEFF1** Reduction in average flight duration	% and minutes	Strategic delay: airborne: direct cost to an airline excl. Fuel (avoided-; additional +)	€	870 M€
	Fuel Efficiency	**FEFF1** Average fuel burn per flight	Kg fuel per movement	Fuel Costs	€	1,566 M€
	Fuel Efficiency	**FEFF2** CO2 Emissions	Kg CO2 per movement	CO2 Costs	€	55 M€
	Noise	**NOI2** Surface of these contours(Km2)	km^2 (per decibel band)	Cost of noise	€	387 M€
	Noise	**NOI4** Number of people inside noise contours	People affected			
Civil-Military Cooperation & Coordination	Civil-Military Cooperation & Coordination	**CMC2.1a** Fuel saving (for GAT operations)	Kg fuel per movement	Fuel Costs	€/year	No Validation Target
		CMC2.1b Distance saving (for GAT operations)	NM per movement	Time Costs	€/year	No Validation Target

661 **Table 14: Results of the benefits monetisation per KPA**

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5 Cost assessment

This section contains the cost assessment information for the stakeholders that need to deploy enablers for PJ.02-W2-14.5. The costs cover the implementation of IGS-to-SRAP at 32 candidate airports, 5 of which will use it to increase airport capacity while all will receive the noise reduction benefits. The costs include the investment costs of acquiring or developing the systems, specific adaptations and functionalities, additional inputs of static information, integration costs, training costs, regulatory costs as well as the costs associated with the project management and development and documentation of procedures, (i.e. everything needed to get IGS-to-SRAP into operations). An assessment has also been made of changes in annual operating costs following the deployment, for example, changes in maintenance costs or ongoing training costs.

The optional enablers related to the separation delivery tool (eORD) are included in the CBA for the 5 airports as they are considered necessary to achieve the airport capacity benefits during peak periods. The airborne optional enablers are not included in the cost assessment.

The values included here were initially defined in Wave 1, by the PJ.02-02 (Enhanced Arrival Procedures) and PJ.02-01 (Wake Turbulence Separation Optimization) CBA teams along with other operational and technical experts, using a bottom-up approach to estimate the stakeholders' implementation and operating costs. The values have been reviewed in Wave 2 leading to some updates.

As mentioned in section 3.2, the institutional enablers related to IGS-to-SRAP, REG-0533 and STD-112, are now linked to the system and human enablers, rather that appearing independently as they did when the PJ.02-02 CBA was produced. For the following cost assessment, it is assumed that:

- STD-112 "Update of EASA/ICAO regulatory frameworks for new visual ground aids (SRAP)" is a pre-requisite to the deployment of IGS-to-SRAP and the costs of updating the frameworks are not included.

- REG-0533 "Regulatory provisions for Increased Glide Slope to Second Runway Aiming Point operations (IGS-to-SRAP)" is an enabler that is addressed for each deployment with the relevant ANSP covering the costs of the activity to get advice from the regulatory authorities on the acceptability of the safety case supporting the IGS-to-SRAP related ATM rule modification.

5.1 ANSPs costs

The ANSP stakeholder covers several different service provision aspects, for PJ.02-W2-14.5 this includes ATS provision at Aerodromes (Tower) and in Approach (terminal airspace, TMA). Within DS23 draft, some of the enablers are identified as applicable for Military ANSPs, however, due to the candidate airports included in the CBA the Military stakeholders are not included in the cost assessment for this solution[1].

5.1.1 ANSPs cost approach

Costs were estimated based on expert judgement and are in line with other PJ.02 solutions considering an increased glide slope and those using the separation delivery tool (eORD) as an optional enabler.

The separation delivery tool is included in the cost assessment for the 5 candidate airports targeting the airport capacity benefit. For the other candidate airports, the eORD is not included as it is not

[1] Some enablers are also required or optional for other solutions in which the Military stakeholders may have a role.

considered necessary to achieve the noise reduction benefits during off-peak periods, especially at night.

What is needed is the information for the approach controller to know which aircraft are capable of flying the IGS-to-SRAP and to record which glide slope a flight has been assigned. The aerodrome (Tower) controller then needs to be provided with the information. The cost impact of providing and capturing this information can differ depending on the system being used, for example, if the controllers are still using paper strips or have electronic strips.

5.1.2 ANSPs cost assumptions

Costs for this solution are mainly borne by the ANSPs to provide the relevant tools and functionalities in the approach and aerodrome (tower) systems. This assumes that costs for the controller systems used at the airports and their relevant maintenance are incurred by the ANSPs[2].

The CBA includes the set of Very High and High complexity Approach Centres handling Terminal Airspace (either Terminal Airspace Only or En-route and Terminal Airspace [10]) and assumes that these handle the arrivals for the Very Large and Large airports, where some handle arrivals for two or more Very Large or Large airports. As a conservative approach, the costs for the optional separation delivery tool are allocated to 5 airports and 5 approach centres.

While not included in the CBA, the following costs, without the separation tool, are considered applicable for other airports, e.g. Medium airports, that may want to deploy IGS-to-SRAP for the noise benefits.

5.1.3 Number of deployment locations (units)

Table 15 shows that the CBA includes the ANSPs providing services at the 32 Very Large and Large candidate airports included in the CBA Solution Scenario. Of those 32 airports, 5 are also allocated costs for the optional separation delivery tool to enable them to benefit from increased airport capacity during peak periods. The other 27 airports are only allocated the required enablers.

Five approach centres are also allocated the costs for the optional separation delivery tool. The other 20 approach centres are only allocated the required enablers.

Airport (Aerodrome)				Approach Centre handling Terminal Airspace				En-route			
VL	L	M	S	VH	H	M	L	VH	H	M	L
5 + 27 (32)		0	0	5 + 20 (25)		0	0	Not applicable			

Table 15: Number of investment instances – ANSPs

5.1.4 Cost per unit

Table 17 shows the cost per enabler for the deployment per airport (aerodrome) while Table 17 shows the costs per approach centre. The tables show the total cost with and without the optional separation tool.

The costs associated with REG-0533 are only allocated to the aerodrome costs to avoid double counting.

[2] In reality the situation will differ across airports as some airports may own and maintain the systems.

Enabler	Enabler Title	Implementation Costs (M€)	Operating costs (M€/year)
AERODROME-ATC-102 (R)	Aerodrome ATC system to support final approach operations (distinguish approach procedures)	0.20	-
AERODROME-ATC-94 (O)	Aerodrome ATC system to support IGS-to-SRAP operations (separation delivery)	2.50	0.05
REG-0533[3] (R)	Regulatory provisions for Second Runway Aiming Points operations (SRAP)	0.05	-
HUM-31 (R)	ATC training for IGS-to-SRAP approach	Included in the tool costs	-
Aerodrome Total for AO-0331	**With optional Separation tool (5 airports)**	**2.75**	**0.05**
	Without the optional Separation tool (27 airports)	**0.25**	**0**

Table 16: ANSP Costs per Enabler (Aerodrome) and per deployment location

Enabler	Enabler Title	Implementation Costs (M€)	Operating costs (M€/year)
APP ATC 163 (O)	Approach ATC system to support IGS-to-SRAP operations (separation delivery)	7.50	0.05
APP ATC 170 (R)	Approach ATC system upgraded to support approach procedure assignment	0.20	-
HUM-31 (R)	ATC training for IGS-to-SRAP approach	Included in the tool costs	-
Approach Total for AO-0331	**With optional Separation tool (5 approach centres)**	**7.70**	**0.05**
	Without the optional Separation tool (20 approach centres)	**0.20**	**0**

Table 17: ANSP Costs per Enabler (Approach) and per deployment location

5.2 Airport operator costs

The Airport operator enabler is identified within the DS23 draft as being applicable to both civil and military airports. Due to the candidate airports included in the CBA the Military airport operators are not considered applicable for this solution[4].

[3] REG-0533 is a regulatory enabler that is now assigned to several of the system and human enablers rather than appearing as a standalone enabler. However, it remains listed here to reflect the structure when the cost assessment was performed.
[4] Some enablers are also required or optional for other solutions in which the Military stakeholders may have a role.

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5.2.1 Airport operator cost approach

Costs were estimated in Wave 1 by expert judgement by PJ.02.02 and PJ.02-01 teams. The value has been refined in Wave 2.

5.2.2 Airport operator cost assumptions

Airports will incur costs related to installing runway lighting, marking and PAPI for the increased glide slope and the second runway aiming point.

The CBA model also calculates costs related to induced investments that the airports would have to do following the additional passengers that the increase in airport capacity brings.

5.2.3 Number of deployment locations (units)

The CBA includes the 32 Very Large and Large candidate airports where it is assumed that IGS-to-SRAP will be deployed. The CBA includes one implementation per airport, the costs of deploying on additional runways are not included.

Airport			
VL	L	M	S
32		0	0

Table 18: Number of deployment locations - Airports

5.2.4 Cost per unit

Table 19 shows the cost for the enabler, which is also the per location.

Enabler	Enabler Title	Implementation Costs (M€)	Operating costs (M€/year)
AIRPORT-56 (R)	Runway marking, lighting and PAPI for SRAP/IGS-to-SRAP approach procedures	1.4	0.30
Total for AO-0331		**1.4**	**0.3**

Table 19: Airport Costs per Enabler and per deployment location

5.3 Network Manager costs

No Network Manager investments are required.

5.4 Airspace User costs

5.4.1 Airspace User cost approach

Airspace users will incur costs related to pilots' training for the IGS-to-SRAP procedures. Training will need to cover topics such as:

- visual references for approaches to runways operating two different thresholds for arrivals (i.e. marking, lightning and VASI/PAPI) and an increased glide path angle (i.e. visual assessment of the external environment)

- energy management and flare for approaches with an increased glide path angle (when no particular assistance is provided by the avionics)
- landing preparation and management as the available landing distance will be reduced when landing on the second threshold
- assessment of feasibility of IGS-to-SRAP operation considering aircraft capabilities and operational conditions

There are no investments required at the Flight Operation Centres (FOC) (ground).

The two airborne enablers are not included in the CBA because they are optional.

- A/C-86 (O): On-board assistance to aircraft energy management - an on-board system that provides energy management cues to the flight crew supporting them in managing appropriately the overall aircraft energy to succeed in reaching energy rendez-vous. The reference used is the stabilization gate, usually at 1000 ft above airport elevation.
- A/C-87 (O): On-board assistance to flare - an on-board system that provides flare assistance information to the flight crew supporting them in landing appropriately.

For both of the above enablers it is mentioned that steeper operations (use of an increased glide slope) is a major driver for providing these kinds of assistance. However, they are optional which reflects that they will only be needed for certain aircraft and as described in the dataset “decisions on providing such systems are left to aircraft manufacturers who must decide on the significance of such assistance versus their products’ capacities (for instance deceleration capacity), operating methods (SOP application), etc.”.

5.4.2 Airspace User cost assumptions

Table 20 shows the Airspace User (Scheduled Airlines and Business Aviation) training costs based on the SESAR Training cost tool data [23]. The value considers ECAC pilots, across a range of Scheduled Airlines and Business Aviation operators, who will operate at the candidate airports. Within the CBA model these costs are allocated 90% for Scheduled Airlines and 10% for Business Aviation.

Enabler	Enabler Title	Development Costs (M€)	Operating costs (M€/year)
HUM-24 (R)	Flight Crew training for IGS-to-SRAP approach	17.5	0
Total for AO-0331		**17.5**	**0**

Table 20: Airspace User (Scheduled Airlines and Business Aviation) Training Costs

5.5 Military costs

No Military investments are required.

5.6 Other relevant stakeholders

No other stakeholders are required to invest for PJ.02-W2-14.5.

5.7 Cost Summary

This section provides a summary of how the data in the previous sections is used to feed the CBA model. The tables show the values that are used to produce the CBA results in section 7.

Investment Costs

	Cost per-unit		Deployment Locations		Cost
ANSP (Aerodrome)	2.75 M€	x	5	=	13.75 M€
	0.25 M€	x	27	=	6.75 M€
ANSP (Approach)	7.70 M€	x	5	=	38.50 M€
	0.20 M€	X	20	=	4.00 M€
Airport Operator	1.4 M€	x	32	=	44.80 M€
Airspace Users (SA)	17.5 M€ total cost x 90%			=	15.75 M€
Airspace Users (BA)	17.5 M€ total cost x 10%			=	1.75 M€
				Total Investment Costs	**125.30 M€**

Table 21: Investment Cost Summary

Annual Operating Cost changes

	Annual costs		Deployment Locations		Cost
ANSP (Aerodrome)	0.05 M€	x	5	=	0.25 M€
ANSP (Approach)	0.05 M€	x	5	=	0.25 M€
Airport Operator	0.3 M€	x	32	=	9.60 M€
				Annual Operating Cost Change	**10.10 M€**

Table 22: Operating Cost Summary

6 CBA Model

The model used to calculate the CBA results will be the Single Solution CBA model (s7.4.1) developed by PJ.19. This CBA Model has been developed in Excel and calculates the costs and benefits of the implementation of the PJ.02-W2-14.5 IGS-to-SRAP Solution as described in the CBA Solution Scenario.

The CBA model uses the benefit values from section4:

- Scenario 1 uses the low benefit values
- Scenario 2 uses the high benefit values
- Scenario 3 uses the average benefit values and is used to produce the results in section 7.

The same cost data is used in the 3 scenarios.

s7.4.1-for-PJ02-S14.5_v0.2.xlsm

6.1 Data sources

Cost Inputs

Cost data reflect a combination of inputs from relevant partners gathered in Wave 1 projects PJ.02-01 and PJ.02-02 and reviewed in PJ.02-W2-14.5. Costs relating to the runway marking, lighting systems and PAPI have been updated in Wave 2. The CBA team together with other project team members calculated pilot training using available information on the number of ECAC pilots. No airborne costs are included.

Benefit Inputs

The main source for the benefit calculation inputs is a combination of Performance Assessment Results from the PJ.02-02 Wave 1 Performance Assessment Report (PAR) [18], as included in the PJ.02-W2-14.5 PAR [25] and separate calculations based on the noise calculation methods used in Wave 1. 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 input sheets of the CBA Model with details provided in the sheet 'Source of Reference'. These are part of the PJ.19.04 Common Assumptions [12].

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7 CBA Results

The following section provides the results of the ECAC-level PJ.02-W2-14.5 V3 CBA that has assessed the deployment of IGS-to-SRAP at 32 candidate airports where it is assumed that 5 airports will realise the airport capacity benefits during capacity-constrained peak hours and all 32 will realise the noise reduction benefits during peak and off-peak periods, including at night.

The CBA has been built on the following information:

- The Investments costs (pre-implementation and implementation costs) and Operating Costs have been identified for the main stakeholders impacted: ANSPs, Airports and Airspace Users[5].
- The impact of IGS-to-SRAP on the Capital Expenditures (CAPEX) has been analysed and only the costs on top of what could be expected in the CBA Reference Scenario have been estimated in the cost assessment and integrated in the CBA Model.
- Benefits (fuel and time efficiency, airport capacity and noise reduction) have been estimated and monetised in the CBA Model for Airspace Users (Scheduled Airlines and BA operating in Large and Very Large Airports) and Airport Operators. See section 4 for more details.
- No airport capacity, fuel or time efficiency benefits are included for Medium Airports and airports operating in mixed mode due, respectively, to a lack of traffics peaks and limitations in the validation modelling tool.
- The noise reduction benefits from IGS-to-SRAP are considered to be attractive for all airports with high surrounding population density. However, this analysis has limited the scope and only assessed noise benefits for the 32 Very Large and Large candidate airports.

The PJ.02-W2-14.5 CBA results[6] shown here are visible in the CBA model (see section 6) by selecting Scenario 3.

The **Net Present Value (NPV)** is **1320 M€**, this is discounted at 8% over the period 2022 to 2043. Table 24 shows the undiscounted values, which show that **without discounting the overall net benefits are 3987 M€.**

The discounted values are detailed in section 7.1.1 while the undiscounted values are detailed in section 7.1.2.

7.1.1 Discounted Values

This section provides the discounted CBA results. The values shown in table 14 below are discounted to account for the time value of money[7]. Undiscounted values are shown in the next section.

The Net Present Value (NPV) for PJ.02-W2-14.5 is **1320 M€**. This is calculated with an 8% discount rate over the period 2022 to 2043.

The payback year is 2027, this is shown in Figure 8 where the discounted cumulative net benefits line crosses back over the x-axis.

[5] No specific aircraft equipment or certification is currently required to fly approach slopes in the range considered by IGS-to-SRAP (between 3.01° and 4.49°). However, in order to enhance safety when IGS-to-SRAP operations get widely deployed, manufacturers might prescribe the use of energy management and flare assisting functions for some aircraft.

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

[7] 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.

Discounted 8% (M€)	Net Present Value	Capex	Opex	Benefits
ANSP	48	-39	-3	89
Airport operators	253	-44	-54	351
Business Aviation	67	-1	0	69
Scheduled Aviation	816	-10	0	826
Societal Benefits	136	0	0	136
Overall	**1320**	**-93**	**-57**	**1471**

Table 23: PJ.02-W2-14.5 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 will explore these results in more detail to see the impact on the NPV of changing some of the assumptions.

Figure 8 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.

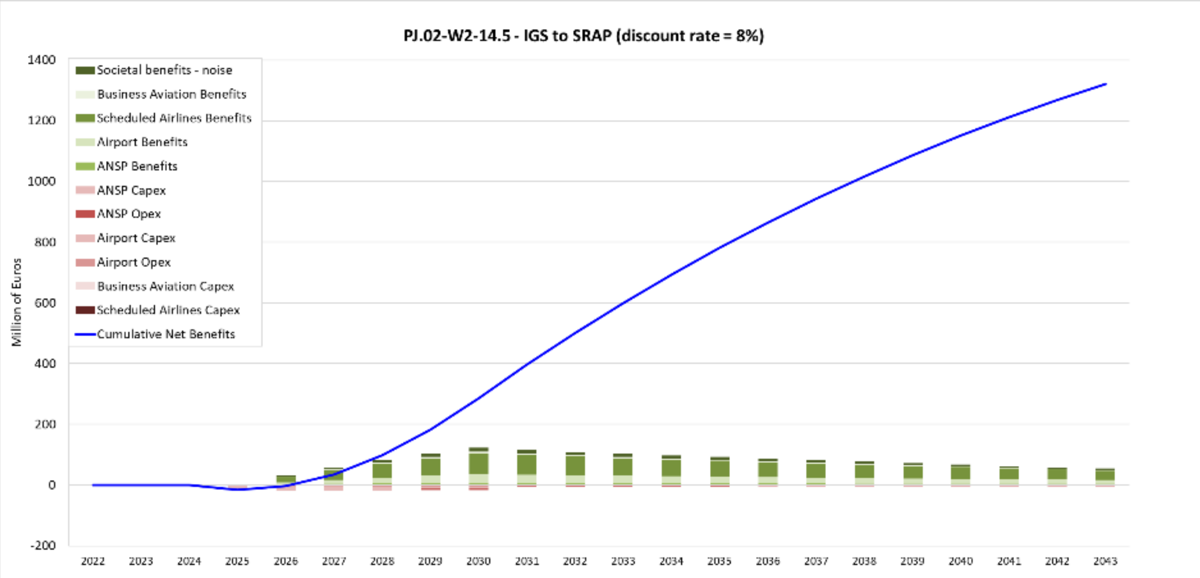

Figure 8: PJ.02-W2-14.5 Annual Investment Levels and Benefits (discounted)

Figure 9 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.

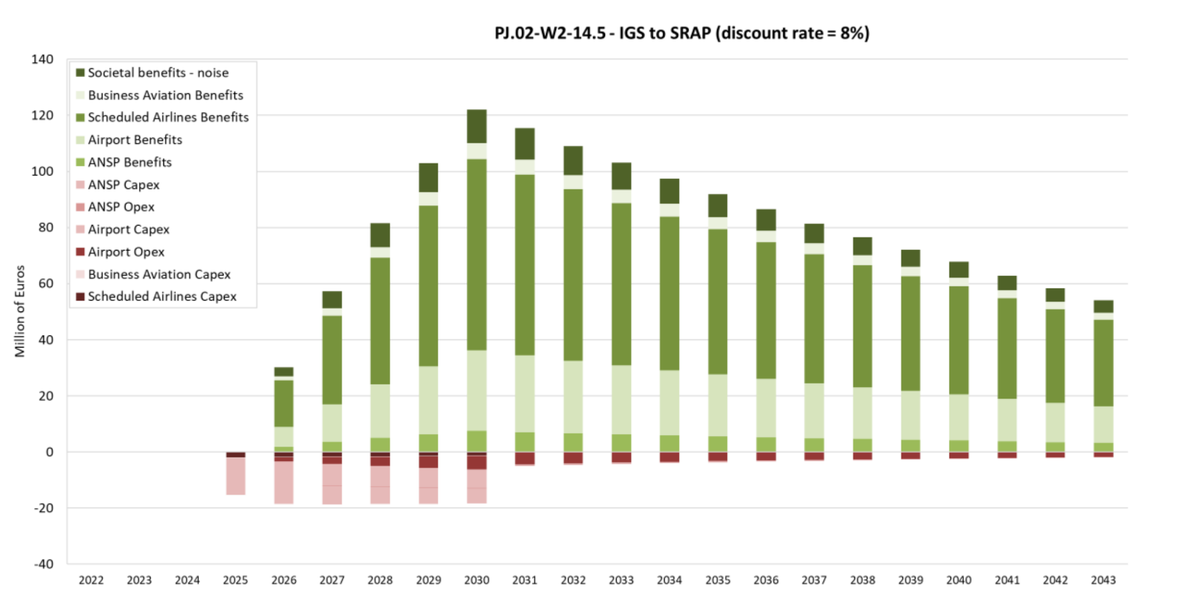

Figure 9: PJ.02-W2-14.5 Annual Investment Levels and Benefits expanded (discounted)

7.1.2 Undiscounted Values

The values shown in this section do not consider the time value of money, so one unit of currency spent or received in 2043 is considered to have the same value as one unit of currency spent or received today.

Table 24 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 **3987 M€**.

Undiscounted	Net Benefits	CAPEX	OPEX	Benefits
ANSP	189	-63	-8	260
Airport operators	802	-76	-154	1032
Business Aviation	199	-2	0	201
Scheduled Aviation	2410	-16	0	2426
Societal Benefits	387	0	0	387
Overall	**3987**	**-157**	**-162**	**4306**

Table 24: PJ.02-W2-14.5 Undiscounted CBA results (per stakeholder and overall)

Figure 10 shows the undiscounted costs and benefits over each year.

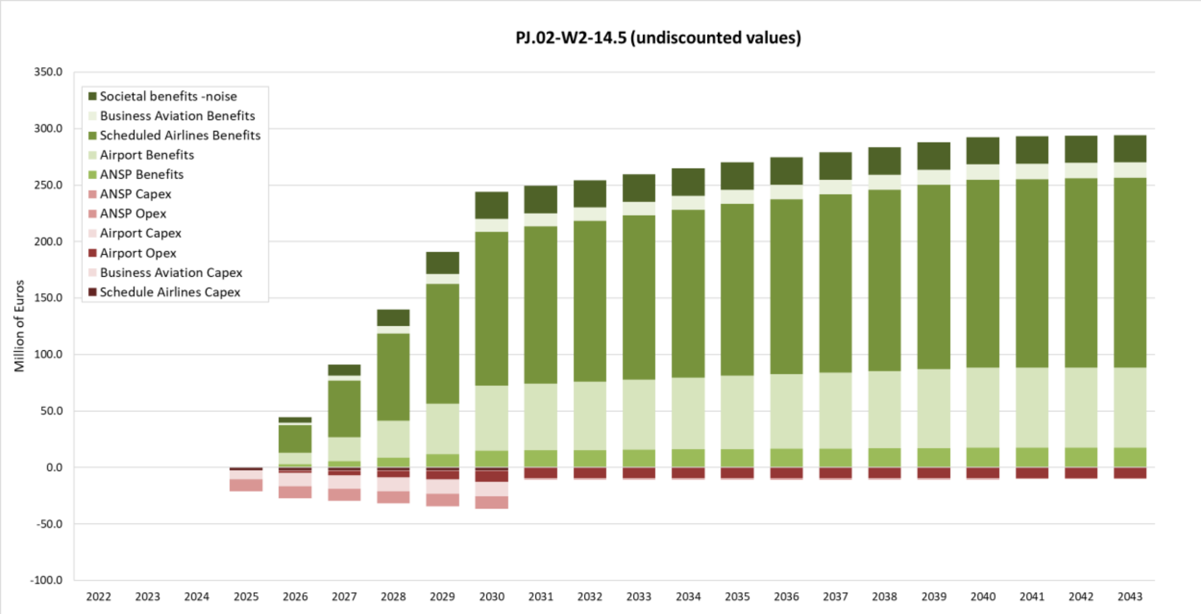

Figure 10: PJ.02-W2-14.5 Annual Investment Levels and Benefits (undiscounted)

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 **157 M€** (CAPEX) to deploy this Solution over the deployment period. The **93 M€** discounted cost value, Table 23, simply reflects the present value of those investments in 2022.

8 Sensitivity analysis

This section[8] provides data on how sensitive the CBA results are to changes in the inputs values. When making investments it is useful to know which values can have the most impact on the results to help focus further work on refining data and assumptions.

8.1 Discount Rate

The discount rate is used to reflect the time value of money[9] so reducing the discount rate reduces the difference between the value of money today and its value in the future. There is often much discussion on which discount rate to use so it is useful to look at a range of values. In this case, doubling the discount rate, from 8% to 16% still provides a positive Net Present Value.

Figure 11 shows that using a lower discount rate increases the NPV.

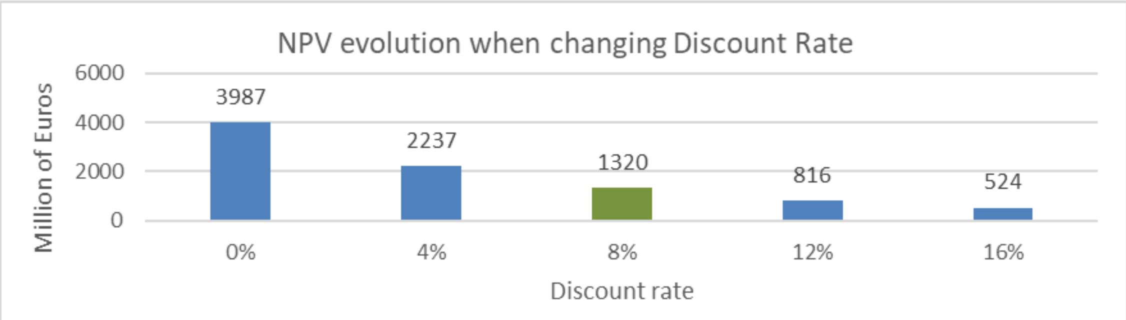

Figure 11: NPV variation

8.2 Sensitivity Comparison

Figure 12 shows the tornado diagram produced when the different cost and benefit inputs were each varied by -10% to +10%. The input values which produce the larger changes in the NPV are candidates for further investigation as they have the most potential to negatively impact the NPV.

The figure shows that the inputs **Fuel Efficiency** and **Airport Capacity** have the largest impact on the NPV, while the costs AU Ground CAPEX (pilot training) along with Ground CAPEX and OPEX (ANSP and Airport) have the lowest impact on the CBA results.

For Fuel Efficiency, the tornado diagram shows that a 10% reduction in fuel burn benefits would result in just over a 4% reduction in the Net Present Value. The CBA is considered to be very sensitive to an input value if the impact on the NPV is higher than the change in the input value, e.g. a 10% change in the input value resulted in a 15% change in the NPV.

[8] Risk Analysis has not been performed for this CBA as the Excel CBA model is not designed to apply Monte Carlo simulation techniques which are needed to calculate the NPV results for thousands of scenarios where different combinations of the input values (taken from probability distributions) are used in each.

[9] 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.

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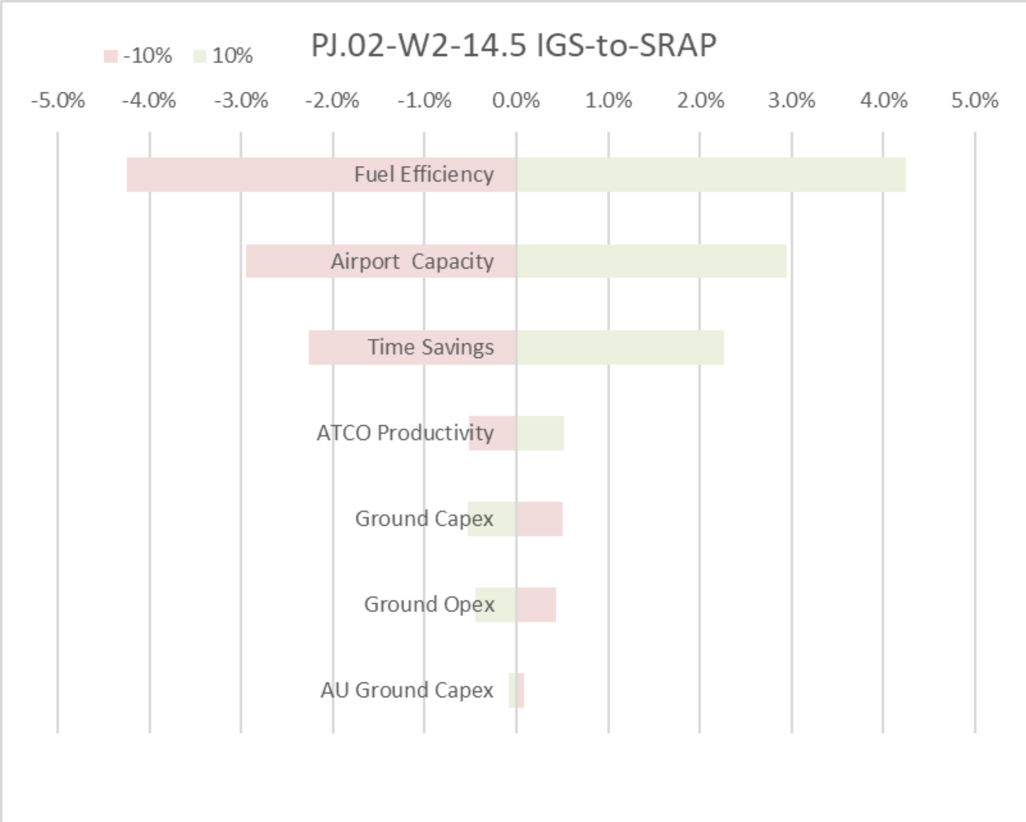

Figure 12: Tornado diagram

8.3 Sensitivity Scenario

This section provides the Net Present Value when the cost inputs are doubled at the same time as the benefit inputs are halved. This can be considered as a pessimistic view.

The CBA input values are shown below.

8.3.1 Costs double

<u>**Investment Costs**</u>

	Cost per-unit		Deployment Locations		Cost
ANSP (Aerodrome)	5.50 M€	x	5	=	27.50 M€
	0.50 M€	x	27	=	13.50 M€
ANSP (Approach)	15.40 M€	x	5	=	77.00 M€
	0.40 M€	X	20	=	8.00 M€
Airport Operator	2.8 M€	x	32	=	89.60 M€
Airspace Users (SA)	17.5 M€ total cost x 90%			=	31.50 M€
Airspace Users (BA)	17.5 M€ total cost x 10%			=	3.50 M€
				Total Investment Costs	**250.60 M€**

Table 25: Investment Cost Summary

<u>**Annual Operating Cost changes**</u>

	Annual costs		Deployment Locations		Cost
ANSP (Aerodrome)	0.1 M€	x	5	=	0.5 M€
ANSP (Approach)	0.1 M€	x	5	=	0.5 M€
Airport Operator	0.6 M€	x	32	=	19.2 M€
				Annual Operating Cost Change	**20.20 M€**

Table 26: Operating Cost Summary

8.3.2 Benefits halved

The benefits are set of half the value listed in section 4.1.7.

- Airport Capacity and ATCO Productivity become $0.15\ \% / 2 = 0.075\%$
- Noise benefits (societal benefits) become 24.2 M€ / 2 = 12.2 M€ per year
- Fuel efficiency becomes -7.07 kg per arrival $/\ 2 = -3.54$ kg per flight
- Time Efficiency becomes -0.12 minutes per arrival $/\ 2 = -0.06$ minutes per flight

8.3.3 Pessimistic Scenario CBA Results

Table 27 shows that even in the pessimistic situation where the costs doubled and the benefits are halved, the NPV was still positive, although much lower, at 460 M€.

Discounted 8%	Net Present Value	Capex	Opex	Benefits
ANSP	-38	-77	-6	45
Airport operators	4	-63	-108	176
Business Aviation	32	-2	0	34
Scheduled Aviation	393	-19	0	413
Societal Benefits	68	0	0	68
Overall	**460**	**-162**	**-114**	**735**

Table 27: PJ.02-W2-14.5 Pessimistic Scenario - Discounted CBA results (per stakeholder and overall)

9 Recommendations and next steps

In summary, the PJ.02-W2-14.5 'Increased glide slope to Second Runway Aiming Point (IGS-to-SRAP)' V3 CBA results are positive with a Net Present Value (NPV) of **1320 M€** reflecting that the benefits from deploying the solution at 32 candidate airports (5 for capacity benefits and 32 for noise benefits) are expected to exceed the costs of deploying and operating it.

The NPV has been calculated with an 8% discount rate over the period 2022 to 2043, with PJ.02-W2-14.5 being deployed between 2025 and 2030 and with benefits starting to be realised from late 2026. The payback year is 2027, which reflects when the cumulative net benefits will exceed the costs.

The expected IGS-to-SRAP **benefits** that are monetised in the CBA are:

- Reduced environmental impact from **Noise Reduction** below the final approach in peak and non-peak periods for aircraft using the IGS-to-SRAP. These benefits are based on the change in size of the noise contours around the airport areas, which reflects a reduction in aircraft noise for impacted residents.
- Increases in **Airport Capacity** during capacity-constrained peak periods when both runway aiming points are used to optimise wake turbulence separations for specific combinations of leader/follower aircraft pairs
- Improvements in **Fuel Efficiency** (reduced fuel burn and CO_2 emissions) and **Time Efficiency** in peak and non-peak periods where the optimised wake separations can help optimise flight profiles and the airport layout allows a reduction in runway occupancy time and taxi-in time for aircraft using IGS-to-SRAP

Confidence in the fuel and time efficiency benefits is medium as they are based on Fast Time Simulation results. Confidence in the noise results is low to medium as they generalise the benefits calculated from the noise simulations produced in the Wave 1 Solution PJ.02-02 'Enhanced Arrival Procedures'.

The CBA results are underpinned by the assumptions that the required "updates to EASA/ICAO regulatory frameworks for new visual ground aids (IGS-to-SRAP)" and "Regulatory provisions for Increased Glide Slope operations to Second Runway Aiming Point (IGS-to-SRAP)" occur in the planned timeframes.

The sensitivity analysis shows that even if the costs doubled and the benefits are halved, the deployment, as described in the CBA Solution Scenario, would still have a positive NPV of 460 M€.

The validation activities have shown that the Solution concept works and can bring airport capacity benefits and reduce the impact of noise on the local inhabitants in peak and non-peak hours, including at night. The scale of the results will differ across airports depending on airport specificities including, but not limited to, traffic mix, runway length, capacity-constrained peak periods, operating mode (mixed/segregated), population density under the final approach and the number of runways where IGS-to-SRAP will be deployed.

The main recommendation is therefore, that airports considering the deployment of this Solution to address their operational needs, should review the content of this CBA and develop their own CBA based on their specific infrastructure, operations, layout, etc. to assess the scale of their potential benefits. They should also review related solutions, such as PJ.02-W2-14.2 Second Runway Aiming Point, which can also offer capacity benefits during peak hours and noise reduction benefits, or PJ.02-W2-14.3 Increased Second Glide Slope, which offers noise reduction benefits, to ensure they deploy the most appropriate solution for their needs.

10 References and Applicable Documents

10.1 Applicable Documents

[1] SESAR 2020 Project Handbook, Edition 02.02.00, 08 June 2020
[2] SESAR Cost-Benefit Analysis Model[31] (Single Solution Wave 2)
[3] EUROCONTROL, Standard Inputs for EUROCONTROL Economic Analyses, Edition 9, December 2020
[4] SESAR 16.06.06-D26_03, Methods to Assess Costs and Monetise Benefits for CBAs, Ed. 00.02.02
[5] EUROCONTROL, Method to assess cost of European ATM improvements and technologies, v1.0, 28 July 2014
[6] SESAR 16.06.06-D26_08, ATM CBA Quality checklist, Edition 02.00.01
[7] SESAR 16.06.06-D26_04, Guidelines for Producing Benefit and Impact Mechanisms, Ed. 03.00.01
[8] European ATM Master Plan Portal 2019, https://www.atmmasterplan.eu/
[9] SESAR 16.06.06-D51 SESAR 1 Business Case 2016, Edition 00.01.01, 13 July 2016

10.2 Reference Documents

[10] SESAR 2020, PJ19.04, En-route & Terminal Airspace OEs_October 2019 Version (1_0).xlsx
[11] SESAR 2020 PJ19.04, Airport OE_October 2019 Version (1_0).xlsx
[12] SESAR 2020, PJ19, D4.0.30 S2020 Common Assumptions (2019), Edition 00.00.02
[13] SESAR 2020 D4.7, Performance Framework (2019), Edition 01.00.01
[14] SESAR 2020 D4.8, Validation Targets (2019), Edition 01.00.01
[15] P06.08.08 D07 Enhanced Arrival Procedures enabled by GBAS – OSED Consolidation, Edition 00.01.01
[16] P06.08.05 D04 – Operational Service and Environment Definition (OSED) Displaced Thresholds, 00.02.00
[17] SESAR 2020 PJ.02-02 V3 SPR-INTEROP/OSED - Part I, Deliverable ID D1.1.021, Edition 00.00.07, 15 November 2019
[18] SESAR 2020 PJ.02-02 V3 SPR-INTEROP/OSED - Part V, Performance Assessment Report Deliverable D1.1.021, Edition 00.00.01, 31 October 2019
[19] SESAR 2020 PJ.02-02 VALR (V3), Deliverable D2.1.048, Edition 00.00.01, 10 September 2019
[20] SESAR 2020 W1, D2.1.05, PJ.02-02 CBA (V3), Edition 00.01.00, 25 March 2020
[21] EUROCONTROL Performance Review Commission (PRC), ATM Cost-Effectiveness (ACE) Benchmarking Report 2019, May 2021
[22] CE Delft (on behalf of European Commission)- Handbook on the External Costs of Transport – Version 2019
[23] SESAR1 Training Cost assessment framework and database, Edition 2, 2019

[31] This reference is no more accessible from Programme library but it is now available in ATM Performance Assessment Community of Practice.

[24]SESAR 2020, D4.5.002, PJ.02-W2-14.5 5 SPR-INTEROP/OSED V3 Part I– Final, Edition 00.01.00, 27 September 2022

[25]SESAR 2020, D4.5.002, PJ.02-W2-14.5 SPR-INTEROP/OSED V3 Part V – Final, Edition 00.01.00, 25 August 2022

[26]SESAR 2020, D4.5.006, PJ.02-W2-14.5 VALR Final, Edition 00.00.04, 29 August 2022

Appendix A Description of the Enhanced Arrival Procedure: IGS-to-SRAP (AO-0331)

IGS-to-SRAP concept consists in having two runway thresholds active at the same time on a runway, with two different final approach segment slope, typically an ILS 3° slope to the first threshold and a higher one to the second one.

Having two arrival slopes active at the same time, it can be envisaged to have one or two interception altitudes, according to each local case. The figures below show the two cases.

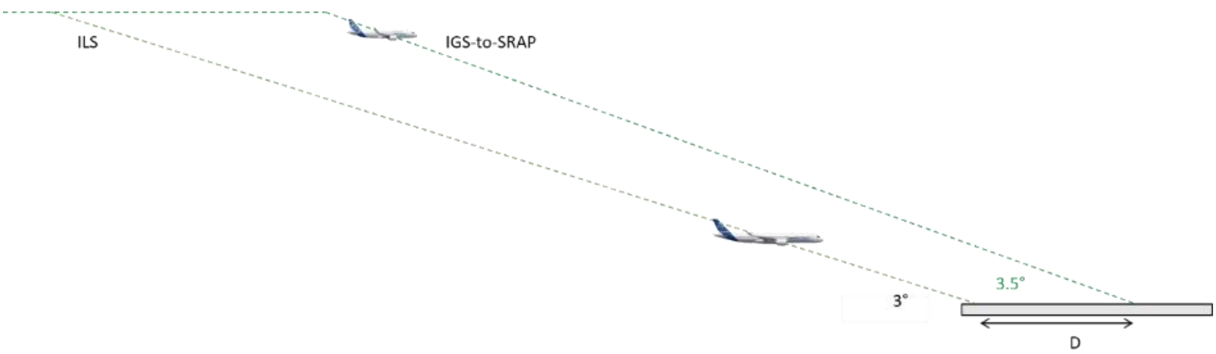

Figure 13: IGS-to-SRAP procedure with one interception altitude

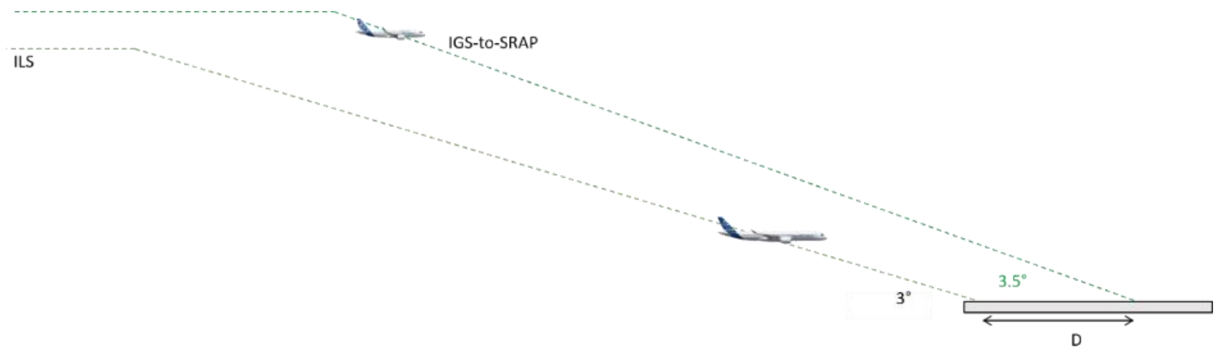

Figure 14: IGS-to-SRAP procedure with two interception altitudes

Appendix B 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 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.

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Appendix C Mapping ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs

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
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

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
	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> see section 3.4	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 28: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs

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