INDUSTRIAL RESEARCH

SESAR SOLUTION 53B: Cost Benefit Analysis (CBA) for V3

Deliverable ID:	D2.2.106
Dissemination Level:	PU
Project Acronym:	PJ18W2 4DSkyways
Grant:	872320
Call:	H2020-SESAR-2019-1
Topic:	SESAR-IR-VLD-WAVE2-09-2019
Consortium coordinator:	EUROCONTROL
Edition date:	19 July 2023
Edition:	02.00.00
Template Edition:	02.00.04

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Authoring & Approval

Authors of the document

Beneficiary	Date
B4 (Integra Consult A/S)	01/06/2023

Reviewers internal to the project

Beneficiary	Date
Airbus	03/05/2023
Skyguide	04/05/2023

Reviewers external to the project

Beneficiary	Date
PJ19 (EUROCONTROL)	13/06/2023

Approved for submission to the S3JU By - Representatives of all beneficiaries involved in the project

Beneficiary	Date
EUROCONTROL	07/06/2023
PANSA	07/06/2023*
DFS	07/06/2023
INDRA	07/06/2023
SKYGUIDE	07/06/2023
ENAV	07/06/2023*
BULATSA	07/06/2023
AIRBUS	07/06/2023

*silent approval

Rejected By - Representatives of beneficiaries involved in the project

Beneficiary	Date

Document History

Edition	Date	Status	Beneficiary	Justification

01.00.00	24/04/2023	Draft	B4 (INTEGRA CONSULT)	Internal review
01.01.00	23/05/2023	Draft	B4 (INTEGRA CONSULT)	Changes in PAR caused changes in the CBA. + review responses
01.02.00	30/05/2023	Draft	EUROCONTROL	Quality corrections
01.03.00	01/06/2023	Pre-approvals	B4 (INTEGRA Consult)	Revised BULATSA capacity figures.
01.04.00	06/06/2023	Revision	B4 (INTEGRA Consult)	PJ19 comment resolution, changes in CBA inputs
01.05.00	18/07/2023	Revision	B4 (INTEGRA Consult)	Maturity gate actions: indirect benefits (4.8), revised FEFF1, TEFF1 (4), Separate En-route and TMA (4.4)
02.00.00	19/07/2023	Final	EUROCONTROL	Quality check and PMB approvals. Latest OI and enablers from EATMA.

PJ18W2 4DSkyways

SOLUTION 53B: IMPROVED PERFORMANCE OF CD/R TOOLS ENABLED BY REDUCED TRAJECTORY PREDICTION UNCERTAINTY

This document is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 872320 under European Union's Horizon 2020 research and innovation programme.

Abstract

The PJ18-Wave 2 4DSkyways project aims to continue the research on Trajectory Management (TM) to enable the deployment of the SESAR Trajectory Based Operations (TBO). Solution 53 aims to improve Separation Management and Monitoring Tools (planned and tactical layers) in the En-route and TMA operational environments and therefore to increase the quality of separation management

services, reducing controller workload per aircraft and separation buffers, and facilitating new controller team organisations.

This document provides the results of the cost benefit analysis (CBA), based on the data available from the validations and the performance assessment of the solution PJ18-W2-53B at the maturity level of V3. The document covers the assumptions, calculations and various analyses performed within the CBA, as well as the outcomes.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Table of Contents

List of Tables

List of Figures

1 Executive Summary

This document provides the Cost Benefit Analysis (CBA) related to the deployment of SESAR Solution PJ.18-W2-53B, which has been matured through validation activities at a V3 level.

The PJ18-Wave 2 4DSkyways project aims to continue the research on Trajectory Management (TM) to enable the deployment of the SESAR Trajectory Based Operations (TBO). Solution 53 aims to improve Separation Management and Monitoring Tools (planned and tactical layers) in the En-route and TMA operational environments and therefore to increase the quality of separation management services, reducing controller workload per aircraft and separation buffers, and facilitating new controller team organisations.

Solutions PJ.18-W2-53A and PJ.18-W2-53B, together, improve Separation Management and Monitoring Tools (planned and tactical layers) in the en-route and TMA operational environments in order to increase the quality of separation management services, reducing controller workload per aircraft, reducing separation buffers and facilitating more efficient controller team organisations.

The original, single solution (PJ.18-W2-53) was split into the two sub-solutions 53A and 53B to allow for a phased approach, taking advantage of concepts and technology that are more mature to enable earlier delivery of benefits:

- PJ.18-W2-53B – Improved Performance of CD/R Tools Enabled by Reduced Trajectory Prediction Uncertainty, targeting V3.
- PJ.18-W2-53A – Increased Automation in Planning and Tactical Separation Management, targeting V2.

Solution PJ.18-W2-53B encapsulates the more mature separation management elements for which V3 maturity is targeted. This solution builds on the work performed in wave 1 solutions PJ.10-02a2 and PJ.18-06a and addresses the improvement of conflict detection and resolution tools that are derived from the improvement of ground Trajectory Prediction (TP) with the use of advanced data from ATN B2 ADS-C reports messages as defined in the EUROCAE standards ED228A and ED75C and improved meteorological data.

The improvements of ground TP in Solution PJ.18-W2-53B address the use of ADS-C data beyond the items that were studied in wave 1 (gross mass, speed schedule, TOC and TOD altitudes, and the predicted speeds at route points) to address in particular:

- The use of the EPP profile to calibrate the BADA performance model;
- Improvements in the calculations of turning manoeuvres thanks to the use of turn radius and the turning strategy (overfly vs fly-by);
- The implementation of catch-up manoeuvres (not depending on EPP data)

In addition, the solution encompasses the handling of MET data and other surveillance data from aircraft (ADS-C reports containing wind and temperature at current aircraft position, NOWCAST from Mode S enhanced surveillance data, ADS-B out reports).

The objective of the CBA is to calculate the monetised values of the benefits and compare them with costs related to the deployment of the solution, in order to determine the net present value (NPV) of the deployment. If the NPV is positive, the deployment of the solution would be beneficial.

The main stakeholders involved and their expected benefits are as follows:

- ANSPs, which expect improvements in the productivity of Air Traffic Controllers, and also bear the costs of implementation and increase in operational costs;
- Airspace users, which expect improvements in time savings, fuel efficiency (reduction in fuel burn and CO_2 emissions), and airspace capacity.

The CBA considers that the aircraft capabilities required for the solution are already deployed by the time the implementation of the solution starts, therefore no investment need is foreseen for airspace users. No benefits or costs have been identified for the Network Manager, military or airport operators.

Due to different possible approaches to the deployment by ANSPs, the CBA calculated the NPV in two sub-scenarios:

- Sub-scenario 1 considered lower investment needs but a higher delta in operational costs, resulting in the **NPV of 3,946M€.**
- Sub-scenario 2 considered higher investment needs, and a low delta in operational costs, resulting in the **NPV of 4,280M€.**

The payback year for the deployment of the solution was estimated at 2037.

The CBA identified some risks with low probability related to the costs of the implementation and the resulting changes in the operational costs, as the ANSP-specific CBA calculation was mildly sensitive to these figures, but none of the identified risks requires mitigation measures beyond normal management practices and due diligence.

Stakeholders are recommended to explore further benefits through synergies with the deployment of PJ.18-W2-53A, once V3 maturity is reached for that solution as well.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

2 Introduction

2.1 Purpose of the document

This document provides the Cost Benefit Analysis (CBA) related to SESAR Solution PJ.18-W2-53B, which has been validated during validation activities at a V3 level. The figures in this CBA are based on the OSED developed by the solution, in particular, the BIMs and Performance Analysis Report developed by the solution, inputs provided by the solution members, and where applicable, expert judgments. This document is the final CBA for the solution at maturity level V3.

The main objective of the CBA is to demonstrate the financial feasibility of the solution, present the costs and benefits associated with the enablers and main concept elements, and calculate the net present value (NPV) for each stakeholder and also the overall NPV, and the payback year for the solution, together with the risks, limitations, and uncertainties. Given that the maturity level of the solution is V3, a sensitivity analysis is also included in the CBA.

2.2 Scope

This document provides the Cost Benefit Analysis (CBA) related to a SESAR Solution PJ.18-W2-53B at V3 level. The CBA is calculated for the time period between 2022 and 2043, for the ECAC region. Stakeholder analysis showed that the affected stakeholder groups are:

- ANSPs, who bear the costs of deployment and operation of the equipment, and also realize some of the benefits;
- Airlines, who also bear the costs of deployment and operation of equipment (although due to way the reference scenario is defined, the CBA does not consider the costs borne by airlines) and realize most of the benefits brought by the solution.

Neither airports nor the wider community is affected significantly, as the solution has no direct effect on airport capacity and does not directly change the distribution of air traffic in a TMA.

2.3 Intended readership

This document is intended for the following audience:

- Other SESAR Solutions within PJ18 that might depend on Solution 53:
  - PJ.18-W2-56: Air/Ground Trajectory Synchronisation via Lateral and Vertical Complex CPDLC Clearances to Support TBO
  - PJ.18-W2-57: Study Of beNefits of InCreased automation in ATM (SONIC)
- Other SESAR Projects that might have a dependency on Separation and Monitoring Tools:
  - PJ.10: Controller Tools and Team Organisation for the Provision of Separation in Air Traffic Management
- Transverse and federating projects:
  - PJ.19-W2: Content Integration
- Stakeholders
  - ANSPs: Management and ATCOs as guidance for the implementation of controller tools.
- Airspace Users: Management and pilots as background information influencing flight operations.

EUROPEAN PARTNERSHIP Co-funded by the European Union

2.4 Structure of the document

This document consists of the following chapters:

- Chapter 1: Executive summary, providing an overview of the CBA at a glance.
- Chapter 2: Introduction, description of the basic facts and context about the CBA.
- Chapter 3: Objectives and Scope of CBA, covering the assumptions, scope definitions, objectives, …etc.
- Chapter 4: Benefits, the description of what benefits have been identified and monetized.
- Chapter 5.: Costs, providing information on the costs associated with the solution.
- Chapter 6: CBA model.
- Chapter 7: CBA Results, interpretation of the calculations and their results
- Chapter 8: Sensitivity and risk analysis, covering the risks inherent in the calculations and the sensitivity of the model to the input variables
- Chapter 9: Recommendations and next steps, summarizing all the conclusions which were drawn from the CBA.
- Chapter 10: References and Applicable Documents.

2.5 Background

The validations and assessments of this solution benefit from the work in the scope of SESAR 2020 Wave 1 projects: PJ.10-02a and PJ.18-06a and VLD project PJ.31 DIGITS. In addition, the project builds on the experience gained in the previous V2 phase and various ANSPs operating the separation management operational concept both in en-route and TMA.

SESAR Wave 1 Solution PJ.10-02a1

PJ.10-02a1 "Improved performance in the provision of separation without use of ADS-C/EPP data". addressed improving the separation (tactical layer) in the en-route and TMA operational environments through improved ground trajectory prediction. This was achieved using existing information on lateral and vertical clearances that are known by the ground system and airborne information such as Mode-S data.

SESAR Wave 1 Solution PJ.10-02a2

PJ.10-02a2, "Improved performance in the provision of separation with use of ADS-C/EPP data", addressed the improvement of separation (tactical layer) in the en-route operational environment through improved ground trajectory prediction. This was achieved using existing information on lateral and vertical clearances that are known to the ground system along with the ADS-C/EPP airborne information.

The maturity level at the end of the project was judged to be V2.

SESAR Wave 1 Solution PJ.10-02b

PJ.10-02b, "Advanced Separation Management", introduced a higher level of automation to the decision support tools with the development of controller tools for conflict detection and resolution recommendations as well as monitoring tools for En-route and TMA (medium to very high complexity).

According to the Automation Taxonomy of PJ16.05.01, solution PJ.10-02b addressed the automation level in the domains of Decision and Action Selection and Action Implementation:

EUROPEAN PARTNERSHIP
Co-funded by the European Union

- The system proposes one or more decision alternatives to the human and with an increasing degree of automation the user may generate alternative options, may only select one of the alternatives or ask the system to generate new options, or the system decides autonomously on the actions to be performed while the user is only informed of its decision;

- The system assists the operator in performing actions. With an increasing degree of automation, the system provides guidance for execution or automatically performs a sequence of actions after activation by the user. The user maintains control of the sequence or only monitors the sequence. The user will still be able to modify or interrupt the actions.

The advanced separation management tools assessed by PJ.10-02b comprised:

1. Conflict detection and resolution tools: airspace-avoidance functionalities indicating no-fly areas (taking into account fixed and flexible constraints, e.g. weather), Conflict Resolver, and What- next functionalities are built on top of existing tools. Dependency Clustering Tools (showing aircraft that have potential dependencies in the sector between entry and exit level) are a new development;

2. Recommendation tools: Provide a subset of qualified conflict-free trajectories which are pre-selected by an algorithm, based on defined quality of service metrics. Enhanced Tactical Window, Corrective Action Tool, and What-next Tool are new tools which are built on existing functionalities. Recommendation Tool, Conflict Resolver and Resolution Advisory are completely new tools;

3. Monitoring Aids: Detect deviations or deviation trends and monitor predicted behaviour on constraint points or within predefined airspace corridors. The monitoring functionalities in this project (Conformance Monitoring, Conflict Resolver) are built on existing tools.

The maturity level at the end of the project was judged to be V1 Completed.

SESAR Wave 1 Solution PJ.18-06a

PJ.18-06a as a technical solution addressing improvements on the Planned Trajectories, in order to improve their accuracy thanks to the usage of new ADS-C reports, extended Flight Plan (eFPL) data and surveillance parameters, together with other algorithm changes derived from common Flight Management System (FMS) manoeuvres during the descent phase. This was expected to enable a reduction of the extra safety margins managed by the system tools (implying a reduction of the nuisance alerts) and also to increase the planner controller's confidence in the prediction. Together with improved mid-term trajectory management tools and procedures, this should enable the planner controller to better de-conflict traffic by following strategies based on more precise management of the flight trajectory within the sector in a mid-term horizon.

The improvement to the ground Planned Trajectory was not achieved by the direct utilisation of the received EPP trajectory, but by extracting from the ADS-C reports high-level preferences that can be applied to whatever flight intent, such as the preferred speed schedule, which should be reasonably stable as long as there is not a big re-routing or Cost-Index change. Then, the ground TP applies those preferences in its algorithm. Once the new clearance or restriction is communicated to the crew and a new EPP is received for any contract triggering a new sending, this EPP can be checked to confirm if the assumed high-level preferences for the manoeuvres are maintained.

Utilisation of high-level preferences in this way also allows the computation of alternative trajectories during conflict resolution processes and flight sequencing. Several what-if trajectories would need to be tested in ground to choose the most appropriate one. In order to ensure that those alternative what-if trajectories are also accurate, they should also take benefit from the ADS-C reports, including the EPP trajectory.

SESAR Wave 1 Solution PJ.18-06b

The PJ18-06b solution grouped TRL4 validation activities related to trajectory prediction improvements and comprised two independent activities:

- Activities related to the improvement to the "Tactical Trajectory", aiming specifically at the use of ADS-C data in a tactical TP algorithm that can operate in a high-density high complexity TMA environment, by NATS.
- Activities related to "NM profile improvement using ADS-C" by EUROCONTROL.

The Tactical TP underpins the Tactical decision tools which are a key enabler to realising the benefits of Trajectory Based Operations (TBO). The tactical tools exist to support medium-term decision-making and are built upon a high-resolution trajectory prediction algorithm with a relatively short prediction horizon of up to 30 minutes.

For the tactical trajectory thread, the baseline trajectory predictor that was used for reference is a TP algorithm which has been developed to support the more dynamic manoeuvres in high-density / high-complexity TMA operations. This tactical TP was enhanced with ADS-C data. Despite the TP being tailored for use in the TMA the anticipated improvements in trajectory prediction performance are likely to also have applicability in the en-route domain.

For the NM activities, the baseline was the ETFMS operational system and its replay infrastructure. No modifications based on ADS-C were made as part of the validation exercise.

SESAR Wave 1 Very Large Scale Demonstration PJ.31 DIGITS

The DIGITS (Demonstration of ATM Improvements Generated by Initial Trajectory Sharing) project assessed the ATM benefits from further usage of TP enhancements for supporting tools (derived from the use of ADS-C data, including EPP), notably in terms of enhancement of conformance monitoring, improvement of predictability, reduction of tactical interventions and improvement of de-confliction of traffic.

The demonstration approach took advantage of revenue flights from six participating airlines involving 91 aircraft by end 2020, equipped with new Aeronautical Telecommunications Network Baseline 2 (ATN-B2) capabilities, fully integrated in the general commercial traffic, to assess how much the aircraft downlinked 4D trajectory could be used to enhance the controller support tools (controller alerting & decision aids), and thus deliver benefits to the end users, i.e. the controllers in charge of these flights and the Airspace Users.

The availability of ADS-C trajectory data from revenue flights forms a key element within the overall ADS-C roadmap as it allows service providers and ground industry to understand the impact of

EUROPEAN PARTNERSHIP
Co-funded by the European Union

different airspace users' operating practices on the downlinked data, which may influence the final requirements for integrating this data into ground systems for full operational deployment.

2.6 Glossary of terms

Term	Definition	Source of the definition
Conflict	Any situation involving aircraft and hazards in which the applicable separation minima may be compromised. Note: this term relates to potential infringements of separation minima. More specifically, it is used in the context of ATCO activities where actions are performed to anticipate and resolve conflicts for separation management purposes. This contrasts with the situations detected and processed by CD/R tools where the terminology used is 'encounters', which relates to the applicable Separation of Interest used by the toolset, rather than Separation Minima.	*SESAR Wave 1 Solution 27*
Conflict Detection Aid	Conflict detection performed by the CD/R Tool in accordance with a pre-defined time horizon suitable for the operation environment with the objective to alert the ATCO of a potential conflict between an aircraft and a hazard.	*SESAR Wave 1 Solution 27*
Conflict Resolution Aid	Conflict resolution options calculated by the CD/R Tool and presented to the controller which ensures that the separation minima are not compromised between an aircraft and a hazard.	*SESAR Wave 1 Solution 27*
Conformance Monitoring to the CD/R input	A system function which detects and alerts the ATCO in case the aircraft behaviour is not in accordance with the CD/R tool.	*SESAR Wave 1 Solution 27*
Cost Benefit Analysis	Quantified statement of the economic worth of a project, in terms of costs and benefits to all parties which takes account of their timings.	SESAR 2020 Methods to Assess Costs and Monetise Benefits [3]

Enabler	New or modified technical system/infrastructure, human factors element, procedure, standard or regulation necessary to make (or enhance) an operational improvement. Note. Enablers are linked to Operational Improvement Steps that they support. The implementation of a set of Enablers allows an Operational Improvement Step to complete. Enablers are the means to implement the Change in the ATM Operational Environment	*PJ19-W2: EATMA Guidance (2020)*
Net Present Value	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.	*Investopedia*
Operational Improvement (OI)	Operational Improvement Steps (OI Steps) describe the improvements to be achieved by the changes in the ATM Operational Environment and described by the SESAR ATM Solutions (and their related enablers). Operational Improvement Steps are as well the mean to describe the improvements in the ATM Performance.	*PJ19-W2: EATMA Guidance (2020)*
Planned Trajectory	The Planned Trajectory represents the stable medium to long term behaviour of the aircraft but may be inaccurate over the short term where tactical instructions that will be issued to achieve the longer-term plan are not yet known. It takes into account the planned route and requested vertical profile, strategic ATC constraints, Closed Loop Instructions/Clearances, co-ordination conditions and the current state of the aircraft. Assumptions may be made to close Open Loop Instructions/Clearances issued by tactical controllers. It is calculated within the planning look-ahead timeframe, starting from the Area of Interest of the unit concerned, or the	*SESAR Solution 53A SPR-INTEROP/OSED for V2 - Part I*

	aircraft's current position (whichever is later). It is constrained during all phases of flight by boundary crossing targets (e.g., standing agreements between the Units concerned).	
Risk Analysis	Risk analysis refers to the assessment process that identifies the potential for any adverse events that may negatively affect organizations and the environment.	*Investopedia*
Sensitivity Analysis	Sensitivity analysis determines how different values of an independent variable affect a particular dependent variable under a given set of assumptions.	*Investopedia*
Sensitivity and risk analysis	Analysis of the impact of uncertainties of costs, benefits and parameters figures on the final CBA results.	SESAR 2020 CBA Template for Technological Solution
Separation Minima	The minimum displacement between an aircraft and a hazard, which maintain the risk of collision at an acceptable level of safety. Note: ICAO Doc 9689 describes the methodology to be used for the determination of Separation Minima	*SESAR Wave 1 Solution 27* *ICAO Doc 9689*
Tactical Trajectory	The Tactical Trajectory is calculated within a short look-ahead time (e.g., up to 15 minutes) during tactical ATC operations (sector planning layer). It therefore reflects an accurate view of the predicted flight evolution, starting from the current flight position (generally, as reported by surveillance), with low uncertainty and high precision. It is kept up to date with all clearances, including tactical instructions, except in case of detected deviation. During any open tactical manoeuvres, it will also be reflecting those temporary conditions. It is usually determined with a fast update rate (e.g., 5 seconds) and with an	*SESAR Wave 1 Solution 27*

	optimised Uncertainty calculation; to maximise response and minimise the incidence of false alarms.	
TMA (Terminal Manoeuvring Area)	A terminal control area is a Control Area normally established at the confluence of ATS Routes in the vicinity of one or more major aerodromes.	*ICAO Doc 4444*

Table 1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
ACC	Area Control Centre
ADS-C	Automatic Dependent Surveillance - Contract
ANSP	Air Navigation Service Provider
AoI	Area of Interest
AoR	Area of Responsibility
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
AU	Airspace User
BIM	Benefit Impact Mechanism
CBA	Cost Benefit Analysis
CD/R	Conflict Detection and Resolution
CPDLC	Controller/Pilot Data Link Communications
DIGITS	Demonstration of ATM Improvements Generated by Initial Trajectory Sharing
ECAC	European Civil Aviation Conference
eFPL	Extended Flight Plan
EPP	Extended Projected Profile
ETFMS	Enhanced tactical flow management system
FMS	Flight Management System
FOC	Full Operational Capability
HPAR	Human Performance Assessment Report
IOC	Initial Operational Capability

KPA	Key Performance Area
KPI	Key Performance Indicator
MTCD	Medium-Term Conflict Detection
NM	Network Manager
NPV	Net Present Value
OSED	Operational Service and Environment Definition
PAR	Performance Assessment Report
PC	Planning Controller
PI	Performance Indicator
PIRM	Programme Information Reference Model
RBT	Reference Business Trajectory
SA	Scheduled Airlines
SAR	Safety Assessment Report
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SONIC	Study Of beNefits of InCreased automation in ATM
SPR	Safety Performance Requirements
TBO	Trajectory Based Operations
TM	Trajectory Management
TMA	Terminal Manoeuvring Area
TP	Trajectory Prediction
VT	Validation Target

Table 2: List of acronyms

3 Objectives and scope of the CBA

3.1 Problem addressed by the solution

This CBA evaluates the financial feasibility of the PJ.18-W2-53B Solution on a V3 maturity level. This solution addresses the improvement of conflict detection and resolution tools that are derived from the improvement of ground Trajectory Prediction. The decision at the focus of the CBA is whether the deployment of these improved tools on ECAC level would generate enough financial benefits for the relevant stakeholders to cover the costs associated with implementation and operation of the tools. In other words, and put very simply: is it financially rational to continue the development of these prototype tools?

3.2 SESAR Solution description

Solutions PJ.18-W2-53A and PJ.18-W2-53B, together, improve Separation Management and Monitoring Tools (planned and tactical layers) in the en-route and TMA operational environments in order to increase the quality of separation management services, reducing controller workload per aircraft, reducing separation buffers and facilitating more efficient controller team organisations.

A phased approach was taken that split what was originally described as a single solution into the two sub-solutions 53A and 53B, taking advantage of concepts and technology that are more mature to enable earlier delivery of benefits:

- PJ.18-W2-53B – Improved Performance of CD/R Tools Enabled by Reduced Trajectory Prediction Uncertainty, targeting V3.
- PJ.18-W2-53A – Increased Automation in Planning and Tactical Separation Management, targeting V2.

This is depicted in the following figure below.

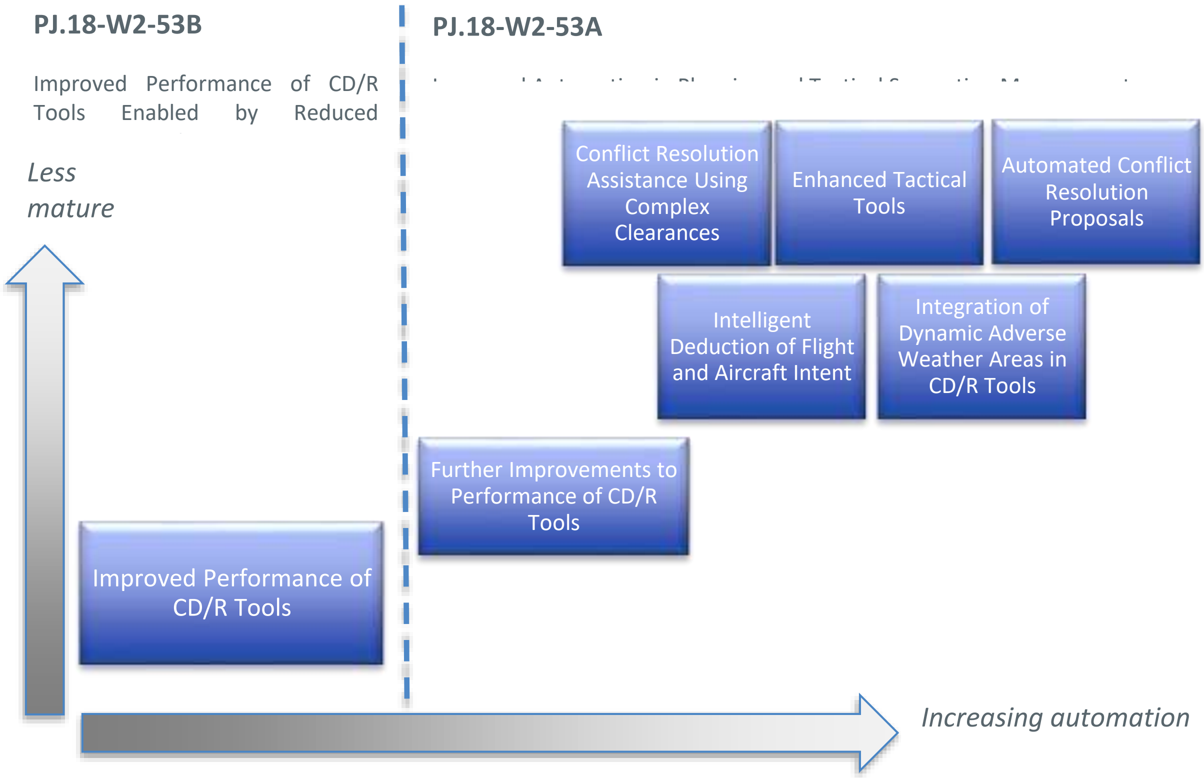

Figure 1 - Solution PJ.18-W2-53A and PJ.18-W2-53B Scope

The table below illustrates the mapping of PJ.18-W2-53B to its wave 1 predecessor solutions and shows how the targeted maturity of its OI steps is consistent with the maturity achieved by the corresponding wave 1 OI steps.

Wave 1 Solution	OI Step	OI Title	Maturity Achieved	Wave 2 Solution	OI Step	OI Title	Maturity Targeted
PJ.10-02a2	CM-0209-b	Conflict Detection and Resolution in En-Route using aircraft data in Predefined and User Preferred Routes environments	V2	PJ.18-W2-53B	CM-0209-b	Improved Separation Management with the use of Aircraft Data in Conflict Detection and Resolution Tools in En-Route Predefined and User Preferred Routes environments	V3
PJ.18-06a	POI-0012-IS	ATC Planned Trajectories improvement with new ADS-C reports, eFPL and surveillance information	V2		CM-0212	Improved Separation Management with the use of Aircraft Data in Conflict Detection and Resolution Tools in the TMA	V3

Table 3: Mapping of PJ.18-W2-53B Wave 1 Solutions

Solution PJ.18-W2-53B encapsulates the more mature separation management elements for which V3 maturity is targeted. This solution builds on the work performed in wave 1 solutions PJ.10-02a2 and PJ.18-06a and addresses the improvement of conflict detection and resolution tools that are derived from the improvement of ground Trajectory Prediction (TP) with the use of advanced data from ATN B2 ADS-C reports messages as defined in the EUROCAE standards ED228A and ED75C and improved meteorological data.

The improvements of ground TP in Solution PJ.18-W2-53B address the use of ADS-C data beyond the items that were studied in wave 1 (gross mass, speed schedule, TOC and TOD altitudes, and the predicted speeds at route points) to address in particular:

- The use of the EPP profile to calibrate the BADA performance model;
- Improvements in the calculations of turning manoeuvres thanks to the use of turn radius and the turning strategy (overfly vs fly-by);
- The implementation of catch-up manoeuvres (not depending on EPP data)

In addition, the solution encompasses the handling of MET data and other surveillance data from aircraft (ADS-C reports containing wind and temperature at current aircraft position, NOWCAST from Mode S enhanced surveillance data, ADS-B out reports).

In continuation of the work performed in wave-1 PJ.10-02a2 using ADS-C MET data to improve CD/R functions, the scope is further enhanced to improve the TP performance of ground trajectories by creating a local MET grid. This local MET grid is composed of ADS-C MET data (downlinked from various ADS-C equipped aircraft in the airspace) overlaid on the MET provider forecast data. The overlaying of ADS-C MET data is carried out by extrapolating in a regressive way so that the applicability of its usage in the ground TP calculations is limited by spatial and/or temporal bounds from the point of its downlink to the ground. The resultant MET grid is used to determine applicable MET parameters for each point in the AoI for ground TP calculations and is applied in both TMA and en-route airspace.

The reduced uncertainty in the TP is expected to improve the usability of existing CD/R tools by reducing the number of false [low probability] conflicts and allow the better identification of actual conflicts. Furthermore, the improved TP should provide a more reliable sector sequence (particularly for vertically evolving flights in complex airspace), easing the burden of coordination and transfer between sectors.

The OIs addressed by PJ.18-W2-53B are listed in the table below. At this stage, the existing enablers are shown but they should be considered as immature, pending a review upon finalization of the OI change requests.

Note that, in coordination with PJ.18-W2-56, the OI step CM-0210-b (entitled “Ground Based Flight Conformance Monitoring in En-Route using aircraft Data”), originally considered in the scope of -53B, has been transferred to -56 where its scope has been subsumed by the OI step CM-0207-B.

SESAR Solution ID	OI Steps ref. (coming from	OI Steps definition	OI step coverage	Source reference

	the Integrated Roadmap)	(coming from the Integrated Roadmap)		
PJ18-W2-53B	CM-0209-b	Conflict Detection and Resolution in En-Route using aircraft data in Predefined and User Preferred Routes environments	Full	SESAR Solution 53 A/B Final SPR-INTEROP/OSED for V2/V3 - Part I
	CM-0212	Improved Separation Management with the use of Aircraft Data in Conflict Detection and Resolution Tools in the TMA	Full	SESAR Solution 53 A/B Final SPR-INTEROP/OSED for V2/V3 - Part I

Table 4: SESAR Solution PJ.18-W2-53B Scope and related OI steps

OI Steps ref.	Enabler[1] ref.	Enabler definition	Enabler coverage	Applicable stakeholder	Source reference
CM-0209-b	A/C-37a	Downlink of trajectory data according to contract terms (ADS-C) compliant to ATN baseline 2 (FANS 3/C)	•Required •Use	•Airspace user	EATMA
	A/C-48a	Air broadcast of aircraft position/vector (ADS-B OUT) compliant with DO260B	•Optional •Use	•Airspace user	EATMA

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

	ER APP ATC 167	ATC Planned Trajectories improvement with new ADS-C reports, and surveillance information	• Required • Develop	ANSP	EATMA
	ER APP ATC 200	ATC Improvement to receive and use more granular MET forecasts	• Required • Develop	ANSP	EATMA
	ER APP ATC 149a	Air-Ground Datalink Exchange to Support i4D - Extended Projected Profile (EPP)	• Optional • Use	• ANSP	EATMA
	ER APP ATC 214	Conflict Detection envelope trajectories improvement with new ADS-C reports	• Optional • Develop	• ANSP	EATMA
ANSP CM-0212	A/C-37a	Downlink of trajectory data according to contract terms (ADS-C) compliant to ATN Baseline 2 (FANS 3/C)	• Required • Use	Airspace user	EATMA
	A/C-48a	Air broadcast of position/vector (ADS-B OUT) compliant with DO260B	• Optional • Use	• Airspace user	EATMA
	ER APP ATC 167	ATC Planned Trajectories improvement with new ADS-C reports, and surveillance information	• Required • Develop	• ANSP	EATMA

	ER APP ATC 200	ATC Improvement to receive and use more granular MET forecasts	•Required •Develop	ANSP	EATMA
	ER APP ATC 82	Enhance EN/APP ACC to use eFPL data	•Optional •Use	•ANSP	EATMA
	ER APP ATC 149a	Air-ground data exchange to support i4D – Extended Projected Profile (EPP)	•Optional •Use	ANSP	EATMA
	ER APP ATC 214	Conflict Detection envelope trajectories improvement with new ADS-C reports	•Optional •Develop	ANSP	eATM portal draft dataset 23

Table 5: OI steps and related Enablers

3.3 Objectives of the CBA

The objective of this CBA document is to assess the monetary value of the benefits which can be realized by the implementation of the developed tools, and also to estimate the costs and investment needs necessary for deploying, operating and maintaining them. In economic terms, the objective is to calculate the net present value of the solution, and to determine the break-even year (in which the cumulated benefits exceed the cumulated costs). The analyses will also cover all impacts, sensitivities, and risks per stakeholder groups. Results from this analysis will be used to support the decision to move the solution through the V3 maturity gate.

The CBA calculates the net present value with all benefits and costs, regardless of which stakeholder group enjoys the benefits or incurs the costs. When assessing the economic feasibility of the solution, it is compared to an as-is scenario, that is, if the solution was not deployed.

3.4 Stakeholders[2] identification

Stakeholder	The type of stakeholder and/or applicable sub-OE	Type of Impact	Involvement in the analysis	Quantitative results available in the current CBA version
ANSP	ACC / APPs with very-high, high and medium complexity	Investment into, deployment and operation of technical equipment, enjoy benefits	Inputs to cost assessment and benefit monetisation	Costs and benefits
Airport Operators	-	-	-	-
Network Manager	-	-	-	-
Scheduled Airlines (Mainline and Regional)	-	Enjoy benefits	Involved in CBA review	Benefits monetised
Business Aviation	-	Enjoy benefits		Benefits monetised
Rotorcraft	-	-	-	-
General Aviation IFR	-	-		-
General Aviation VFR	-	-	-	-
Military – Airborne	-	-		-
Military – Ground			-	-
Other impacted stakeholders (ground handling, weather	-	-	-	-

[2] 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.

forecast service provider, NSA….)				

Table 6: SESAR Solution PJ.18-W2-53B CBA Stakeholders and impacts

3.5 CBA Scenarios and Assumptions

The following sections outline the scenarios used for the purposes of the CBA: the reference scenario, which serves as a baseline for the analysis, and the solution scenario which considers what will happen once the solution is deployed.

3.5.1 Reference Scenario

The solution is built on enablers which foresee the upgrade of aircraft equipment, as well as changes made to the Trajectory Prediction and CD/R tools in the ATS systems of ANSPs. Enabler A/C-48a reached FOC in 2017, thus it is considered as part of the reference scenario. Further to this, the deployment of Enabler A/C-37a is expected to start with forward fitting new aircraft, given its relations to CP1 ATM sub-functionality S-AF6 Initial Trajectory Information Sharing. Therefore both aircraft-related enablers are assumed to be part of the reference scenario.

All assumptions regarding the general input parameters for this scenario are those of the SESAR CBA model (see section 6.), no changes were introduced during the analyses.

In simple terms, the Reference Scenario is defined as a ‘do nothing’ scenario, with the caveat on enabler A/C-48a. This translates into a scenario, where ANSPs do not implement the use of ADS-C data developed in the tools by the solution and consequently cannot realise the improvements and benefits through their operations.

3.5.2 Solution Scenario

The Solution Scenario focuses on the changes brought by the implementation of the tools developed by the solution (use of ADS-C data), and their impact on performance. The solution scenario assumes the implementation of both OI steps covered by the solution and thus foresees the following impacts.

The improvements of ground TP in Solution PJ.18-W2-53B address the use of ADS-C data beyond the items that were studied in wave 1 (gross mass, speed schedule, TOC and TOD altitudes, and the predicted speeds at route points) to address in particular:

- The use of the EPP profile to calibrate the BADA performance model;
- Improvements in the calculations of turning manoeuvres thanks to the use of turn radius and the turning strategy (overfly vs fly-by);
- The implementation of catch-up manoeuvres (not depending on EPP data)

In addition, the solution scenario also considers s the handling of MET data and other surveillance data from aircraft (ADS-C reports containing wind and temperature at the current aircraft position, NOWCAST from Mode S enhanced surveillance data, ADS-B out reports).

3.5.2.1 Deployment scope

The solution is essentially an improvement of various ATM system components, therefore the solution scenario considers that the deployment scope consists of:

- Implementation of new tools and/or upgrade of existing functionalities in the ATM system of ANSPs
- Changes in procedures, and the associated training needs.

The solution scenario assumes the implementation of both operational improvement steps and all enablers. For the enablers which are optional and developed by the solution, this approach ensures that all the costs are factored into the CBA. For enablers which are not developed by the solution and are optional, this simplification is possible as the costs of these enablers are already considered in the CBAs of solutions based on operational improvement where those enablers are required.

3.5.2.2 Interdependencies with other solutions

There are strong interdependencies with solution PJ.18-W2-53A, which builds on the results of PJ.18-W2-53B, as it considers the enhanced tools and functionalities developed in 53B. In close coordination with the CBA team of PJ.18-W2-53A, it was agreed that the CBA of 53A will consider the costs associated with the deployment of 53B as a given, in other words, as part of the reference scenario, in order to avoid any double counting of costs.

3.5.2.3 Time horizon

The solution scenario is defined with the following milestones:

- Deployment to start as from 01/01/2027, that is implementation costs start occurring from this date onwards, assuming a gradual implementation until 01/01/2030.
- Initial operational capability (IOC) is assumed from 01/01/2028, assuming a linear ramp-up in the benefits.
- Full operational capability is expected from 01/01/2031.

The time horizon for the Net Present Value calculations was set until 2043, as defined in the SESAR CBA model (see section 6.)

3.5.2.4 Geographical scope

Geographical scope of the solution scenarios is that of the PAR [13], defined as Medium to Very High Complexity TMAs and Very High Complexity Area Control Centres (en route) within the ECAC region. These are the OEs, in which the solution can bring significant benefits. This translates into the following list of operational environments.

OE	Applicable sub-OE	Special characteristics
En-route	Very high, High, Medium traffic density and complexity	The airspace considered by solution PJ.18-W2-53 is a managed airspace, where a separation service is provided by ATM services providers.

TMA	Very high, High, Medium traffic density and complexity	The vertical scope extends from FL0 to FL660, comprising of upper and lower airspace, but excludes airspace dedicated to final approach and aerodrome vicinity. Separation minima are expected to continue to be based on guidance, regulations, and factors used in today's environment and the choice of separation standard is made on a case-by-case basis depending on both the pair of aircraft to assess and the airspace where the separation is assessed. Separation may not be homogeneous throughout the whole controlled sector.

Table 7: Applicable Operating Environments.

There are altogether 152 OEs falling into the above categories. See Table 8 below for an overview of the distribution of OEs across the relevant complexity classifications.

Terminal Airspace				En-route			
VH	H	M	L	VH	H	M	L
14	12	69	N/A	19 (13 ER + 6 Mixed)	13 (7 ER + 6 Mixed)	25 (13 ER + 12 Mixed)	N/A

Table 8: Number of operational environments in the scope of PJ.18-W2-53B.

The PAR [13] notes that validation exercises did not provide information for medium complexity OEs, therefore they are not included in the extrapolation of the benefits. However, the CBA considers the costs for all OEs thereby ensuring a prudent and conservative approach and robust NPV calculations.

3.5.2.5 Discount rate and traffic evolution

The discount rate for the CBA was set at 8%, in accordance with the standard input in the CBA model file.

3.5.3 Assumptions

While both aircraft enablers are considered as being part of the reference scenario, thus no costs are calculated in the CBA model related to them, the CBA model still considers the equipage rate of the aircraft fleet as a key input.

The CBA team of solution PJ.18-W2-56 conducted a survey of the main aircraft manufacturers to see how the equipage ratio of the European fleet will evolve. Following a discussion with PJ.18-W2-56, it has been agreed, that in order to ensure a consistent approach within PJ.18, the CBA for PJ.18-W2-53B will use the same inputs for the equipage ratio as in the CBA of PJ.18-W2-56 [18]. To this end, this CBA uses the following assumptions:

- The starting point for the equipage ratio at the end of 2027 will be 3%.
- The share of forward-fitted new aircraft will be 89%.

All common assumptions are taken from the SESAR CBA model, and none of the common inputs or assumptions were changed for the CBA calculations.

4 Benefits

The relevant KPAs and the associated performance indicators for PJ.18-W2-53B in accordance with the SESAR Performance Framework [11] are summarised in Table 9 below. Note that safety and human performance related benefits are not monetised, however, they are covered in detail in the PAR [13].

KPA	KPI		Definition	Units
Operational Efficiency	**Fuel Efficiency**	**FEEF1**	Actual average fuel burn per flight.	saving kg/flight
	Flight Time	**TEFF1**	Gate-to-gate flight time	saving min/flight
	Predictability	**PRD1**	Average of Difference in actual & Flight Plan or RBT durations	minutes.
Capacity	**TMA Capacity**	**CAP1**	TMA throughput, in challenging airspace[3], per unit time.	% Increase in peak hour throughput
	En-Route Capacity	**CAP2**	En-route throughput, in challenging airspace[4], per unit time.	% Increase in peak hour throughput
Cost-Efficiency	**ATCO Productivity**	**CEF2**	Flights per ATCO-Hour on duty.	% Increase in ATCO productivity
Environment	**CO_2 emissions**	**ENV1**	Actual Average CO2 Emission per flight	Kg of CO_2 per flight
Human Performance[5]	**Human performance indicator 1**	**HP1**	Consistency of human role with respect to human capabilities and limitations	-
	Human performance indicator 2	**HP2**	Suitability of technical system in supporting the tasks of human actors	-
	Human performance indicator 3	**HP3**	Adequacy of team structure and team communication in supporting the human actors	-
	Human performance indicator 4	**HP4**	Feasibility with regard to HP-related transition factors	-
Safety	**Various safety assessment criteria[6]**	**-**	-	-

Table 9: KPAs and PIs relevant for PJ.18-W2-53B.

[3] Airspace where the current operating concept and technology is close to the limit of throughput that can be sustainably handled (typically VHC, HC and MC under period of high traffic demand)
[4] See footnote 5 above
[5] Human performance Pis were derived from HP arguments considered during the HP assessment process. For more details, see PAR/HPAR **Error! Reference source not found.**.
[6] For details see PAR/SAR [14].

The performance assessment process considered the outcomes of all 5 exercises within the scope of the solution. The overview of the results from the performance assessment process is shown below in Table 10.

KPI	Performance Assessment Result	Stakeholder that benefits in the CBA
Operational Efficiency **FEFF1: Fuel Efficiency**	**-11.34 kg/flight**	AU
Operational Efficiency **TEFF1: Flight Time**	**-0.33 minutes/flight**	AU
Operational Efficiency **PRD1: Predictability**	**No trends**	ANSP
Capacity **CAP1: TMA Capacity**	**+2.75 %**	AU, ANSP
Capacity **CAP2: En-Route Capacity**	**+1.46 %**	AU, ANSP
Cost Efficiency **CEF2: ATCO Productivity**	**+1.9 %**	ANSP
Safety	**OK**	ANSP, AU
Human Performance	**OK**	ANSP, AU

Table 10: Overview of the performance assessment results of PJ.18-W2-53B.

The following sections provide a detailed view of the benefit monetisation process for each affected KPA and KPI.

4.1 Operational efficiency and Environment (FEFF1 and ENV1)

The PAR of Solution PJ.18-W2-53B shows a reduction in fuel consumption and associated CO_2 emissions saving per flight:

FEFF1: Fuel Efficiency – Fuel burn	**-11.34 kg/flight** (positive impact)
ENV1: CO2 emissions saving – CO_2 emission	**-36.94 kg CO_2/flight** (positive impact)

The figure below shows the monetisation mechanism used in the CBA model for fuel saved, and also for CO_2 saved. The calculation is made in each year, so the values include the evolution of the number of flights and fuel price over the CBA period.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

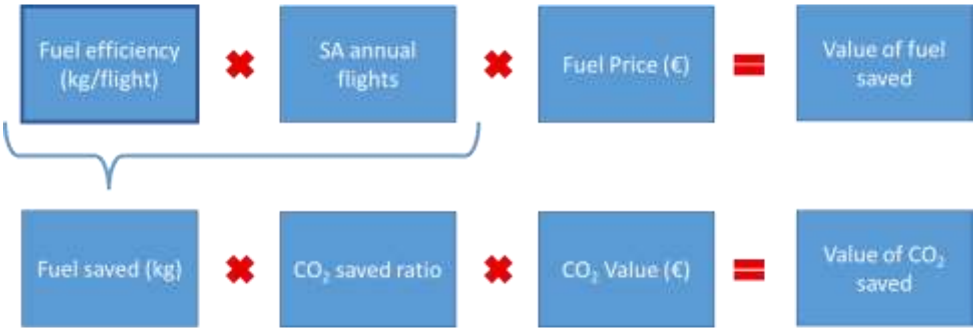

Figure 2: Monetisation mechanism for Fuel efficiency and CO_2

The overall (undiscounted) monetary value of improved fuel burn and CO_2 emissions is **2,222 M€.**

4.2 Flight Time (TEFF1)

The performance assessment exercise for the solution identified an improvement in the KPI of Flight Time of:

TEFF1: Flight Time – Gate-to-gate flight time (%)	**-0.32% (positive impact)**

The monetisation mechanism used in the CBA model for flight time (TEFF1) is shown in the figure below.

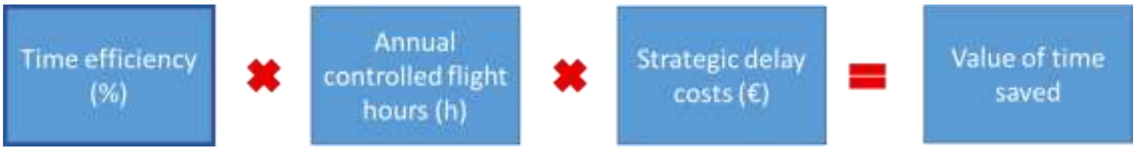

Figure 3: Monetisation mechanism for Flight Time

The overall (undiscounted) monetary value of the improvements in predictability is: **1,723M€.**

4.3 Predictability (PRD1)

The PAR for Solution PJ.18-W2-53B yielded no conclusive results in the KPI of Average of Difference in actual & Flight Plan or RBT durations.

PRD1: Predictability	**No trends**

For the sake of transparency, and in order to provide a fully comprehensive view, the figure below shows the monetisation mechanism used in the CBA model for PRD1.

Figure 4: Monetisation mechanism for Strategic Delay Cost Saving (due improvements in the difference in actual and Flight Plan or RBT durations).

EUROPEAN PARTNERSHIP
Co-funded by the European Union

Given that no significant impact has been assessed, no overall (undiscounted) monetary value of changes in Predictability has been calculated**.**

4.4 Airspace capacity (CAP1 and CAP2)

The PAR for solution PJ18.-W2-53B concluded that the airspace capacities of TMAs and en route airspace have increased by:

CAP1: TMA Capacity – Tactical and Strategic Delay	**+2.75 %** (positive impact)
CAP2: En-Route Airspace Capacity – Tactical and Strategic Delay	**+1.46 %** (positive impact)

Both improvements are monetised by translating them into tactical and strategic delay savings. The figures below show the monetisation mechanism used in the CBA model for airspace capacity. The calculation is made each year, so the values include the evolution of the number of flights and the cost of delay over the CBA period. The delay calculated is divided into tactical and strategic delays:

- Tactical ATFM Delay is an unpredictable delay on the day of operations that exceeds the delay buffer foreseen in the flight plan.
- Strategic Delay is a delay that is included in airline schedules (flight plans).

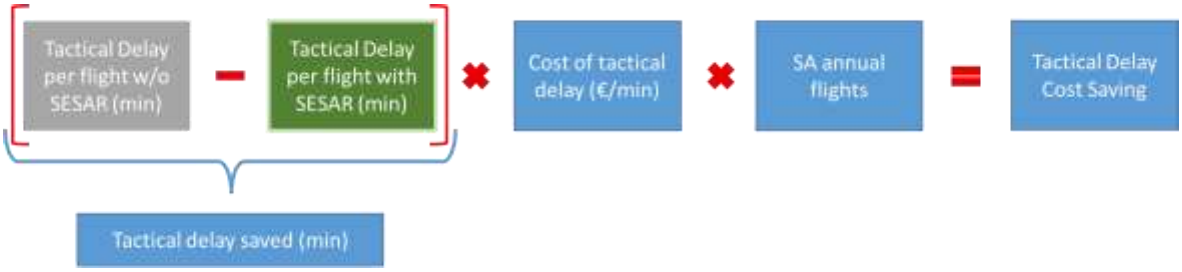

Figure 5: Monetisation mechanism for Tactical Delay Cost Saving

The link between the two types of delay is monetised through the assumption that as tactical delay is reduced, strategic delay is also reduced. The assumption is that a ratio of 1 to 0.25 is plausible and can be used.

Figure 6: Monetisation mechanism for Strategic Delay Cost Saving

Figure 7: Monetisation mechanism for Total Delay Cost Saving

The overall (undiscounted) monetary value of delay savings due to the increase in the TMA and en-route airspace capacity is **4,146 M€.**

4.5 Cost Efficiency: ATCO Productivity (CEF2)

The PAR for the solution concluded, that the ATCO productivity improved, and the number of flights per ATCO-hour on duty increased by :

CEF2: ATCO Productivity – Flights per ATCO-Hour on duty	APP: **+2.41%** (positive impact) ACC: **+1.32%** (positive impact) Combined: **+1.90%** (positive impact)

The benefits in ATCO productivity for ACC and APP ATCOs have been combined using the following formula.

$$CEF2 = \left[\frac{55\%}{1 + CEF_{ACC}} + \frac{45\%}{1 + CEF_{APP}} \right]^{-1} - 1$$

CEF_{ACC} describes the benefit in en-route ATCO productivity while CEF_{APP} is the benefit in ATCO productivity for approach and tower controllers. The formula uses data from the EUROCONTROL ACE benchmarking report 2019 (i.e., 55%/45% is the ATCO-Hr split between ACC and APP-TWR controllers) to calculate a weighted average between the two values and it is compatible with the SESAR Single Solution CBA model.

The deployment of tools developed by the solution enable a decrease in ATCO workload, thus leading to an increase in the number of flights that can be managed by the controller per hour on duty. This means additional capacity is created by maintaining the same number of ATCO workforce, all the rest being equal.

ATCO productivity is monetised in the CBA through the number of flights that can be managed by the controller per hour on duty. When a Solution decreases controller workload[7] then additional flights can be managed with the same number of controllers, all else remaining equal. Therefore, the forecast traffic growth can be handled with a smaller increase in controller numbers than if the Solution was not deployed.

The change in ATCO Productivity is used in the CBA model to calculate Operating cost savings (ATCO employment costs, Support staff costs and non-staff operating costs). The Support staff costs can be calculated based on the ratio of support staff to ATCO hours. The Non-staff operating costs are based on the traffic growth rate.

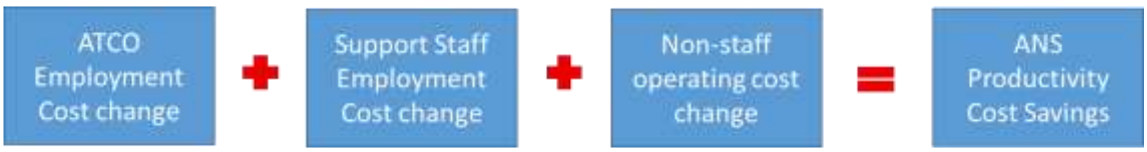

Figure 8: Monetisation mechanism for ATCO Productivity

[7] During peak-hours reduced controller workload is considered to provide an increase in capacity, while in non-peak-hours it is allocated to ATCO Productivity.

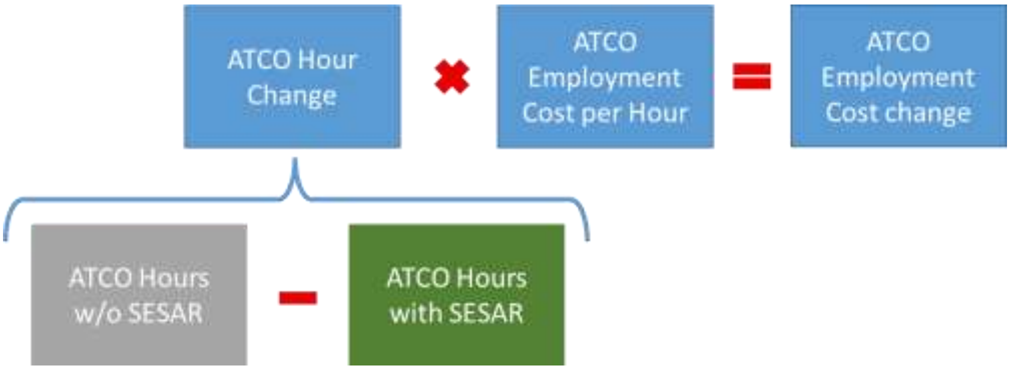

Figure 9: Monetisation mechanism for ATCO Employment Cost change

The ATCO Hours Without and With SESAR are calculated through the flight hours and the ATCO Productivity.

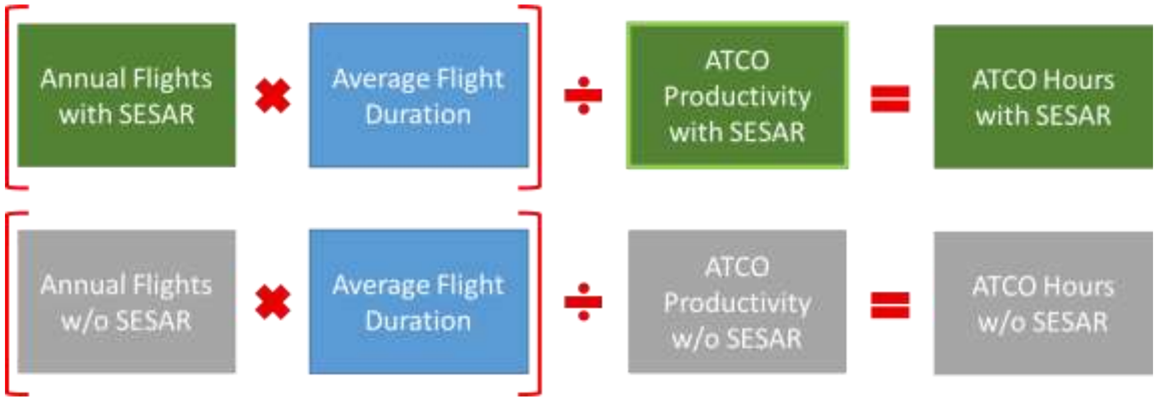

Figure 10: Monetisation mechanism for ATCO hours with and w/o SESAR

The (undiscounted) monetary value of the improvement in the number of flights per ATCO-hour on duty is: **2,124 M€.**

4.6 Safety

The safety assessment conducted across the exercises had been shown to be comprehensive and relies on a range of data sources (Real-Time simulations, technical demonstration, gaming exercises and workshops). Overall, it has been concluded that the level of safety is maintained with the enhanced TP improvements feeding the CD/R tool. Based on quantitative and qualitative results (data logs) the level of safety is maintained with the use of the new functionalities while traffic has been increased.

The evidence derived from validation related to abnormal conditions (EXE-008 and EXE-012) demonstrated that although in some cases the number of conflicts increased, the safety was maintained. No specific negative effect on human performance, which would impact safety, was identified.

The validation did not explicitly address degraded modes of operation however, some technical issues occurred (loss of ADS-C EPP) in EXE-012. The CD/R tools were designed to dynamically revert to conventional functioning mode (flight data treating without ADS-C EPP) and ATCOs were informed with the appropriate warning (reverting to reference scenario CD/R tools performance). Although the

ATCO reported that the degradation did not affect their working methods, further investigation of degraded modes was recommended.

For more details on the impact on safety, refer to the SAR [14].

4.7 Human Performance

The Human Performance (HP) assessment activities aimed to ensure that HP aspects related to SESAR technical and operational developments are systematically identified and managed. The assessment comprised of all five V3 validation exercises as they all cover the Human Performance aspects.

The HP assessment made use of HP arguments, which are used to help identify and capture changes to ATM actors' work and also screen and scope the HP assessment. They are essentially claims that need to be proven by the HP assessment. From the changes that would result from the introduction of the operational concept, it is identified that the following eight V3 level HP arguments need to be considered by the HP assessment.

Hence the arguments to be considered by the HP assessment process are:

- Argument 1.2: Operating methods (procedures) are exhaustive and support human performance.
- Argument 1.3: Human actors can achieve their tasks (in normal & abnormal conditions of the operational environment and degraded modes of operation).
- Argument 2.1: There is appropriate allocation of tasks between the human and the machine.
- Argument 2.2: The performance of the technical system supports the human in carrying out their tasks.
- Argument 2.3: The design of the HMI supports the human in carrying out their tasks.
- Argument 3.3: The communication between team members supports human performance.
- Argument 4.1: The proposed solution is acceptable to affected human actors.
- Argument 4.3: Staffing requirements & staffing levels. The operating methods for normal operating conditions for new functionality/ies of the CD&R tool need to be clear and consistent.

The human performance assessment also considered the interactions with PJ.18-W2-53A and PJ.18-W2-56.

The most important observations from the HPAR are shown in the table below.

PIs	Most important observation of the solution
HP1 Consistency of human role with respect to human capabilities and limitations	The operating methods for normal operating conditions for new functionality/ies of the CD&R tool need to be clear and consistent.
HP2 Suitability of technical system in supporting the tasks of human actors	The task allocation between the human and the machine brought by the introduction of CD&R tools is consistent with automation principles improving human performance in terms of controllers' productivity. It is also important that the user interface supports specific needs of controllers' tasks.

PIs	Most important observation of the solution
HP3 Adequacy of team structure and team communication in supporting the human actors	Due to availability of the CD&R tools for both EC and PC, it is expected that team situational awareness will increase.
HP4 Feasibility with regard to HP-related transition factors	It is expected that the benefits brought by the usage of the CD&R support tool will have a positive affective response of the controllers.

Table 11: Most important HP observations from the HPAR of PJ.18-W2-53B.

The SESAR CBA model does not monetise human performance related impacts.

4.8 Indirect benefits

The cost benefit analysis of SESAR Solution PJ18-W2-56 [18] has demonstrated that gains in en route airspace capacity may induce additional benefits in fuel efficiency (FEFF1). This indirect benefit could be due to more airspace users being able to plan and fly along their preferred, shorter routes, as the improvement in capacity would result in less ATFM regulations.

The CBA of Solution 56 estimates this potential indirect benefit at the level 23kg per flight less fuel burn on average (11 kg per flight due to horizontal rerouting measures, and 12 kg per flight due to flight-level measures). This estimation is based on the analysis of the Network Manager in relation to its 2019 eNM/S19 measures and as such, they are likely to be overestimating the total indirect benefits.

For the purpose of maintaining the robustness of the CBA and in order to keep the calculations as conservative as possible, the CBA for Solution 53B does not consider such indirect benefits in the monetisation process.

Performance Framework KPA[8]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	IOC Year	FOC Year	Final Year
Cost Efficiency	ANS Cost efficiency	**CEF2** Flights per ATCO-Hour on duty	Nb	ATCO employment Cost change	€/year	-1.5M	-41M	-89M
				Support Staff Employment Cost Change	€/year	-1.6M	-44M	-95M
				Non-staff Operating Costs Change	€/year	N/A	N/A	N/A
		CEF3 Technology cost per flight	EUR / flight	G2G ANS cost changes related to technology and equipment	€/year	N/A	N/A	N/A
	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	N/A	N/A	N/A
		AUC4 Indirect operating costs for an airspace user	EUR / flight	Impact on operating costs that don't relate to a specific flight. Examples: parking charges, crew and cabin salary, handling prices at Base Stations	€/year	N/A	N/A	N/A

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

EUROPEAN PARTNERSHIP
Co-funded by the European Union

Performance Framework KPA[8]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	IOC Year	FOC Year	Final Year
		AUC5 Overhead costs for an airspace user	EUR / flight	Impact on overhead costs. Examples: dispatchers, training, IT infrastructure, sales.	€/year	N/A	N/A	N/A
Capacity	Airspace capacity	**CAP1** TMA throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	Calculated together with CAP2		
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year			
		CAP2 En-route throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	-3M	-102M	-320M
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	-1M	-18M	-57M
	Airport capacity	**CAP3** Peak Runway Throughput (Mixed mode)	% and # movements	Value of additional flights	€/year	N/A	N/A	N/A
	Resilience	**RES4a** Minutes of delays	Minutes	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
		RES4b Cancellations	% and # movements	Cost of cancellations	€/year	N/A	N/A	N/A

Performance Framework KPA[8]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	IOC Year	FOC Year	Final Year
		Diversions	% and # movements	Cost of diversions	€/year	N/A	N/A	N/A
Predictability and punctuality	Predictability	**PRD1** Variance of Difference in actual & Flight Plan or RBT durations	Minutes^2	Strategic delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
	Punctuality	**PUN1** % Departures < +/- 3 mins vs. schedule due to ATM causes	% (and # movements)	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
Flexibility	ATM System & Airport ability to respond to changes in planned flights and mission	**FLX1** Average delay for scheduled civil/military flights with change request and non-scheduled / late flight plan request	Minutes	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
Environment	Time Efficiency	**FEFF3** Reduction in average flight duration	% and minutes	Strategic delay: airborne: direct cost to an airline excl. Fuel (avoided-; additional +)	€/year	N/A	N/A	N/A
	Fuel Efficiency	**FEFF1** Average fuel burn per flight	Kg fuel per movement	Fuel Costs	€/year	0M	-80M	-178M
	Fuel Efficiency	**FEFF2**	Kg CO2 per movement	CO2 Costs	€/year	0M	-5M	-13M

Performance Framework KPA[8]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	IOC Year	FOC Year	Final Year
		CO2 Emissions						
Civil-Military Cooperation & Coordination	Civil-Military Cooperation & Coordination	**CMC2.1a** Fuel saving (for GAT operations)	Kg fuel per movement	Fuel Costs	€/year	N/A	N/A	N/A
		CMC2.1b Distance saving (for GAT operations)	NM per movement	Time Costs	€/year	N/A	N/A	N/A
Operational efficiency	Flight time	**TEFF1** Gate-to-gate flight time	minutes	Flight time	€/year	0M	-69M	-149M

Table 12: Results of the benefits monetisation per KPA

EUROPEAN PARTNERSHIP
Co-funded by the European Union

5 Cost assessment

The following sections detail the costs associated with the implementation of the solution per stakeholder group. The costs shown in the following sections represent only the delta in the costs, that is, the cost elements which occur exclusively due to the solution scenario. All costs which are already incurred in the reference scenario are disregarded by the CBA.

Since both aircraft-related enablers of the solution are part of the reference scenario, and no stakeholders have been identified apart from ANSPs and airspace users, only section 5.1 contains meaningful information. For the sake of maximum transparency and structural integrity of CBA documents, all stakeholder sections are retained but left empty.

5.1 ANSPs costs

ANSP costs related to the solution are driven by the changes/updates necessary to be made to the ATM systems and their functionalities, and/or by the introduction of new service procurements. The enablers mostly driving the costs and investments related to the solution are:

- ER APP ATC 104b: Adapt Controller Conflict Detection and Resolution Tools to Use Enhanced Trajectory Prediction
- ER APP ATC 167: ATC Planned Trajectories improvement with new ADS-C reports, and surveillance information
- ER APP ATC 200: ATC Improvement to receive and use more granular MET forecasts
- ER APP ATC201: ATC Improvement to build and use MET model using ADS-C reported MET data from A/Cs
- ER APP ATC 214: Conflict Detection envelope trajectories improvement with new ADS-C reports.

Since all the enablers encompass changes to the functionality of the ATM systems and tools, it is reasonable to analyse costs on the solution level, rather than for each enabler, as it is probable that ANSPs will invest in these changes in larger batches, rather than one-by-one.

5.1.1 ANSPs cost approach

The costs associated with PJ.18-W2-53B were collected following a CBA workshop, where the guidelines for estimating the costs were discussed in detail. ANSPs and industry members were invited to provide their cost estimates on the basis of the standard cost estimation sheet of SESAR CBAs, covering pre-implementation costs, implementation costs and changes in operational costs due to the implementation of the solution. ANSPs and industry members were also provided with a written summary of the data request, and were consulted on demand to ensure quality data inputs. ANSPs and industry members confirmed their understanding of the cost data requirements and provided their estimations accordingly.

Two ANSPs and one industry member submitted cost estimations for the solution. None of the stakeholders provided estimates as regards the pre-implementation costs. Both ANSPs estimated implementation costs and changes to the operational costs, while the industry member only provided estimates for implementation costs (which would be incurred by the ANSP purchasing the system upgrade/tool).

EUROPEAN PARTNERSHIP

Co-funded by the European Union

5.1.2 ANSPs cost assumptions

There was a significant difference in the cost estimates provided by the ANSPs, as regards the distribution of cost items across the implementation costs and changes in operational costs: one ANSP estimated a lower level of capital costs and a significantly higher level of changes in operational costs, mostly driven by the increase in personnel-related costs and the introduction of a new service that was necessary to be obtained (MET service). The other ANSP estimated significantly higher implementation and capital costs, but an almost negligible impact on operational costs. These two approaches were both deemed reasonable and plausible, given the significant differences in the operational and business models of ANSPs. Therefore the cost assessment was split into sub-scenarios, to make sure both approaches are reflected in the CBA.

- For the first sub-scenario (lower investments, high operational costs), capital costs were based on the middle values of the range provided by the ANSP, with the caveat, that the investments were increased by the inputs provided by the industry member so that a careful and prudent calculation could be enabled.
- For the second sub-scenario (high investments, low operational costs) the figures provided by the ANSP were used without any changes applied, as all relevant cost categories were filled in with reasonable estimates.

5.1.3 Number of investment instances (units)

The number of investment instances was estimated based on the number of operational environments, where the solution is applicable:

- TMAs with Medium to Very High Complexity, and
- En route OEs (single or mixed) with Medium to Very High Complexity.

Airport				Terminal Airspace				En-route			
HC	HS	LC	LS	VH	H	M	L	VH	H	M	L
N/A	N/A	N/A	N/A	14	12	69	N/A	19	13	25	N/A

Table 13: Number of investment instances – ANSPs

In total, 152 investment instances have been identified, which represents the maximum possible number of applicable investment units. It is highly probable that ANSPs will require less investment instances due to the fact that some terminal and en route operational environments are supported by integrated ATM systems and tools, and therefore will only require a single investment associated with the solution. Despite this fact, the CBA considered the total number of OEs as the number of investment instances so that the results of the NPV calculation are robust and prudent.

As noted under section 3.5.2, the PAR did not include medium complexity OEs in the extrapolation of the benefits. Nevertheless, the CBA does consider all applicable OEs, those of medium complexity included, in order to make calculations more conservative, and eliminate the downside risk.

5.1.4 Cost per unit

Based on the cost assumptions and the number of instances, the extrapolation of the costs for each specific OE category and each cost item is summarised in the table below. The table provides the figures per the sub-scenarios introduced in section 5.1.2.

Cost category	Terminal Airspace				En-route			
	VH	H	M	L	VH	H	M	L
Pre-Implementation Costs sub-scenario 1	0	0	0	N/A	0	0	0	N/A
Implementation costs sub-scenario 1	19.78	16.96		N/A	26.85	18.37	35.33	N/A
Operating costs sub-scenario 1	8.4	7.2		N/A	11.4	7.8	15	N/A
Pre-Implementation Costs sub-scenario 2	0	0	0	N/A	0	0	0	N/A
Implementation costs sub-scenario 2	31.64	27.12		N/A	42.94	29.38	56.5	N/A
Operating costs sub-scenario 2	0.56	0.48		N/A	0.76	0.52	1	N/A

Table 14: Costs per OE category – ANSPs

The two sub-scenarios were used to create two CBA scenarios in the CBA model, both of them assuming that all ANSPs follow the respective strategies.

5.2 Airport operators costs

No costs have been identified for airport operators by Appendix A of the OSED of PJ.18-W2-53B..

5.3 Network Manager costs

No costs have been identified for the Network Manager by Appendix A of the OSED of PJ.18-W2-53B..

5.4 Airspace User costs

Given that all enablers are associated with the reference scenario, there are no investment needs or costs identified for airspace users.

5.5 Military costs

Appendix A of the OSED for PJ.18-W2-53B did not identify any costs for the Military.

5.6 Other relevant stakeholders

No other relevant stakeholders were identified during the stakeholder analysis.

6 CBA Model

For the CBA, the SESAR CBA model version 7.3.8 was used.

PJ18-53B CBA v4 (4_0).xlsm

6.1 Data sources

Cost Inputs

The data sources for the cost inputs were the estimations provided by the solution members, as discussed in section 5.1.

Benefit Inputs

Benefit inputs were source from the Performance Assessment Report of Solution PJ.18-W2-53B [13]. For additional contextual information, the Validation Plan (VALP) [16], the Validation Report (VALR) [17], the Human Performance Assessment Report (HPAR) [15], and the Safety Assessment Report (SAR) [14] were also used.

Other Input Parameters

The data sources for the non-Solution specific CBA Model parameters are referenced in the various input's sheets of the CBA Model with details provided in the sheet 'Source of Reference'. These are all part of the Common Assumptions [5]. Additionally, the rest of parameters have been obtained from CBA reference documentation.

Inputs for the equipage ratio of enabler A/C 37 are discussed under section 3.5.3.

7 CBA Results

This section outlines the key results from the cost-benefit analysis related to Solution PJ.18-W2-53B. The CBA compares the benefits detailed in section 4 and the costs detailed in section 5 of this report, for each year and each stakeholder, and calculates the value of benefits and costs both on a discounted and undiscounted basis, for both sub-scenarios (see section 5.1.2 for details on sub-scenarios).

The results of the CBA are overall positive, that is, the NPV of implementing the solution scenario is positive for each stakeholder group and thus on the solution level as well. The sub-scenario with higher investment costs and low operational costs (sub-scenario 2) yielded a significantly higher NPV, simply due to the nature of the CBA calculations (due to the relatively long period of the CBA, operational costs occurring each year have a relatively higher impact on the NPV than upfront investment costs).

The main drivers of the positive NPV are the benefits realised by airspace users in terms of fuel efficiency, capacity, and time savings: these benefits are responsible for 45%, 30% and 23% of the NPV respectively. The cost-efficiency benefit realised by the ANSPs through an increase in ATCO productivity corresponds to around 16% of the NPV.

A more detailed description of the results of the CBA is offered in the following sections.

7.1 Undiscounted costs and benefits

Figure 11 shows the undiscounted results of the CBA for sub-scenario 1 (lower investments, high operational costs). Once the equipage rate starts to ramp up in 2029, the benefits already outweigh the costs.

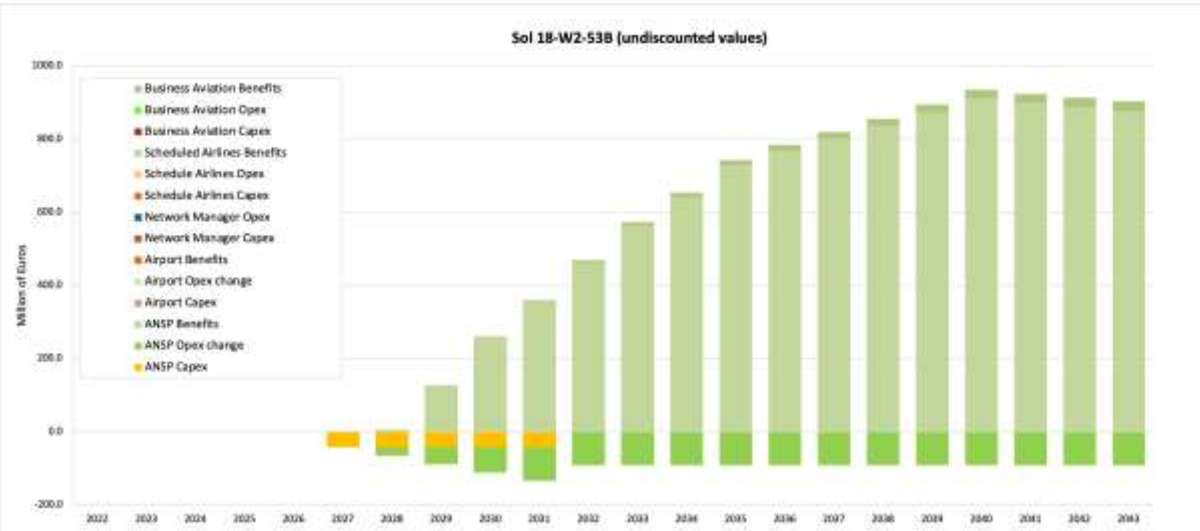

Figure 11: Undiscounted yearly benefits and OPEX/CAPEX for PJ.18-W2-53B Sub-scenario 1.

The table below shows the results of the CBA without applying the discount rates. As can be seen, the net benefits are overly positive.

PJ.18-W2-53B - 2022-2043 (undiscounted) (M€)

Undiscounted	Net Benefits	Capex	Opex	Benefits
ANSP	586.7	-214.8	-1,322.4	2,123.9
Airports	0.0	0.0	0.0	0.0
Network Manager	0.0	0.0	0.0	0.0
Business Aviation	219.1	0.0	0.0	219.1
Scheduled Aviation	7,872.2	0.0	0.0	7,872.2
RPAS-Civil	0.0	0.0	0.0	0.0
RPAS Military	0.0	0.0	0.0	0.0
Overall	**8,677.9**	**-214.8**	**-1,322.4**	**10,215.1**

Figure 12: Undiscounted results of the CBA of PJ.18-W2-53B Sub-scenario 1.

The two figures below show the undiscounted results for Sub-scenario 2 (high investments, low operational costs). The low operational costs allow for even higher net benefits than for sub-scenario 1.

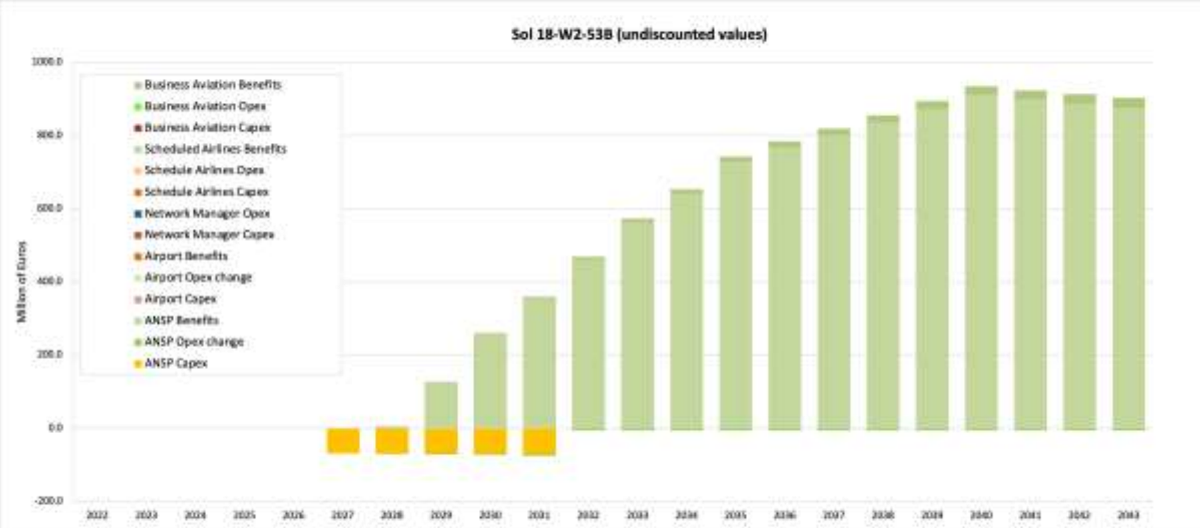

Figure 13: Undiscounted yearly benefits and CAPEX/OPEX Solution PJ.18-W2-53B Sub-scenario 2.

The driver in the difference between the two sub-scenarios is of course the higher ANSP net benefits in sub-scenario 2, which is a result of low operational costs, with the same benefits.

PJ.18-W2-53B - 2022-2043 (undiscounted) (M€)

Undiscounted	Net Benefits	Capex	Opex	Benefits
ANSP	1,692.2	-343.5	-88.2	2,123.9
Airports	0.0	0.0	0.0	0.0
Network Manager	0.0	0.0	0.0	0.0
Business Aviation	219.1	0.0	0.0	219.1
Scheduled Aviation	7,872.2	0.0	0.0	7,872.2
RPAS-Civil	0.0	0.0	0.0	0.0
RPAS Military	0.0	0.0	0.0	0.0
Overall	**9,783.5**	**-343.5**	**-88.2**	**10,215.1**

Figure 14: Undiscounted results of the CBA of PJ.18-W2-53B Sub-scenario 2

While the overall CBA is highly positive, and each stakeholder group has a positive net benefit as well, ANSPs of course face a negative cash flow during the implementation and transition phases, when they need to realise the investments and apply all the necessary changes to their operational procedures. For airspace users, the cash-flows are positive from the year of IOC, as no investments or operational costs have been identified for this stakeholder group.

7.2 Net Present Value

The undiscounted results are useful to help create an understanding of what cash-flows will look like in the future years, but are not taking into account the value of time. In order to properly compare two investment decisions in general, and the two sub-scenarios in particular, the net present value of the sub-scenarios also needs to be calculated. This ensures that future cash flows are translated into their present values so that any difference in when benefits and expenditures occur is accounted for.

The following tables show the discounted results for both sub-scenarios.

PJ.18-W2-53B - 2022-2043 (discounted 8%) (M€)

Discounted		NPV	Capex	Opex	Benefits	Discounted
	ANSP	84.9	-116.7	-432.7	634.4	
	Airports	0.0	0.0	0.0	0.0	
	Network Manager	0.0	0.0	0.0	0.0	
	Business Aviation	59.4	0.0	0.0	59.4	
	Scheduled Aviation	2,299.4	0.0	0.0	2,299.4	
	RPAS-Civil	0.0	0.0	0.0	0.0	
	RPAS Military	0.0	0.0	0.0	0.0	
	Overall	**2,443.7**	**-116.7**	**-432.7**	**2,993.2**	

Figure 15: Discounted benefits and CAPEX/OPEX for PJ.18-W2-53B Sub-scenario 1.

For sub-scenario 1, the net present value of implementing the solution is 2,443.7M€. As discussed previously, the NPV is largely driven by the benefits realised by airspace users.

PJ.18-W2-53B - 2022-2043 (discounted 8%) (M€)

Discounted		NPV	Capex	Opex	Benefits	Discounted
	ANSP	418.8	-186.7	-28.8	634.4	
	Airports	0.0	0.0	0.0	0.0	
	Network Manager	0.0	0.0	0.0	0.0	
	Business Aviation	59.4	0.0	0.0	59.4	
	Scheduled Aviation	2,299.4	0.0	0.0	2,299.4	
	RPAS-Civil	0.0	0.0	0.0	0.0	
	RPAS Military	0.0	0.0	0.0	0.0	
	Overall	**2,777.6**	**-186.7**	**-28.8**	**2,993.2**	

Figure 16: Discounted benefits and CAPEX/OPEX for PJ.18-W2-53B Sub-scenario 2.

For sub-scenario 2, the NPV is even more positive than for sub-scenario 1. The NPV of this sub-scenario is 2,777.6M€, which is 13.7% more than for sub-scenario 1. This does not mean, that ANSPs need to follow sub-scenario 2 instead of 1, but rather illustrates, that even larger different approaches to implementing the solution lead to high benefits for all stakeholders.

7.3 Payback period

The undiscounted cash flow of ANSPs turns positive in 2037 for sub-scenario 1 and in 2033 for sub-scenario 2. The discounted cumulative cash flow of ANSPs turns positive in 2039 for sub-scenario 1 and in 2034 for sub-scenario 2. The figures below illustrate the evolution of discounted benefits and expenditures.

Figure 17: Discounted OPEX/CAPEX, benefits and cumulative net benefits fo PJ.18-W2-53B Sub-scenario 1.

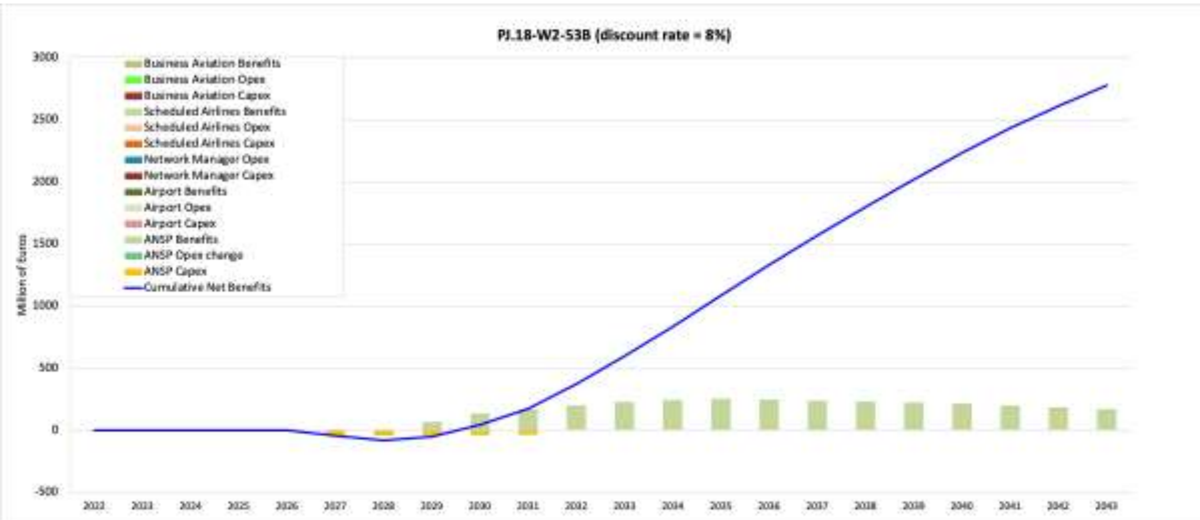

Figure 18: Discounted OPEX/CAPEX, benefits and cumulative net benefits fo PJ.18-W2-53B Sub-scenario 2.

8 Sensitivity and risk analysis

8.1 Sensitivity analysis

The discount rate is a fundamental parameter of the net present value calculation, as it determines how much weight is given to future cash flows. As the choice of the discount rate is always somewhat arbitrary, it is good practice to analyse how sensitive results are to changes in the discount rate. The figure below shows the NPV at different discount rates. Discount rates are set from 50% to 150% of the original value (which is 8%).

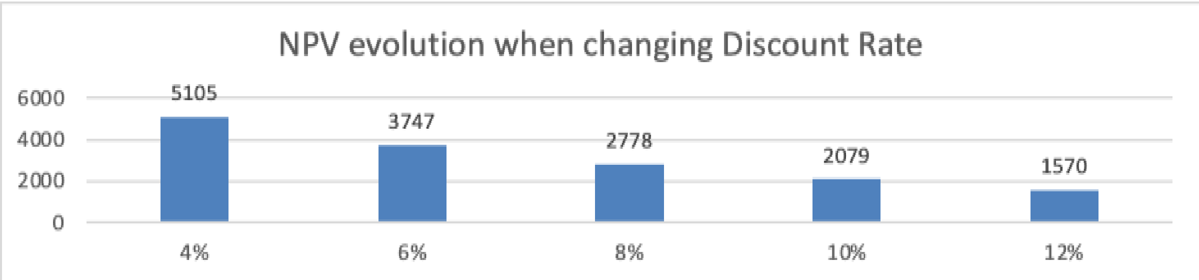

Figure 19: Changes in the NPV when different discount rates are applied.

The profile follows the same trend for both sub-scenarios, and the NPV remains positive even when the calculation is stress-tested with unreasonably high values (20% or more).

Apart from the discount rate, the sensitivity of the CBA calculation needs to be evaluated for all key input parameters: costs and benefits alike. The following tornado diagrams indicate how the NPV would change, if each parameter would be changed by +/-5-10%, ceteris paribus (without changing any other parameter). The tornado diagrams show the same general characteristics for both sub-scenarios, which is natural, as the CBA model is the same between the sub-scenarios with the only difference being in the CAPEX and OPEX changes. The CBA calculations are most sensitive to changes in airspace capacity: a 5% change in the parameter triggers a change of 1.8% in the NPV, and similarly, a 10% change in the parameter results in a change of 3.6% in the NPV. The NPV is also quite sensitive to changes in fuel efficiency and ATCO productivity, with a 5% change triggering a 1.2% and 1.1% change in the NPV respectively, and a 10% change causing the NPV to change by 2% for both parameters. The sensitivity of the CBA over these parameters is understandable, as these are the main drivers of the benefits. Changes in time savings have slightly less impact on the NPV: a 10% change would result in around 1.8% variation of the NPV.

While ATCO productivity variations do affect the overall NPV significantly, it is also plausible to expect that with a sufficiently large reduction in the parameter, the NPV for the ANSPs could become negative. The analysis indeed found, that if the ATCO productivity benefit parameter was 1.64%, the NPV for the ANSPs was zero (0.64% in sub-scenario 2), and any lower values for the parameter resulted in a negative NPV for the ANSPs.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

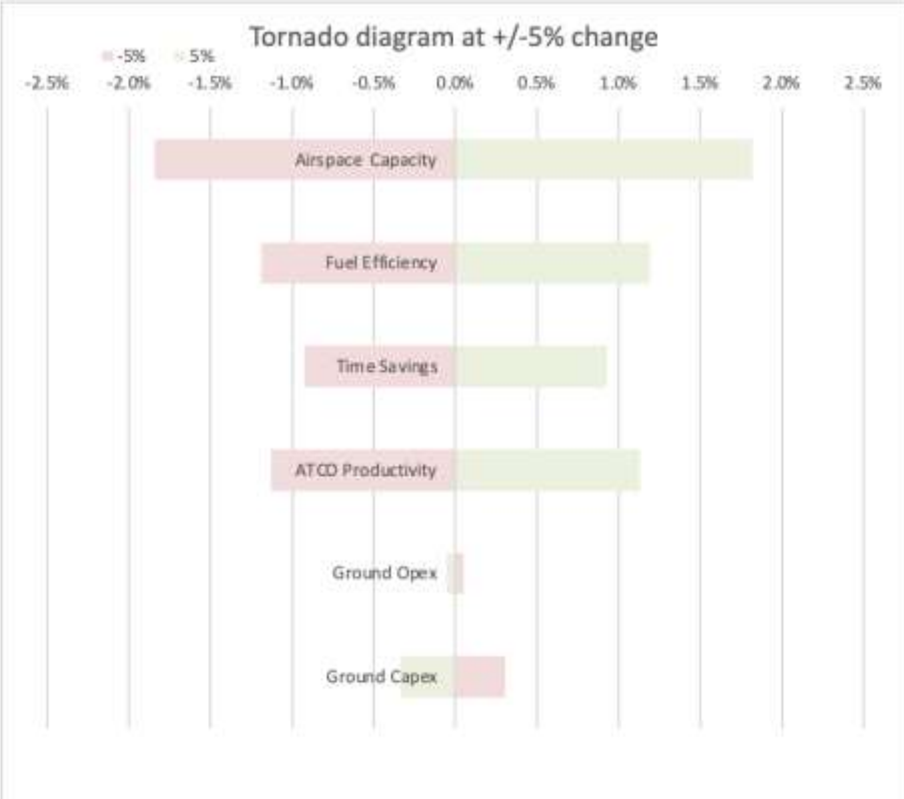

Figure 20: Tornado diagram with +/-5% change in the input parameters of the CBA.

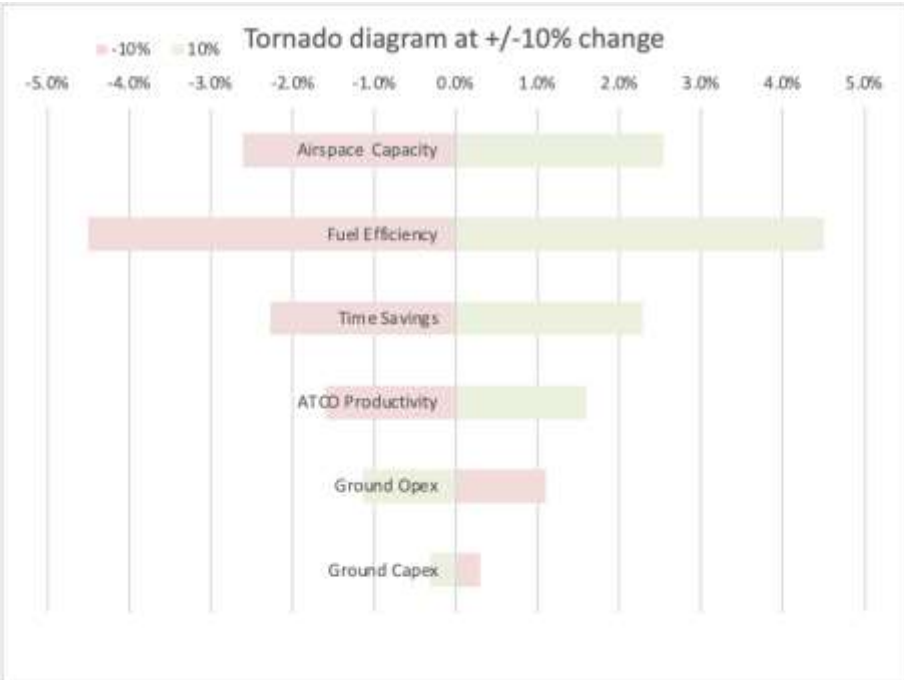

Figure 21: Tornado diagram with +/- 10% change in the input parameters of the CBA.

When looking at the costs of the ANPs and the sensitivity of the NPV to changes therein, the overall results are sufficiently robust: even larger variations in the cost parameters would not turn the overall

NPV negative. This is reassuring, as costs are not validated through demonstration exercises, and usually involve greater uncertainty. The NPV for ANSPs is obviously more sensitive to changes in the cost parameters: in sub-scenario 1, a 20% increase in the delta of operating costs would turn the ANSP NPV zero. For sub-scenario 2, the NPV for ANSPs is even less sensitive to changes in the operational cost delta parameter, due to the very low absolute value of the baseline input. The NPV of ANSPs in sub-scenario 2 would still remain positive even if the change in operational costs were 15 times higher.

The CBA for ANSPs is not so sensitive to changes in one-off implementation costs. In sub-scenario 1, NPV remained positive even with a 70% increase in implementation costs, while in sub-scenario 2, one-off costs could be increased by more than 2 times before the NPV for ANSPs became zero.

Finally, in order to understand the combined impact of changes in the benefits on the CBA, the NPV was calculated for both sub-scenarios with all benefit parameters being changed by +/-25-50% at the same time. Needless to say, such changes in all of the inputs at the same time are highly unlikely, but the fact that the NPV remained positive shows that the CBA calculations are robust. Figure 22 shows how the NPV would change if all benefit inputs were reduced/increased at the same time.

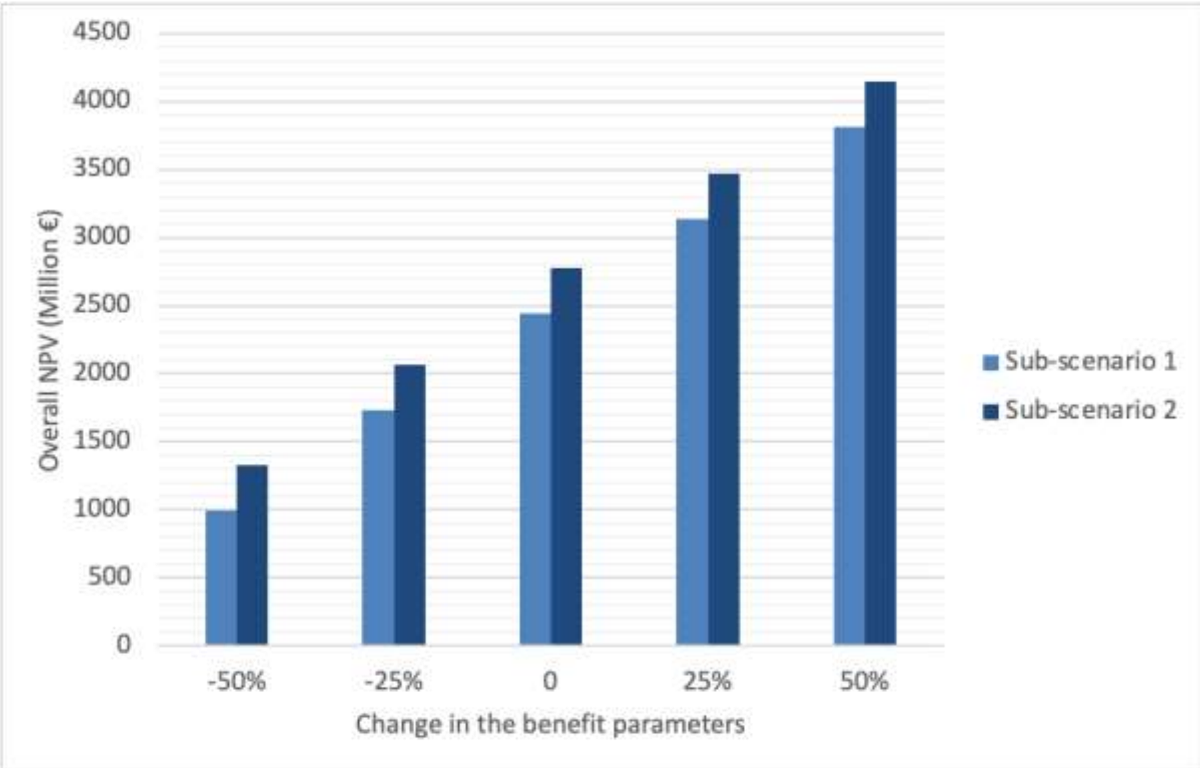

Figure 22: NPV profile if all benefits parameters are changed simultaneously.

8.2 Risk analysis

The key risks associated with the CBA are summarised in Table 15. While there are some risk items which may have a significant impact (especially on the CBA of ANSPs), all risks can be mitigated with reasonable efforts and normal management practices.

Risk	Likelihood	Impact
ANSP operational cost changes are higher than estimated	Low-Medium: In Sub-scenario 1 the operational cost delta parameter is already high, and based on the cost assessment it is highly unlikely that significantly higher costs would be incurred by ANSPs. In Sub-scenario 2 the baseline parameter is very low, therefore a risk of higher than estimated costs is more likely.	The sensitivity analysis details the impact. ANSP CBA may be negative at significant variations, but the overall CBA is not affected.
ANSP investments and implementation costs are higher than planned.	Low: In both sub-scenarios, the one-off costs associated with implementation are relatively high (and have been adjusted for Sub-scenario 1 to an even higher level than the original input based on the combination of inputs).	The sensitivity analyses details the impact. ANSP CBA may be negative, but only with significant changes.
ATCO productivity is not improved	Medium: If the implementation of the solution is not accompanied by proper change management processes and sufficient training, improvements in ATCO productivity may not be realised.	ANSP CBA may become negative (overall CBA not affected).

Risk	Likelihood	Impact
Implementation of the solution is elongated, postponed, disrupted	Medium: If the tools/functionalities developed by the solution are not specified properly during the implementation, or technical difficulties arise during the deployment, implementation may take longer than planned. This is not too likely, as the solution provides detailed technical specifications.	Same impact as for the increase of costs, as the longer implementation period would result in higher implementation costs. ANSP CBAs may be negative, overall CBA not affected dramatically.

Table 15: Overview of risks associated with the CBA of PJ.18-W2-53B

EUROPEAN PARTNERSHIP

Co-funded by the European Union

9 Recommendations and next steps

The following recommendations are formulated for PJ.18-W2-53B, based on the CBA.

Recommendation 1: The solution is very much related to PJ.18-W2-53A, which looks at how the tools developed by 53B can be enhanced for even more benefits. While 53A is at V2 maturity as of the writing of this CBA, and 53B is targeting V3, it might be reasonable for ANSPs to deploy the two solutions at once, thereby saving implementation costs. This might even result in a reduction of investment needs as well.

Recommendation 2: Based on the finding that the CBA of ANSPs is sensitive to changes in ATCO productivity improvements, ANSPs are invited to put in place thorough change management processes during the implementation, and make sure that all human performance related issues are properly addressed, so that the benefits can be realised in full.

Recommendation 3: Given the sensitivity of the ANSPs CBA on implementation and operational costs, and that these costs might be subject to risks related to problems with the implementation, ANSPs and industry members are invited to engage in detailed discussions when specifying the implementation of the solution, in order to avoid unforeseen complications.

Recommendation 4: Large changes operational costs can affect the CBA of ANSPs adversely, therefore ANSPs are recommended to explore all options which enable a reduction in operational cost delta.

Recommendation 5: The CBA is dependent on the timely implementation of aircraft related enablers, therefore airspace users are invited to ensure that enablers are implemented as planned.

10 References and Applicable Documents

10.1 Applicable Documents

[1] SESAR Project Handbook;

[2] Guidelines for Producing Benefit and Impact Mechanisms;

[3] Methods to Assess Costs and Monetise Benefits .

[4] SESAR Cost-Benefit Analysis Model[9]

[5] Cost Benefit Analyses – Standard Input

[6] Cost Benefit Analyses – Method to assess costs

[7] ATM CBA Quality checklist

[8] Methods to Assess Costs and Benefits for CBAs

10.2 Reference Documents

[9] Common assumptions

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

[11] Performance Framework

[12] SESAR Solution 53B SPR-INTEROP_OSED for V3 - Part I

[13] SESAR Solution 53B SPR-INTEROP_OSED for V3 - Part V - PAR

[14] SESAR Solution 53B SPR-INTEROP_OSED for V3 – Part II – SAR

[15] SESAR Solution 53B SPR-INTEROP_OSED for V3 - Part IV - HPAR

[16] PJ.18-W2-53B Validation Plan

[17] SESAR Solution 53B VALR for V3

[18] SESAR Solution 56 Cost Benefit Analysis for V2

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

11 Appendix

Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs, source reference *[11]*

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

EUROPEAN PARTNERSHIP

Co-funded by the European Union

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

[19] **Table 16: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs**

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Insert project logo here

-END OF DOCUMENT-