SESAR Solution PJ.02-W2-21.4: Cost Benefit Analysis (CBA) for V3

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AART

PJ.02 AART

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

Abstract

This document provides the final version of Cost Benefit Analysis (CBA) at V3 level for Solution PJ.02-W2-21.4 in SESAR 2020 Wave 2. This final version of the document is based on the refinement of the research findings of the Intermediate CBA for Solution PJ.02-W2-21.2-3-4-6, delivered at the end of 2020. This predecessor document was based on the further refinement of Wave 1 activities of solution PJ.03a-01 (recorded in the PJ.03a-01 CBA for V2). Moreover, this CBA takes into account the last operational and technical developments included in the OSED, addressing the Operational Improvement step (OI) AO-0222-B.

According to the recent update and split of data packs in PJ.02 AART, this document covers the solution PJ.02-W2-21.4, achieving V3 maturity.

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1 Executive Summary

This document reports the **final version** of the **Cost Benefit Analysis (CBA)** for the following solution expected to reach **V3 maturity at the end of 2022**:

PJ.02-W2-21.4 - Full Guidance Assistance to mobiles using 'Follow the Greens' procedures based on Airfield Ground Lighting (aprons/taxiways/runways).

This solution intends to automate the prioritization of mobiles along their cleared route on the whole movement area. The Guidance Service considers other traffic to guide the mobile as it progresses along its assigned route and at the holding points. It allocates priorities between mobiles based on local operating rules (e.g. runway exit versus parallel taxiways, aircraft versus vehicle, aircraft converging or crossing at intersections and taxiways passing close to push-back routes or other taxiways where insufficient wingtip separation exists) as well as known constraints from the surface management system. Automatic Guidance will be provided using the “Follow the Green” concept on the Airfield Ground Lighting infrastructure.

Developments of this solution in Wave 2 start from the activities performed and related outcomes obtained in the Wave 1 solution PJ.03a-01, continuing respectively the work done on the Operational Improvement (OI) step AO-0222-B. In turn, solution PJ.03a-01 was based on the achievements of previous SESAR 1 Solutions #22, #47 and #70 for the enhancement of traffic situational awareness, provision of assistance to controllers and guidance to pilots and drivers also through the airfield ground lightning.

According to the final OSED document [23], this solution could be implemented predominantly in Very Large and Large airports, the geographical scope of this CBA. Deployment activities are planned to start in Q4 of 2024 and last six years, ending in Q4 2030. Thanks to a sequenced deployment of the solution at different locations, the first set of airports deploying the solution are expected to start generating benefits in 2026.

As defined in the Benefits Impact Mechanisms (BIMs) included in Appendix B, the solution generates benefits in the Cost Efficiency (CEF) and Human Performance KPAs. The former ones have been monetised according to the Performance Framework rules.

Costs are expected to impact on ANSPs and Airport Operators accounts in different proportions. Moreover, cost estimations were provided by solution partners and are considered as main inputs to this CBA.

At current conditions, overall cash flow is unequivocally positive, achieving the payback year already in 2026, one year after the start of benefits generation, and a total cumulated NPV of 596 M€ in 2043. At the same time, it is important to highlight that all the benefits are accounted for the ANSPs, while AOs will assume part of the investments required.

The current level of confidence in results is considered medium. Recommendations and additional activities that will be performed to increase the confidence level of results are reported in section 9 of this report.

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2 Introduction

2.1 Purpose of the document

This document provides the Cost Benefit Analysis (CBA) for Solution 21.4 for the V3 level, part of the SESAR Project PJ.02-W2-21 – Digital evolution of integrated surface management.

According to SESAR 2020 Project Handbook [1], CBA in V3 should include all the evidence gathered in terms of impacts, benefits and costs of the solution. CBA task should provide the overall NPV of the solutions and their distribution per stakeholder group, a sensitivity analysis identifying the most critical variables to the value of the project, a risk analysis, the CBA model, a report and a set of recommendations.

This CBA has been developed to identify and agree on:

- The deployment scenario approach for the solution,
- The assumptions related to the solutions and reference scenario,
- The stakeholders impacted by each solution, i.e. those who will support the deployment and operating costs and those who will benefit from the solutions,
- The cost elements to be assessed for each stakeholders' group considering the operating environments where the solutions are expected to provide benefits, as defined in the deployment scenario approach and in the final version of the SESAR Solutions PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 [23],
- The mechanisms to quantify the benefits, based on the BIMs (Benefit and Impact Mechanisms) developed in the OSED task and presented in Appendix A of the SESAR Solutions PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 document.

This V3 CBA provides a consolidated evaluation of the overall costs at the solution level and per affected stakeholder. Costs have been quantified and monetised in the CBA for ANSPs and Airport Operators. This has been done based on the gathering of inputs from solutions partners and their correspondent extrapolation to estimate the impact on the rest of the EU stakeholders.

Regarding benefits, these have been quantified ANSPs being estimated using the SESAR Performance Framework for Cost Efficiency KPA. Moreover, benefits monetisation is based on the results obtained in the validation exercises and PAR activities, providing the expected value of enhancements the solutions will bring.

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2.2 Scope

In accordance with the OSED, the scope of this document consists of the assessment of the cost incurred and benefits generated by the OI Step and enablers of the Solutions PJ.02-W2-21.4, which are:

SESAR Solution ID	SESAR Solution Title	OI Steps ID	OI Steps Title	Enabler ID	Enabler Title	OI Step/Enabler Coverage
PJ.02-W2-21.4	Full Guidance Assistance to mobiles using 'Follow the Greens' procedures based on Airfield Ground Lighting (aprons/taxiways/runways)	AO-0222-B	Full Guidance Assistance to mobiles using 'Follow the Greens' procedures based on Airfield Ground Lighting (aprons/taxiways/runways)	**AERODROME-ATC-07c**	A-SMGCS incorporating the function that provides No FtG CMAC Alert for Controllers	Fully
				AERODROME-ATC-61b	Advanced surface guidance management services to process the automatic triggering of airport ground signs and lighting according to the route issued by ATC	Fully
				REG-0541	Update of EASA Appendix 1 to AMC1 SERA.14001	Fully

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SESAR Solution ID	SESAR Solution Title	OI Steps ID	OI Steps Title	Enabler ID	Enabler Title	OI Step/Enabler Coverage
					General for a possible update of phraseology	
				STD-131	Update of ICAO Doc 4444 for a possible update of phraseology	Fully

Table 1: SESAR Solutions PJ.02-W2-21.4 Scope and related OI steps/enablers

2.3 Intended readership

The intended readership for this document includes:

- PJ.02-W2-21.4 Solution Members,
- All other PJ.02-W2 Project Members,
- SESAR Programme Management,
- PJ.19, as Content Integration Project,
- PJ.20, as Master Plan Maintenance project,
- SESAR Joint Undertaking.

2.4 Structure of the document

This report is structured as follows:

- **Section 1** provides the executive summary,
- **Section 2** provides the overall scope, time horizon, intended audience, structure of the document, background, glossary of terms and acronyms,
- **Section 3** presents the objectives and scope of this CBA, describing the PJ.02-W2-21.4 solutions and the problem addressed by them, identifies the main stakeholders impacted and describes the different scenarios compared in the CBA,
- **Section 4** provides a view of the overall contribution to Key Performance Indicators and a description of the expected benefits per stakeholder,
- **Section 5** describes the cost approach and the main assumptions taken when assessing the cost elements of the solutions and presents the results of the cost assessment per stakeholder group,
- **Section 6** provides a description of the CBA model and the main sources of data used to build the CBA Model,
- **Section 7** reports the overall CBA results, considering on one side the single perspective of each relevant stakeholder and on the other side the overall results obtained from the sum of the previous perspectives,
- **Section 8** includes sensitivity and risk analysis, identifying the main variables and parameters whose variation has a relevant impact on the assessment,
- **Section 9** includes recommendations and next steps extracted from the results of the analysis,
- **Section 10** includes the references and applicable documents,
- **Appendix A** provides the mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs,
- **Appendix B** provides the Benefit Impact Mechanisms (BIMs), as reported in the OSED document,
- **Appendix C** provides the list of applicable deployment locations, a part of which has been considered for the definition of the geographical scope of the CBA.

2.5 Background

Previous activities relevant to SESAR Solution PJ.02-W2-21.4:

Internal to SESAR 1

- OFA04.02.01 Final OSED
- OFA04.02.01 Final SPR
- OFA04.02.01 SAR

Internal to SESAR 2020

- Solution PJ03a-01 Final SPR-INTEROP/OSED V2 (PJ03a-01 D2.010) [15]
- Solution PJ03a-01 Final CBA for V2 (PJ03a-01 D2.210) [16]
- Solutions PJ02-W2-21.2-21.3-21.4-21.6 Intermediate version SPR-INTEROP/OSED V3 (PJ02-W2-21.2-21.3-21.4-21.6 D6.2.001) [17]
- Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part I (PJ02-W2-21.4 D6.4.001) Final version [23]
- Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part II Safety Assessment Report (PJ02-W2-21.4 D6.4.001) Final version [20]
- Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part V Performance Assessment Report (PAR) Final version (PJ02-W2-21.4 D6.4.001) [21]
- Solution PJ.02-W2-21.4 VALR (PJ02-W2-21.4 D6.4.003) [22]

2.6 Glossary of terms

Term	Definition	Source of the definition
Net Present Value	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.	*Investopedia*
Key Risk Area	A key risk area is defined by its potential accident outcome and by the immediate precursors of that accident outcome. In other words, each area collects the number of occurrences that lead or could have led to a specific type of accident (e.g. Runway collision)	*EASA*
Cost Benefit Analysis (CBA)	A cost-benefit analysis is a systematic process that businesses use to analyze which decisions to make and which to forgo. The cost-benefit analyst sums the potential rewards expected from a situation or action and then subtracts	*Investopedia*

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Term	Definition	Source of the definition
	the total costs associated with taking that action.	
Sensitivity Analysis	Sensitivity analysis is a financial model that determines how target variables are affected based on changes in other variables known as input variables. It is a way to predict the outcome of a decision given a certain range of variables.	*Investopedia*
Risk Analysis	The term risk analysis refers to the assessment process that identifies the potential for any adverse events that may negatively affect organizations and the environment. Conducting a risk analysis can help organizations determine whether they should undertake a project or approve a financial application, and what actions they may need to take to protect their interests.	*Investopedia*

Table 2: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
AMM	Airport Moving Map
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
AO	Airport Operator
APT	Airport
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASR	Annual Safety Report
ATC	Air Traffic Control
ATCO	Air Traffic COntroller
ATM	Air Traffic Management
ATS	Air Traffic Services
AU	Airspace User
BIM	Benefit Impact Mechanism
CAPEX	CAPital EXpenditure

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Acronym	Definition
CATC	Conflicting ATC Clearances
CBA	Cost Benefit Analysis
Civ	Civil
CMAC	Conformance Monitoring Alerts for Controllers
CTA	Controlled Time of Arrival
EFS	Electronic Flight Strips
EN	ENabler
EOBT	Estimated Off-Block Time
FOC	Final Operational Capability
GH	Ground Handler
GTD	Ground Traffic Display
INTEROP	Interoperability
IOC	Initial Operational Capability
KPA	Key Performance Area
KPI	Key Performance Indicator
Mil	Military
MTOW	Maximum Take-Off Weight
NPV	Net Present Value
OE	Operating Environment
OI	Operational Improvement
OPEX	OPerating EXpenditure
OSED	Operational Service and Environment Definition
PAR	Performance Assessment Report
PCP	Pilot Common Project
R/T	Radio Telephony
RMCA	Runway Monitoring and Conflict Alerting
RWY	Runway
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SPR	Safety and Performances Requirements
TWY	Taxiway

Acronym	Definition
VALR	Validation Report
VDS	Vehicle Display System

Table 3: List of acronyms

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3 Objectives and scope of the CBA

3.1 Problem addressed by the solution

The main objective of the solution in the scope of this CBA is to enhance the automatic guidance and user prioritisation on the ground of taxiing aircraft thanks to the implementation of a taxi route manager service in combination with the "Follow the greens" concept using the aircraft surface lightning infrastructure.

This document is developed to:

- Identify and agree on the main elements and assumptions that have been used in the development of the CBA Model,
- Identify impacted stakeholder groups and propose the number of airports to be considered in the deployment scenario approach, taking into account the Operational Improvements (OIs) and Enablers (ENs) implementation requirements,
- Provide a mechanism for the evaluation of the potential costs of the Solutions for Air Navigation Service Providers (ANSPs) and Airport Operators (AOs),
- Update the results obtained in the intermediate version of CBA for this solution, starting from a refined list of benefits, mainly on Cost Efficiency and Human Performance,
- Update the previous results according to the new geographical scope, including 14 Very Large and 18 Large airports,
- Update the previous version of the CBA report including content modifications aligned with the final version of the OSED.

3.2 SESAR Solution description

3.2.1 Solution PJ.02-W2-21.4

This solution intends to automate the prioritisation of mobiles along their cleared route on the whole movement area. The Guidance Service considers other traffic for spacing to guide the mobile as it progresses along its assigned route and at the holding points. It allocates priorities between mobiles based on local operating rules (e.g. runway exit versus parallel taxiways, aircraft versus vehicle, aircraft converging or crossing at intersections and taxiways passing close to push-back routes or other taxiways where insufficient wingtip separation exists), as well as known constraints from the surface management system. Automatic Guidance will be provided using the "Follow the Greens" concept on the Airfield Ground Lighting infrastructure.

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SESAR Solution ID	OI Steps ref. (coming from the Integrated Roadmap)	OI Steps definition (coming from the Integrated Roadmap)	OI step coverage	Source reference
PJ.02-W2-21.4	**AO-0222-B**	Full Guidance Assistance to mobiles using 'Follow the Greens' procedures based on Airfield Ground Lighting (aprons/taxiways/runways)	Fully	EATMA DS23 Draft

Table 4: SESAR Solution PJ.02-W2-21.4 Scope and related OI steps

OI Steps ref.	Enabler ref.	Enabler definition	Enabler coverage	Applicable stakeholder	Source reference
AO-0222-B	**AERODROME-ATC-07b**	A-SMGCS incorporating the function that provides an advanced set of Conformance Monitoring Alerts for Controllers (CMAC) on the movement area	Fully	ANSP	EATMA DS23 Daft
	AERODROME-ATC-61b	Advanced surface guidance management services to process the automatic triggering of airport ground signs and lighting according to the route issued by ATC	Fully	ANSP Airport Operator	EATMA DS23 Draft
	REG-0541	Update of EASA Appendix 1 to AMC1 SERA.14001 General for the possible update of phraseology	Fully	Unassigned	EATMA DS23 Draft
	STD-131	Update of ICAO Doc 4444 for the possible update of phraseology	Fully	Unassigned	EATMA DS23 Draft

Table 5: SESAR Solution PJ.02-W2-21.4 OI steps and related Enablers

3.3 Objectives of the CBA

The objective of the V3 CBA is to provide a consolidated assessment of the costs and benefits generated thanks to the deployment of Solution PJ.02-W2-21.4 in a specific set of Very Large and Large airports, as will be further discussed in the deployment scenario description. This CBA will compare the benefits expected for the deployed solution with the costs incurred by stakeholders over the CBA time horizon.

According to the Benefit Impact Mechanisms described in the OSED, section 12.1, this solution is expected to generate benefits in the SESAR Performance Framework (PF) KPAs of Cost-efficiency and Human Performance. The first two KPA benefits will be monetised according to the SESAR PF monetisation methodology.

This V3 CBA will help in building an assessment of whether the PJ.02-W2-21.4 solutions are worth deploying from an economic perspective for the involved stakeholders, although a more general

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perspective should be also considered taking into account other qualitative reflections linked to the impacted KPAs.

The CBA development is structured as three consecutive phases illustrated in Figure 1:

1. Scenario definition: the reference scenario upon which the solution will be deployed (i.e. solution scenario) is defined, assessing also the prerequisites of the solution to be fulfilled at least before the start of benefits generation,
2. Benefit and cost items identification: benefits and cost figures characterising the delta between the reference and solution scenario are identified, enabling the following and final phase,
3. Benefits and costs quantification: these are quantified by applying ad-hoc methodologies and assumptions that will be clearly stated along with the CBA analysis reported in this document.

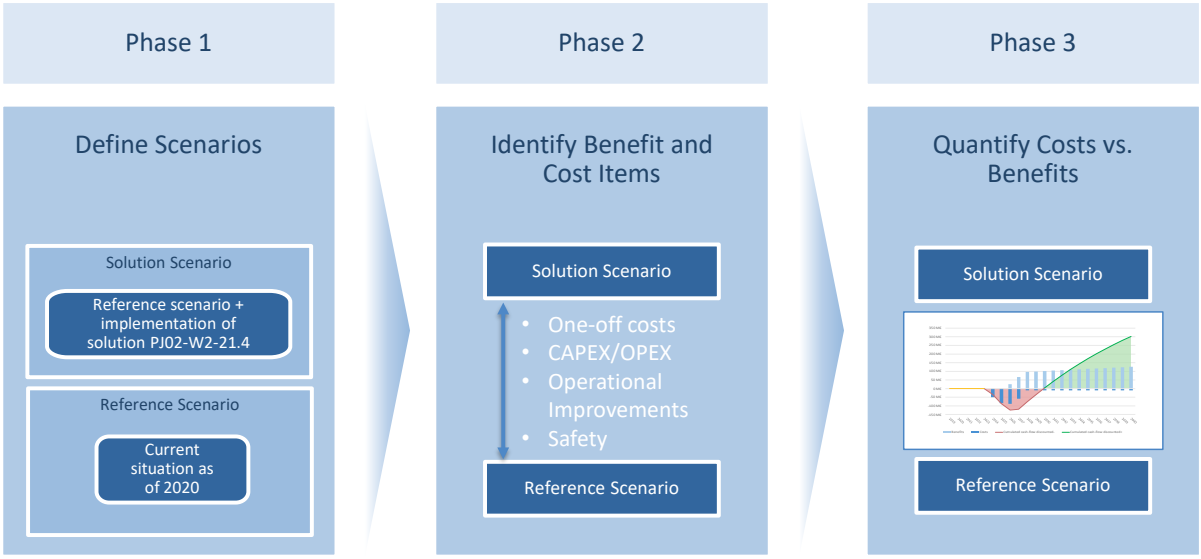

Figure 1: PJ.02-W2-21.4 CBA development phases

3.4 Stakeholders[1] identification

Table 6 lists the stakeholders considered in the solution in the scope of the CBA. They provide also an overview of the costs they will afford to deploy the solution (if any) and the benefits generated by its implementation (if any, including indirect benefits on stakeholders not investing in solution deployment). It also reports if the stakeholder was involved in the CBA production and whether the related costs and benefits have been finally included in the CBA calculations.

[1] 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.

3.4.1 Solution PJ.02-W2-21.4

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	ANSP providing ATS Aerodrome services at the deploying airports (Very Large and Large Airports)	Costs: investments to be made in the ANSP systems to include the planned functionalities Benefits: Controllers will have improved situational awareness, will avoid last-minute actions and avoid the workload associated.	To provide cost estimates for ground system upgrades. These cost estimates are requested to be provided not only by ANSPs but also by Industry Partners. The provision of cost estimates is not related to the involvement in validation.	ANSP costs included in this CBA version. ANSP benefits related to cost efficiency are quantified in this version according to validation results.
Airport Operators	Very Large and Large airports	Costs: Ground costs derived from the upgrade of Airport AGL system defined at paragraph 3.5.3.1. Benefits: No benefits	Not involved	Airport Operators costs included in this CBA version
Network Manager	Network	Costs: No costs Benefits: No benefits	Not involved	No costs or monetised benefits in this CBA version
Airspace Users: - Scheduled Airlines (Mainline / Regional) - Business Aviation - Rotorcraft - General Aviation IFR / VFR	CBA focuses on Scheduled Airlines (Mainline / Regional) Specific fleet depends on the airports that deploy	Costs: No costs Benefits: No benefits.	Not involved	No costs or monetised benefits in this CBA version. No performance improvements were estimated for fuel efficiency, time efficiency and predictability (despite being identified by PJ19.4 as validation targets) due to insufficient results from validation exercises.

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
Airspace Users – Ground (FOC)	Flight Operation Centres for the fleet operating at deploying airports	Costs: No costs Benefits: No benefits	Not involved	No costs or monetised benefits in this CBA version
Military – Airborne	Military fleet operating at an airport that deploys	Costs: No costs Benefits: No benefits	Not involved	No separate military costs or monetised benefits in this CBA version
Military – Ground	Military ATS Aerodrome Service Provider depending on deploying airports Military Airport Operator	Costs: No costs as it is assumed that either (a) deployment will be made by civil ANSPs operating at the deploying airports or (b) the military costs will be the same as for the civil (if applicable) Benefits: Quantified within civil ANSP.	Not involved	No separate military costs or monetised benefits in this CBA version. According to the Airport OE repository, airports in scope are Civil or Civil/Military, but not only Military.
Other impacted stakeholders (ground handling, weather forecast service provider, NSA….)	Ground handlers Catering Fuel providers …	Costs: No costs Benefits: No benefits	Not involved	No costs or monetised benefits in this CBA version.

Table 6: SESAR Solution PJ.02-W2-21.4 CBA Stakeholders and impacts

3.5 CBA Scenarios and Assumptions

This CBA aims at providing sufficient results about the economic and financial viability of deploying this SESAR solution at the European level, calculated as the difference between the solution scenario proposed and a reference scenario, where the solution would not be deployed. The reference scenario is built considering what has already been introduced by SESAR 1 and relevant to the solution considered.

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3.5.1 Reference Scenario

The reference scenario considers the future situation without the deployment of the solution in the scope of this CBA. This solution requires a set of prerequisites which will be listed and described in paragraph 3.5.3.1 whose costs and benefits are not accounted for in this CBA. This scenario will not be quantified but only used to assess the delta that the solution will bring.

3.5.2 Solution Scenario

The solution scenario estimates the potential benefits and costs derived from the implementation of the solution upon the reference scenario, considering such impacts as a delta. The main new functionalities introduced by the solution have been already summarised in chapter 3.2 and more information could be found in the OSED document. The enablers considered in the solution are summarised in the next paragraphs and related tables, whereas additional characteristics of the scenario are collected in the next paragraph and related tables, in terms of deployment prerequisites, geographical scope, time-horizon and traffic evolution.

The solution scenario concerns the deployment of SESAR solution PJ.02-W2-21.4 described in paragraph 3.2.1 and based on the OI step AO-0222-B, which is composed of the enablers reported in Table 7.

PJ.02-W2-21.4 Solution	
Enabler	**Description**
AERODROME-ATC-07b	A-SMGCS incorporating the function that provides an advanced set of Conformance Monitoring Alerts for Controllers (CMAC) on the movement area
AERODROME-ATC-61b	Advanced surface guidance management services to process the automatic triggering of airport ground signs and lighting according to the route issued by ATC
REG-0541	Update of EASA Appendix 1 to AMC1 SERA.14001 General for possible update of phraseology
STD-131	Update of ICAO Doc 4444 for possible update of phraseology

Table 7: PJ.02-W2-21.4 Solution Enablers list

3.5.3 Assumptions

This paragraph describes the main assumptions taken in terms of deployment prerequisites, geographical scope, time horizon of the solution and traffic evolution, which are relevant for the definition of the scope of this CBA. Additional assumptions are presented also in the following chapters, embedded into the explanation of the methodologies applied for the costs and benefits quantification.

3.5.3.1 Deployment prerequisites

The prerequisites assumed to be in place at the airports in the scope of this solution (by the IOC date at the latest) are:

- ATC systems are already equipped with A-SMGCS, including the Routing & Planning service (AO-0205 – SESAR Solution #22), collected in the MP L3 implementation objective AOP13,
- Airport Ground Lighting (AGL) system works properly for the provision of guidance assistance, as defined in the MP L3 implementation objective AOP16 (SESAR 1 Solution #47).

3.5.3.2 Geographical Scope

The solution scenario considers the deployment of the OI step at the relevant airport operating environments as shown in Table 8, which is based on the airport classification reported in Table 9.

Appendix C provides a complete list of which may be the deployment locations, providing also additional information about airports' volume of traffic. The airport list presented is produced to give a high-level overview of which airports may take advantage in the future of the solution functionalities and does not constitute any commitment regarding deployment.

Solution	Number of potential airports			Notes
	Very Large	Large	Medium	
21.4	14	18	-	-

Table 8: PJ.02-W2-21.4 potential implementation locations

	Operating Environment Categories (OEs)			
Overall Category	"Network"			
Primary Categories (OEs)	"En-route"	"Terminal"	"Airport"	
			Annual airport's movements (range)	Sub-OEs
Secondary Categories (Sub-OEs)			>250 000	Very large
			[250 000; 150 000]	Large
			(150 000; 40 000]	Medium
			(40 000; 15 000]	Small
			< 15 000	Other
			No available data	Not classified

Table 9: Airport Classification scheme according to OEs

	Airport OE	Nº of airports	Location list
Solution 21.4	Very Large	14	Frankfurt, Amsterdam, Paris, London Heathrow, Istanbul, Muenchen, Madrid Barajas, Barcelona El Prat, Roma Fiumicino, London Gatwick, Zurich, Kobenhavn, Oslo, Wien-Schwechat.

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	Airport OE	Nº of airports	Location list
	Large	18	Stockholm, Dulin, Paris-Orly, Brussels, Istanbul, Palma de Mallorca, Duesseldorf, Lisboa, Athinai, Manchester, London Standsted, Milano, Helsinki-Vantaa, Chopina W Warszawie, Antalya, Berling-Tegel, Geneva, Praha.

Table 10: CBA geographical scope of solution PJ.02-W2-21.4

It must be reminded that the solution scenario considers a simplified situation involving the deployment of the solution in the number of airports in each applicable operating environment. It does not consider specific requirements and constraints of any specific airport.

The final number of airports has been defined through expert judgement during the extrapolation at ECAC level of the CEF2 benefits, taking into account that the solution might be deployed only in VL and L airports.

3.5.3.3 Time-Horizon of the CBA

The deployment timeframe of the CBA is based on the combination of the expected implementation timeframes of the solution OI steps / Enablers previously introduced and summarised in Table 11:

- Deployment Start date(s) – reflect the start of investments for the first deployment location (assumed 2 years before the start of benefit generation),
- Deployment End date(s) – reflect the end of the investments for the final deployment location (equivalent to the FOC date),
- Initial and Final Operating Capability (IOC/FOC dates) – reflect the ramp-up of benefits across the ECAC area, as more locations deploy the solution.

OI step	Deployment Start date	Deployment End date	Initial Operating Capability (IOC)	Final Operating Capability (FOC)
AO-0222-B	30/12/2024	30/12/2030	30/12/2026	30/12/2030

Table 11: SESAR Solution PJ.02-W2-21.3-21.6 Deployment timeframe

Figure 2 summarises the key dates implemented in the CBA model. For simplicity and thanks to the almost correspondent key milestones of the solution, a unique investments and benefits generation timeframe is considered for the definition of the overall CBA time horizon. Figure 2 summarises the key dates implemented in the CBA model.

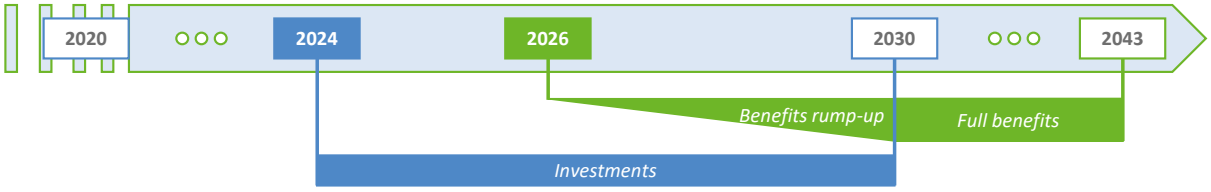

Figure 2: Overall CBA implementation and benefit timeframes

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3.5.3.4 Traffic Evolution

The traffic evolution values were taken from the “STATFOR Long-term forecast 2019-2040 Challenges of Growth” already embedded in the CBA model 7.3.8 [4] for SESAR solutions. The traffic forecast is assumed to growth approximately 53% from 11.7 M flights in 2022 to 16.2 M flights in 2043.

4 Benefits

This section provides an overview of the monetised benefits generated in the case of implementation of the solution under analysis. Such benefits are monetised according to the SESAR Performance Framework [3].

The benefits analysis starts with the review of the Benefit Impact Mechanisms (BIMs) defined in the OSED and reported in Appendix B. Once identified the impacted KPAs and KPIs, the performance results obtained during the validation exercises and qualitative performance estimations reported in the VALR, PAR and SAR are analysed. These values are translated into monetary values in the CBA according to the two benefits groups methodologies previously introduced. Figure 3 summarises the methodology presented.

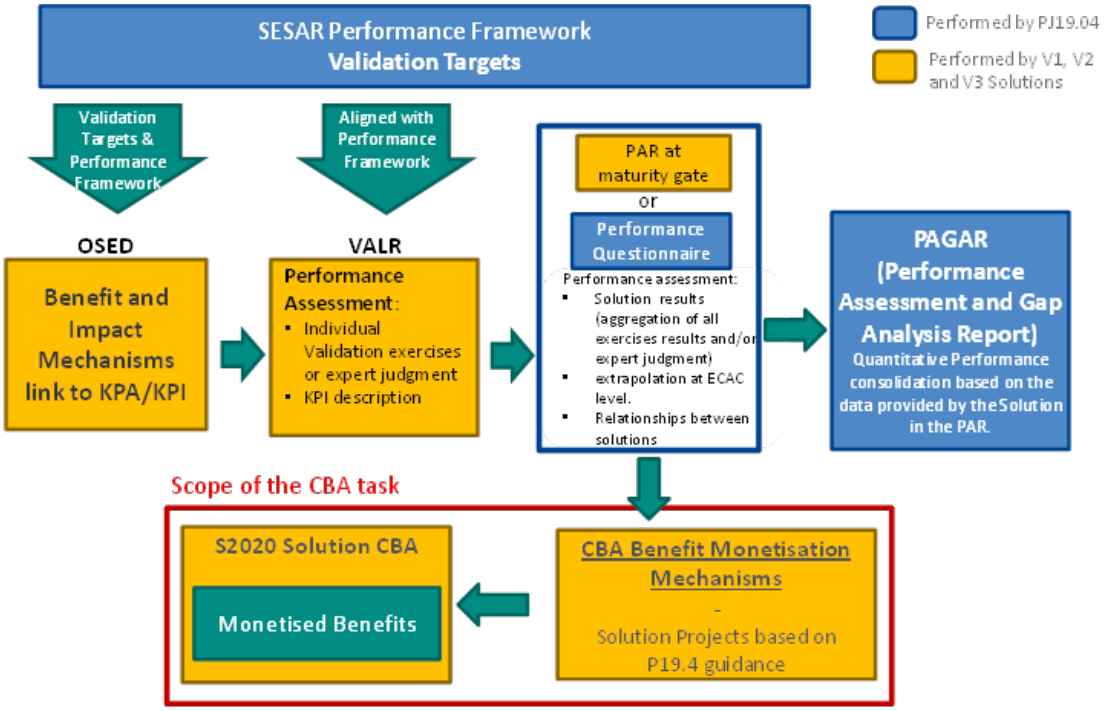

Figure 3: CBA Logic Model

4.1 Overall benefits assessment

This chapter presents the methodology and computations performed in the benefits assessment. A more detailed benefits distribution per stakeholder group has been implemented in the CBA model to extract results that will be shown in section 7.

4.1.1 Benefits Monetisation related to the Performance Framework

According to the Benefit Impact Mechanisms (BIMs) developed in the scope of the OSED and included in Appendix B, this solution is generating benefits in Cost Efficiency and Human Performance KPAs.

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Performance Framework KPA[1]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	2024	2026	2030
Cost Efficiency	ANS Cost efficiency	**CEF2** Flights per ATCO-Hour on duty (thanks to increase automation)	%	ATCO employment Cost change	M€/year (undiscounted)	0,00	8,67	48,33
				Support Staff Employment Cost Change	M€/year (undiscounted)	0,00	9,27	51,71
				Non-staff Operating Costs Change	M€/year (undiscounted)	0,00	0,00	0,00
		CEF3 Technology cost per flight	EUR / flight	G2G ANS cost changes related to technology and equipment	€/year	Not addressed by any solution and not included in the CBA.		
	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			
		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	€/year			

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

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Performance Framework KPA[1]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	2024	2026	2030
				cabin salary, handling prices at Base Stations				
		AUC5 Overhead costs for an airspace user	EUR / flight	Impact on overhead costs. Examples: dispatchers, training, IT infrastructure, sales.	€/year			
Capacity	Airspace capacity	**CAP1** TMA throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	Not addressed by any solution and not included in the CBA.		
			% 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			
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year			
	Airport capacity	**CAP3** Peak Runway Throughput (Mixed mode)	% and # movements	Value of additional flights	€/year			
Resilience	Resilience	**RES4a** Minutes of delays	Minutes	Tactical delay cost (avoided-; additional +)	€/year	Not addressed by any solution and not included in the CBA.		
		RES4b Cancellations	% and # movements	Cost of cancellations	€/year			
		Diversions	% and # movements	Cost of diversions	€/year			

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Performance Framework KPA[1]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	2024	2026	2030
Predictability and punctuality	Predictability	**PRD1** Variance of Difference in actual & Flight Plan or RBT durations	Minutes^2	Strategic delay cost (avoided-; additional +)	€/year	Not addressed by any solution and not included in the CBA. No performance improvements were estimated for fuel efficiency, time efficiency and predictability (despite being identified by PJ19.4 as validation targets) due to insufficient results from validation exercises.		
	Punctuality	**PUN1** % Departures < +/- 3 mins vs. schedule due to ATM causes	% (and # movements)	Tactical delay cost (avoided-; additional +)	€/year	Not addressed by any solution and not included in the CBA.		
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	Not addressed by any solution and not included in the CBA.		
Environment	Time Efficiency	**FEFF3** Reduction in average flight duration	% and minutes	Strategic delay: airborne: direct cost to an airline excl. Fuel (avoided-; additional +)	€/year	Not addressed by any solution and not included in the CBA. No performance improvements were estimated for fuel efficiency, time efficiency and predictability (despite being identified by PJ19.4 as validation targets) due to		
	Fuel Efficiency	**FEFF1**	Kg fuel per movement	Fuel Costs	€/year			

Performance Framework KPA[1]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	2024	2026	2030
		Average fuel burn per flight				insufficient results from validation exercises.		
	Fuel Efficiency	**FEFF2** CO2 Emissions	Kg CO2 per movement	CO2 Costs	€/year			
Civil-Military Cooperation & Coordination	Civil-Military Cooperation & Coordination	**CMC2.1a** Fuel saving (for GAT operations)	Kg fuel per movement	Fuel Costs	€/year	Not addressed by any solution and not included in the CBA.		
		CMC2.1b Distance saving (for GAT operations)	NM per movement	Time Costs	€/year			

Table 12: Results of the benefits monetisation per KPA

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5 Cost assessment

The costs included in the CBA reflect the investments that stakeholders will need to make to deploy the solution and bring it into operation, as part of the proposed solution scenarios. Also, any variation in operating expenditures has been analysed, leading to the conclusion that no changes are expected since the solution will increase or decrease them.

This final version of CBA updates the cost values initially considered in the previous Intermediate version. More in detail, costs have been quantified for ANSPs and Aircraft Operators in terms of ground costs, transition costs and operating costs.

Figure 4 summarises the methodology used in the CBA model, mainly based on a Bottom-Up approach. Cost estimations provided by solution partners, both ANSP and industry partners, are considered as inputs.

Figure 4: Cost assessment methodology

5.1 ANSPs costs

5.1.1 ANSPs cost approach

Costs are distributed in three different categories, depending on their rationale:

1. Ground or implementation costs: collecting those costs incurred for the implementation of new systems and functionalities, which could be further on classified as:
   a. One-off: covering the required initial training, project management, administrative costs, certification and installation/commissioning,
   b. Capital: related to the buying of the equipment and deployment costs,
2. Transition costs: required to complete the transition from legacy systems to the ones implemented by the solution,
3. Operating costs: identifying the change in the current costs needed to maintain systems operability, including related administration, maintenance, training and supply costs, among others.

Table 13 summarises the main costs considered in the CBA.

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Cost Item	One-off or routine cost	Cost assessors
Initial Training	Implementation (One-off)	ANSPs, Industry partners
Project Management		
Administrative costs		
Certification		
Installation/Commissioning		
Purchase of equipment and construction costs	Implementation (Capital)	
Operational and technical trials for entry into operation: - Project management during trials - Human and material resources	Transition cost	
Yearly Equipment maintenance and training	Operating (Maintenance)	
Communication costs Energy, Supplies, Utilities, Property Taxes Rent & Lease Furniture & equipment	Operating (Administration)	

Table 13: Cost categorisation for PJ.02-W2-21.4

5.1.2 ANSPs cost assumptions

Each cost figure is used as input in the cost model. Final values considered are reported in the next paragraphs. Timeframes of each cost figure have been already defined for each solution, starting 2 years before the solution IOC date.

5.1.3 Number of investment instances (units)

As defined in the geographical scope of this CBA, the solution is expected to be potentially implemented at different subsets of airports, as summarised in Table 14.

	Airport			
	VL	L	M	S
Sol 21.4	14	18	0	-

Table 14: Number of investment instances - ANSPs

5.1.4 Cost per unit

OI step AO-0222-B is characterised mainly by costs for the implementation of the systems for the provision of advanced surface guidance management services and processing of the automatic triggering of airport ground signs and lighting according to the route issued by ATC, as contemplated in EN AERODROME-ATC-61b and EN AERODROME-ATC-07c. Costs are reported in Table 15, as extracted from solution partners' estimations:

- Ground costs:
  - Implementation costs: 750.0 k€ /Airport,
  - Training costs: 90.0 k€,
- Transition costs: 0.00 k€/Airport,
- Operating costs: no additional costs are expected as new functionalities will not require any additional maintenance over the one provided in the Reference scenario.

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Cost category	Airport			
	VL	L	M	S
Ground costs	840.0 k€			
Transition costs	0.0 k€		-	-
Operating costs	0.0 k€			

Table 15: Cost per Unit – ANSP

Costs assessed are in the range of values provided by solution partners. Anyway, costs are expected to vary significantly depending on the size of each airport. The confidence level on the proposed cost values is considered medium.

5.2 Airport operators costs

5.2.1 Airport operators cost approach

Similarly to what was done for the assessment of ANSPs related costs, the same Bottom-Up approach has been applied to the estimation of implementation costs shown in Table 13. Values used in the CBA for the cost modelling are reported in the next paragraphs and tables.

5.2.2 Airport operators cost assumptions

Similarly to ANSP costs, each cost figure is used as input in the cost model. Final values considered are reported in the next paragraphs. Timeframes of each cost figure have been already defined for each solution, starting 2 years before the solution IOC date.

5.2.3 Number of investment instances (units)

As defined in the geographical scope of this CBA, the solution is expected to be potentially implemented at different subsets of airports, as summarised in Table 16.

	Airport			
	VL	L	M	S
Sol 21.4	14	18	0	-

Table 16: Number of investment instances - AOs

5.2.4 Cost per unit

Costs are reported in Table 15, as extracted from solution partners' estimations:

- Ground costs:
  - Implementation costs: 150.0 k€ /Airport for the upgrade of the AGL system,
  - Training costs: 0.00 k€ /Airport,
- Transition costs: 0.00 k€/Airport,
- Operating costs: no additional costs are expected as new functionalities will not require any additional maintenance over the one provided in the Reference scenario.

Cost category	Airport			
	VL	L	M	S
Ground costs	150.0 k€			
Transition costs	0.00 k€		-	-

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Cost category	Airport			
	VL	L	M	S
Operating costs	0.0 k€			

Table 17: Cost per Unit – ANSP

Costs assessed are in the range of values provided by solution partners. Anyway, costs are expected to vary significantly depending on the size of each airport. The confidence level on the proposed cost values is considered medium, and it is expected to increase along with the development of the solution.

5.3 Network Manager costs

The Network Manager is not required to invest in any enabler for this solution.

5.4 Military costs

According to the PJ.20 Airport OE list [14], only 5 Large airports of the 32 Very-Large and Large ones in the scope of the CBA are classified per type of operations as Civil/Military, which are currently operated by private or State-owned enterprises. In addition, no implementation and operating cost differences are expected between a civil or military airport, thus all costs have been accounted for under the Airport Operator category umbrella.

5.5 Other relevant stakeholders

No other stakeholders are required to deploy Enablers.

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6 CBA Model

The PJ.02-W2-21.4 V3 CBA Model (.xlsx file) is attached as a supporting document of the CBA report. This CBA Model has been developed starting from the SESAR 2020 CBA model template and aims at calculating the costs and benefits of the implementation of PJ.02-W2-21.4 solution based on the deployment scenario approach that has been defined in the context of the CBA task and in the context of SESAR 2020 Wave 2 Framework.

It should be remembered that all costs are analysed in the form of a “delta”, this is the difference between the reference scenario, where operations continue “as usual”, and the solution scenario, where the stakeholders implement the solution under analysis.

Solution
PJ.02-W2-21.4_CBA_

6.1 Data sources

The model uses the following main data sources:

- SESAR 2020, PJ03a.01 SPR-INTEROP/OSED for V2 – Part I, IV, V [11]
- SESAR 2020, PJ03a.01 CBA for V2 [12]
- SESAR 2020, PJ02-W2-21.2-21.3-21.4-21.6 SPR-INTEROP/OSED for V3 – Intermediate version [9]
- Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part I – Final version (PJ02-W2-21.4 D6.4.001) [23]
- Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part II Safety Assessment Report – Final version (PJ02-W2-21.4 D6.4.001)
- Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part V Performance Assessment Report (PAR) – Final Version (PJ02-W2-21.4 D6.4.001)
- Solution PJ.02-W2-21.4 VALR (PJ02-W2-21.4 D6.4.003)
- EATMA Dataset 23 [16]
- STATFOR Challenges of Growth 2018 [8]
- Standard Inputs for EUROCONTROL Cost-Benefit Analyses [15]
- SESAR ATM CBA for Beginners [20]
- Safety guidelines for Solution CBAs [10]

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7 CBA Results

This section presents the financial results of the PJ.02-21.4 CBA at V3 Level. At the current stage, the presented results are based on the inputs extracted from the V2 CBA report, the preliminary information reported in the V3 OSED and a set of assumptions explained in this report. This CBA leverages on three main pillars, defining the main scope of the assessment:

- The impact of the solution in terms of benefits and costs has been estimated on top of what is already considered in the reference scenario. Results shown in this section should be considered as a delta between the solution scenario (where the solution is implemented) and the reference scenario (where the solution is not implemented),
- Quantified benefits are mainly related to Cost Efficiency KPAs for Airspace Users (i.e. scheduled airlines) in this final version. The benefits model methodology is thus based Performance Framework quantification rules for Cost Efficient KPA.
- Costs have been quantified for ANSPs and AOs that meet prerequisites for the implementation of the solution, based on the cost estimations provided by the solution partners and taking into consideration the costs assumed in the previous V2 CBA. Both capital and operating expenditures have been analysed and quantified.

This CBA report describes the annual costs, benefits and cash flow from the perspective of the different stakeholders impacted by the solution implementation. Specific financial KPIs, like Payback year and NPV evolution, are also analysed to compare solution implementation feasibility and profitability.

CBA results are reported in the following chapter showing on one hand the annual evolution of benefits and costs leading to the creation of the cumulated NPV, to be then deepened from different perspectives, presenting the quantified benefits and assumed costs per type of stakeholder impacted (i.e. ANSPs, Airport Operators and Airspace Users).

7.1 Solution annual results

Table 18 reports the annual results for Solution PJ.02-W2-21.4. It can be observed how:

- Investments required for CAPEX start in 2024, 2 years before the IOC date, with a -4,53 M€ expenditure (undiscounted),
- From 2026, IOC for solution 21.4, performance framework benefits are accounted for Air Navigation Service Providers, with an initial income of 17.94 M€ (undiscounted),
- Maximum negative peaks of undiscounted cumulated cash flow and NPV (cumulated discounted cash flow) are obtained in 2025, the second year of implementation and the previous year to the start of revenues generation, with a total undiscounted value of -9,05 M€ and -6,92 M€ discounted. From a rough estimation, it is equivalent to -0,28 M€ undiscounted and -0,21 M€ discounted cumulated cash flow for every single airport,
- Payback year is found in 2026, from when cash flow will continue to increase at a consistent peace with traffic forecast,
- From 2030 no costs are accounted for, reaching 2043 with a positive NPV of 596 M€.

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Annual results [M€]	2022	2023	2024	2025	2026	2027	2028
Performance Framework benefits	0.00	0.00	0.00	0.00	17.94	36.87	56.83
Safety benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAPEX	0.00	0.00	-4.53	-4.53	-4.53	-4.53	-4.53
OPEX	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow	0.00	0.00	-4.53	-4.53	13.41	32.34	52.30
Cumulated cash flow	0.00	0.00	-4.53	-9.05	4.36	36.70	89.00
Discounted benefits	0.00	0.00	0.00	0.00	12.21	23.23	33.16
Discounted cumulated benefits	0.00	0.00	0.00	0.00	12.21	35.44	68.60
Discounted costs	0.00	0.00	-3.59	-3.33	-3.08	-2.85	-2.64
Discounted cumulated costs	0.00	0.00	-3.59	-6.92	-10.00	-12.85	-15.49
Cumulated NPV	**0**	**0**	**-4**	**-7**	**2**	**23**	**53**

Annual results [M€]	2029	2030	2031	2032	2033	2034	2035
Performance Framework benefits	77.87	100.04	102.60	105.23	107.92	110.69	113.52
Safety benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAPEX	-4.53	-4.53	0.00	0.00	0.00	0.00	0.00
OPEX	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow	73.35	95.51	102.60	105.23	107.92	110.69	113.52
Cumulated cash flow	162.35	257.87	360.47	465.70	573.62	684.31	797.83
Discounted benefits	42.07	50.04	47.52	45.13	42.86	40.70	38.65
Discounted cumulated benefits	110.67	160.72	208.24	253.37	296.23	336.93	375.58
Discounted costs	-2.45	-2.26	0.00	0.00	0.00	0.00	0.00
Discounted cumulated costs	-17.94	-20.20	-20.20	-20.20	-20.20	-20.20	-20.20
Cumulated NPV	**93**	**141**	**188**	**233**	**276**	**317**	**355**

Annual results [M€]	2036	2037	2038	2039	2040	2041	2042	2043
Performance Framework benefits	115.92	118.37	120.87	123.43	126.04	127.30	128.57	129.86
Safety benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CAPEX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OPEX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow	115.92	118.37	120.87	123.43	126.04	127.30	128.57	129.86
Cumulated cash flow	913.75	1032.12	1152.99	1276.42	1402.47	1529.77	1658.34	1788.20
Discounted benefits	36.54	34.55	32.67	30.89	29.21	27.31	25.54	23.89
Discounted cumulated benefits	412.12	446.67	479.34	510.23	539.43	566.75	592.29	616.18
Discounted costs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Discounted cumulated costs	-20.20	-20.20	-20.20	-20.20	-20.20	-20.20	-20.20	-20.20
Cumulated NPV	**392**	**426**	**459**	**490**	**519**	**547**	**572**	**596**

Table 18: Annual results summary

7.2 Results per stakeholders perspectives

7.2.1.1 Air Navigation Service Providers

The cash flow for ANSPs is positive thanks to the impact on Cost-Efficiency. The expected volume of cumulated benefits is of 12,21 M€ in 2026 and 140,5 M€ in 2030 (discounted values). Implementation costs are distributed between the start of the deployment year (i.e. 2 years before IOC, 2024) and the FOC year (i.e. 2030). No changes in operating costs take place. Figure 5 reports the cost distribution and NPV up to 2043, taking into consideration also the impact of the annual discount rate (8%).

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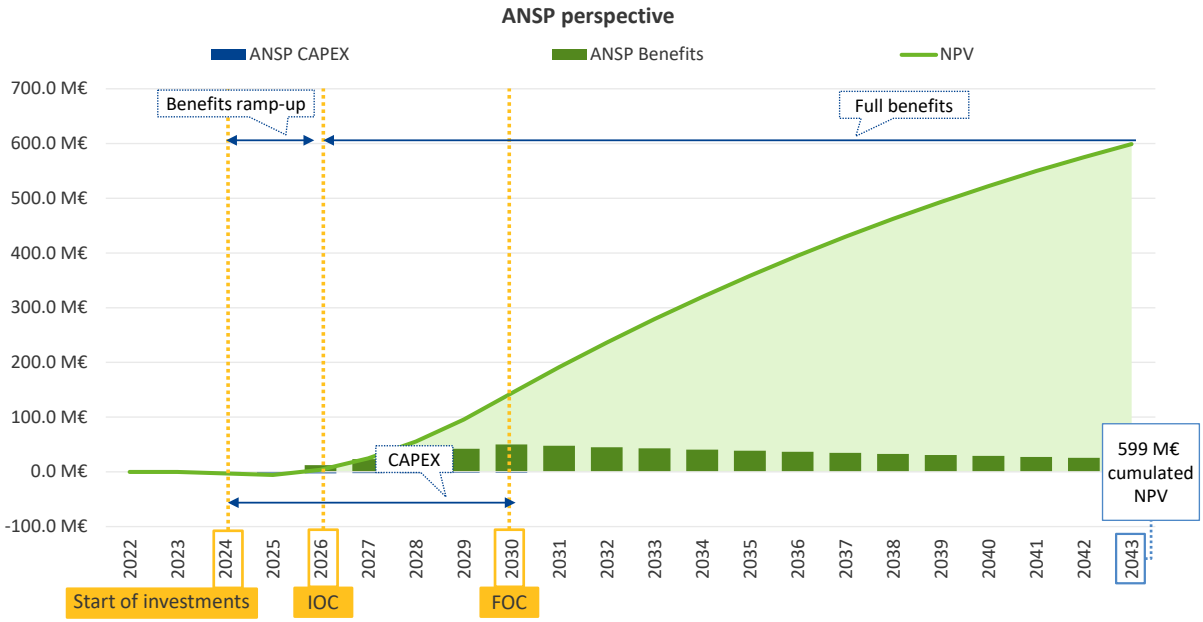

Figure 5: Solution 21.4 - ANSP perspective (discounted values)

7.2.1.2 Airport Operators

The solution is expected to require limited investments for airport operators. The total NPV is almost stabilising around -3,05 M€ from 2030 onwards. Having a look at the local perspective, it would be equivalent to a negative cash flow of 95.62 k€ for every single airport.

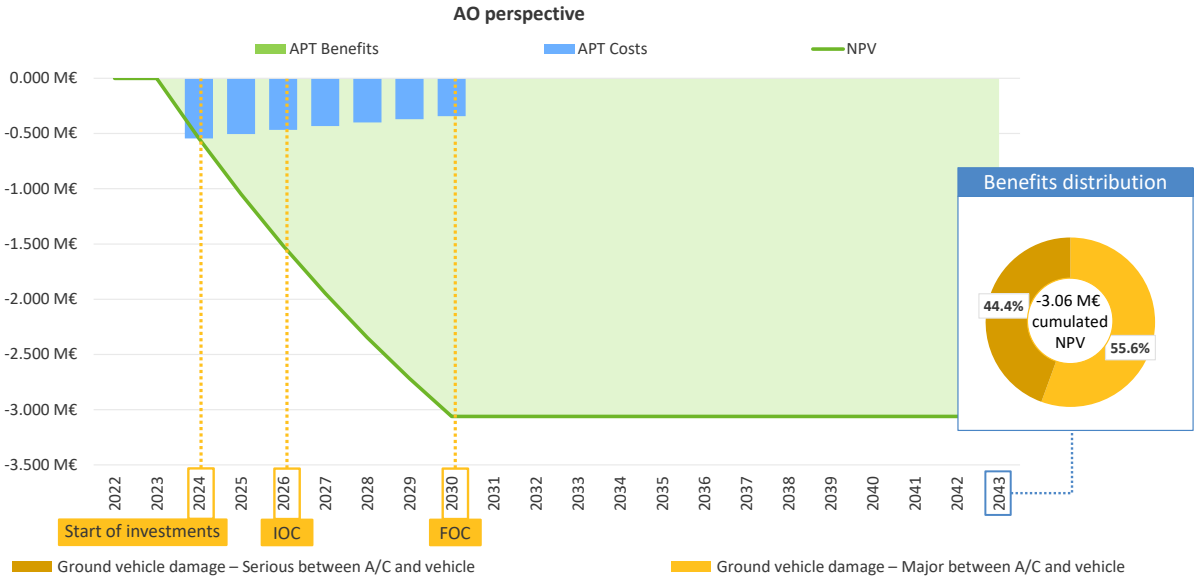

Figure 6: Solution 21.4 – AO perspective (discounted values)

7.2.1.3 Airspace Users

No costs or monetised benefits in Airspace Users.

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7.2.1.4 Overall solution perspective

Figure 7 shows the overall NPV obtained for solution 21.4. A positive cumulated NPV of 140,5 M€ is found in 2030, strongly improving in the long-term. The payback year is expected to be reached already in 2026.

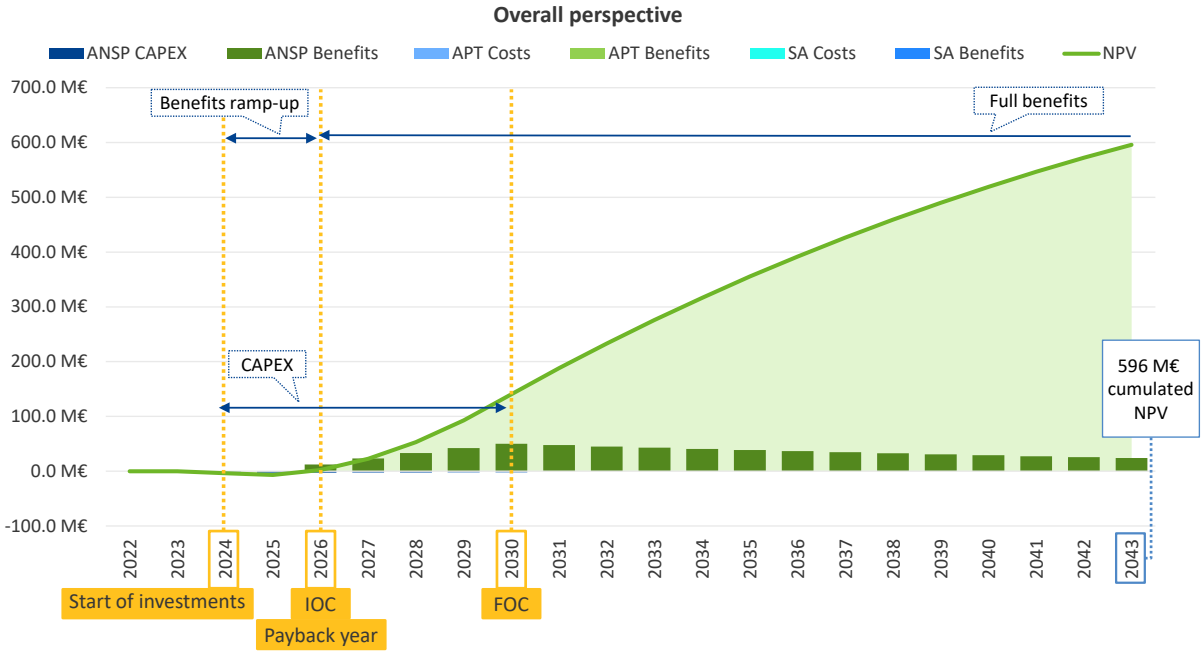

Figure 7: Solution 21.4 – Scenario perspective (discounted values)

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8 Sensitivity and risk analysis

The following section provides an initial analysis of which impacts may have the uncertainties related to the main variables identified during the modelling of the PJ.02-W2-21.4 CBA on the outcomes of the model.

All the variables presented in this section are analysed by applying a "*ceteris paribus*" criteria, meaning that only the impacts of one variable are evaluated at each time, leaving the other variables constant facilitating the comparison between the evaluated variables.

8.1 Sensitivity analysis

Sensitivity analysis is based on the evaluation of the impacts that a set of variables have on the NPV at 2040, being evaluated separately by applying a range of variations around their initial value. The list of variables analysed, the range of variation and a brief description of the expected impacts are reported in Table 19 below.

Sensitivity variables	Range[3]	Impact description
Airport Capacity	±10%	Evaluates the impact of a variation in Airport Capacity (CAP3), which evaluates the peak runway throughput.
Airspace Capacity	±10%	CAP1 and CAP2 evaluate the TMA throughput, in challenging airspace per unit time and the en-route throughput, in challenging airspace, per unit. This variable evaluates the impact of a variation on these KPIs.
Fuel Efficiency	±10%	This variable applies a variation in the KPIs of: FEFF3 evaluates the reduction in average flight duration FEFF2 evaluates de CO2 emissions FEFF1 evaluates the average fuel burn per flight.
Delay	±10%	It applies a variation in the tactical delay and evaluates its impact on the overall NPV.
Time Savings	±10%	It applies a variation in the time saving and evaluates its impact on the overall NPV.
Predictability	±10%	This variable applies a variation in the KPI PRD1, which evaluates the variance of difference in actual & Flight Plan or RBT durations.
ATCO Productivity	±10%	The ATCO productivity is automatically calculated by the SESAR CBA model v7.3.8, considering the embedded assumptions from the STATFOR Accommodated demand ("Traffic"), the average flight duration and the ATCO hours in the base year (ACC and APP + TWR). The sensitivity analysis evaluates the variation in the ATCO productivity change (CEF2 – benefit of the solution) that will generate a variation in the NPV of the CBA.

[3] Variable variation is applied to the baseline value assumed for the nominal scenario, for example for the discount rate factor: [7.2% - lower limit; 8% - baseline value; 8.8% - upper limit].

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Sensitivity variables	Range[3]	Impact description
Ground OPEX	±10%	It evaluates the impact on the operating expenditure of Ground costs, generated by a variation in the sensitivity factor.
Ground Capex	±10%	It evaluates the impact that a variation in capital ground costs has on the NPV, generated by a variation in the sensitivity factor.
AU Airborne Capex	±10%	It evaluates the impacts on the NPV of a variation of Airborne costs for Airspace Users.
AU Ground Capex	±10%	It evaluates the impacts on the NPV of a variation of Ground costs for Airspace Users.
AU Ground Opex	±10%	It evaluates the impact on the NPV of a variation of operating costs for Airspace Users.

Table 19: Sensitivity analysis variables

In this final version of CBA, only Ground Capex and ATCO Productivity have an impact on the sensitivity analysis. ATCO productivity causes a 10% variation in the NPV in 2040 given a 10% variation of the related sensitivity variable. Ground CAPEX variation has a much lower effect on the NPV at 2040, showing how the model is much more dependent on any variation in benefits generation than on costs encountered.

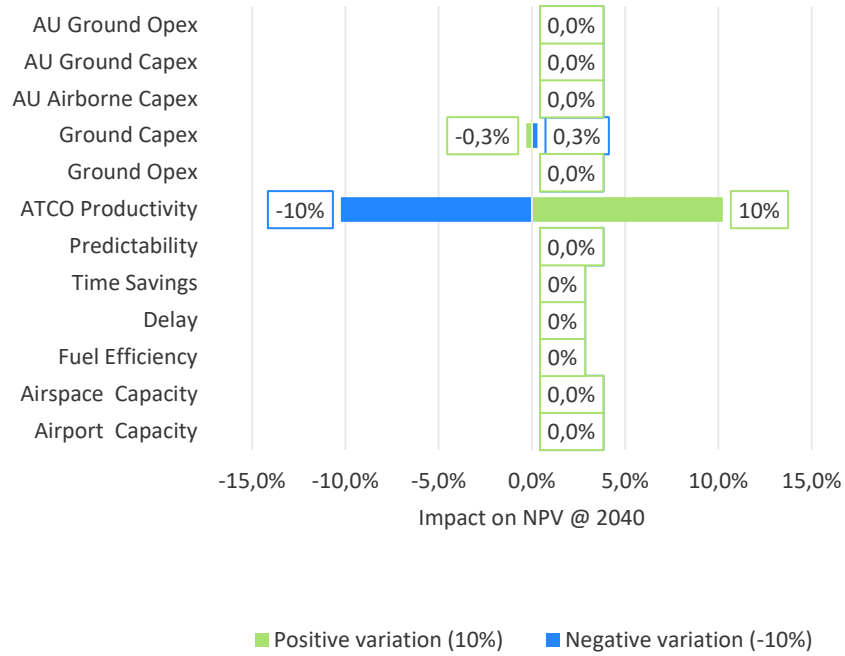

Figure 8. Sensitivity analysis

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8.2 Risk analysis

NPV risk modelling is an extension of the basic NPV method in which input variables are allowed to vary between defined maximum and minimum values through a predefined probability distribution, to calculate the risk effects around the most probable and expected variable value. As the inputs vary during the simulation, the output varies as well.

The model is run using Monte Carlo algorithms and applying a triangular probability density function to represent the risk associated with each of the selected variables. Such distribution is shown in Figure 9. During each iteration of the simulation, a random value is selected for each input variable (i.e. the same used in the sensitivity analysis) according to the probability density function, thus obtaining a random combination of costs and benefits that will be used to evaluate the solution NPV.

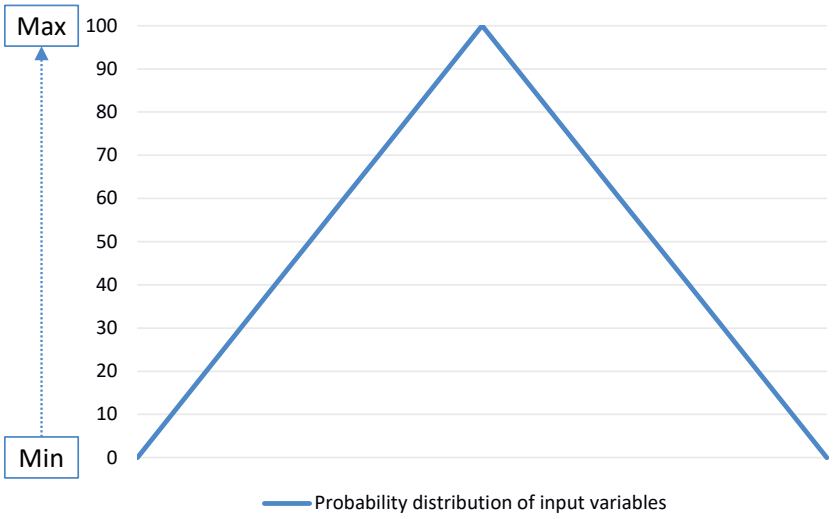

Figure 9: Combined solution scenario – Risk variable profile

The output of the risk analysis is an NPV risk profile, as shown in Figure 10 representing the probability of obtaining that value of NPV in 2043 and showing the distribution of the values through the cumulated probability. Such NPV distribution is mainly influenced by the probability distribution function, thus maintaining the triangular shape.

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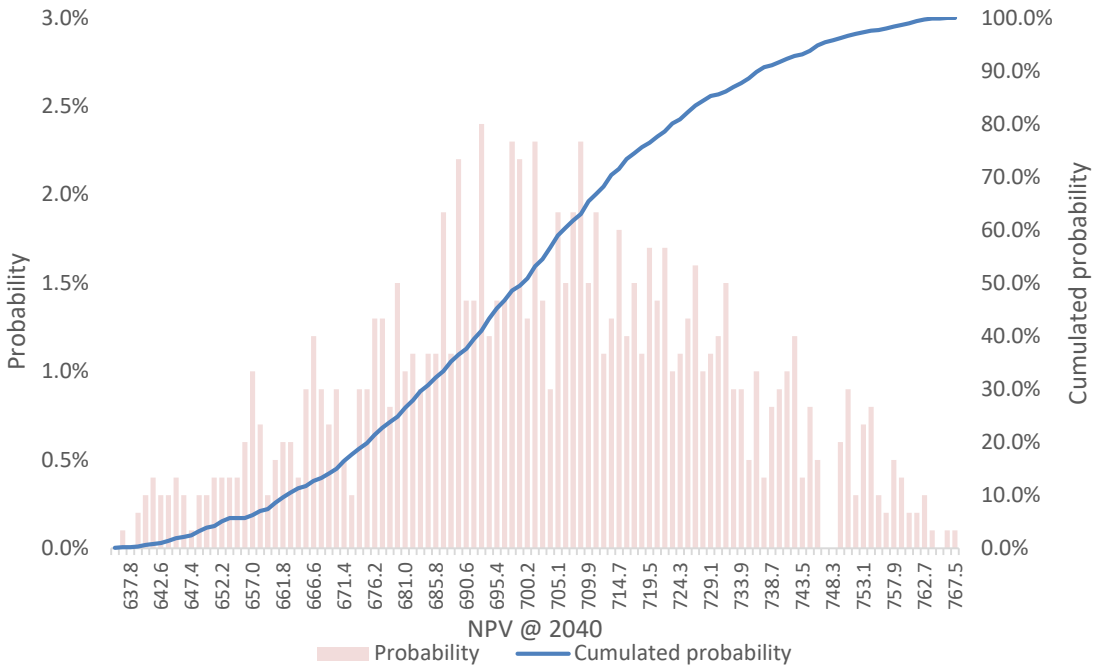

Figure 10 Combined solution scenario – Risk analysis results

Additional statistical results are also provided by the risk modelling exercise, which are collected in Table 20.

Results description	Value
Mean NPV	702,28 M€
Maximum NPV	766,63 M€
Minimum NPV	636,21 M€
NPV standard deviation	28,07
Variance	788,05
Skewness	0,029

Table 20: Risk analysis statistical results

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9 Recommendations and next steps

The analysis performed in the scope of this CBA highlighted how the implementation of solution PJ.02-W2-21.4 will be fruitful mainly, but not exclusively, for ANSP of Very Large and Large airports in Europe.

This solution will be crucial in the future for the decongestion of the airports included in the geographical scope of this CBA, providing a quite cheap solution generating an important volume of benefits, among which the reduction of ATCOs' workload and their increased situational awareness.

The CBA shows that the deployment of solution 21.4 at 32 airports would positively impact the European aviation industry. It would develop a 596 M€ net present value in 2043 (8% discount rate) and achieve breakeven in 2026 (the payback period would be two years).

The level of confidence in the CBA results is considered medium, being evaluated after several years of analysis and developments in the scope of SESAR2020, and resulting in a solid iteration of previous results calculated in the Intermediate CBA version.

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[4]

[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

[9] EASA ASR 2020

[10] Environment Dataset

10.2 Reference Documents

[11]Common assumptions

[12]ICAO iSTAR tool

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

[14] Performance Framework

[15] Solution PJ03a-01 Final SPR-INTEROP/OSED V2 (PJ03a-01 D2.010)

[16] Solution PJ03a-01 Final CBA for V2 (PJ03a-01 D2.210)

[17] Solutions PJ02-W2-21.2-21.3-21.4-21.6 Intermediate version SPR-INTEROP/OSED V3 (PJ02-W2-21.2-21.3-21.4-21.6 D6.2.001)

[18] Solutions PJ02-W2-21.2-21.3-21.4-21.6 Intermediate version CBA V3 (PJ02-W2-21.2-21.3-21.4-21.6 D6.2.023)

[19] Safety Benefits monetisation

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

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[20]Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part II Safety Assessment Report (PJ02-W2-21.4 D6.4.001)

[21]Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part V Performance Assessment Report (PAR) – Final version (PJ02-W2-21.4 D6.4.001)

[22]Solution PJ.02-W2-21.4 VALR – Final version (PJ02-W2-21.4 D6.4.003)

[23]Solution PJ.02-W2-21.4 SPR-INTEROP/OSED for V3 Part I – Final version (PJ02-W2-21.4 D6.4.001)

11 Appendix A

Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs, source reference *[14]*

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

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

Table 21: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPI

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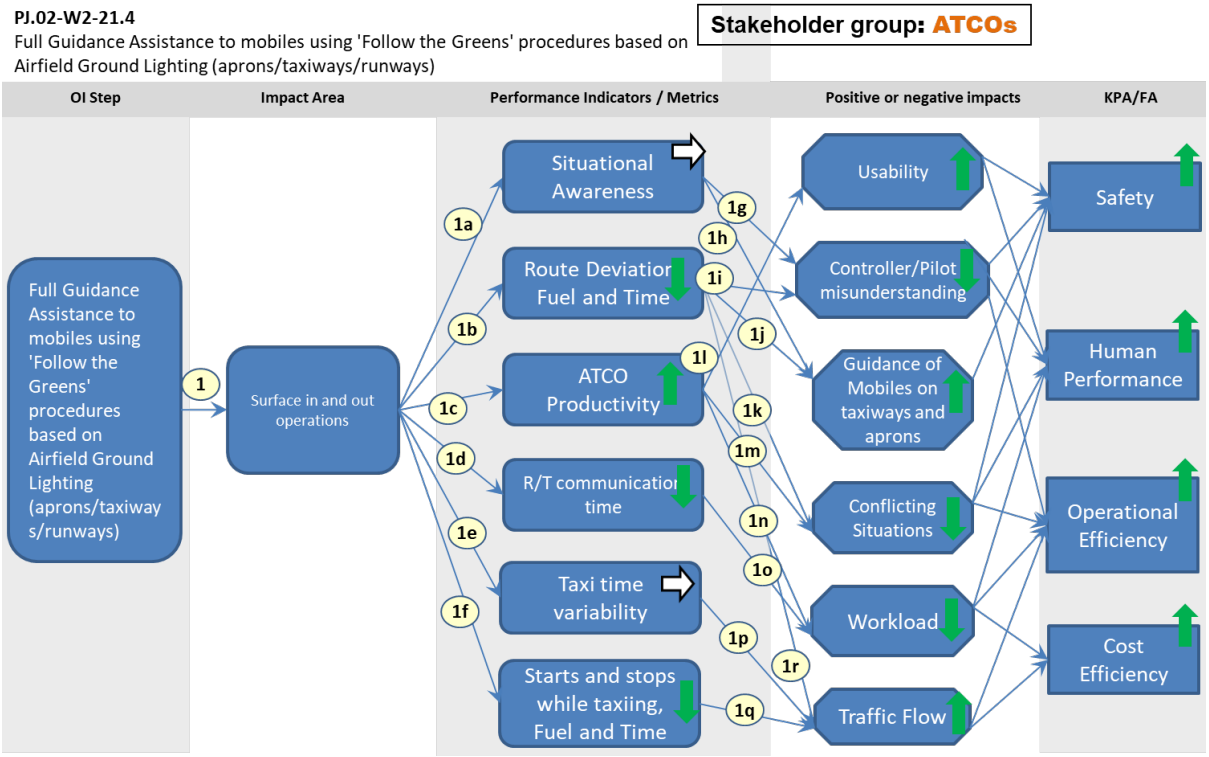
12 Appendix B

12.1 Benefit Impact Mechanisms (BIM)

12.1.1 Solution PJ.02-W2-21.4



N°	Mechanism descriptions
	Full Guidance Assistance to mobiles using "Follow-the-Greens" procedures Using Airfield Ground Lighting, mobiles will be guided along their cleared route
1	**Taxi in and Taxi out operations** Taxi in and Taxi out operations are expected to be impacted by the definition of Full Guidance Assistance to mobiles using "Follow-the-Greens" procedures
1a	**Situational Awareness** The higher level of automation is expected. The task of conflict detection and resolution is somewhat shifted to the machine which may lead to reduced situational awareness, especially in dense traffic situations. However, ATCO would be able to modify the route if the conflicting situation could be solved more efficiently. His/her

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	active involvement would be essential to stay in the loop. Note that the stakeholders in this BIM are the ATCOs- the flight crew SA is expected to increase.
1b	**Route deviations, Fuel and Time** The precise guidance of the follow the greens concept will ensure that mobiles adhere to the route that ATCOs has assigned leading to less route deviations, optimised fuel consumption and taxi time
1c	**ATCO Productivity** The solution is expected to support the ATCO's efficiency as it will take on the conflict detection and resolution tasks by automatically switching the TCL and Stop bars. It is expected that the number of managed aircraft by one ATCO will be higher thus it will have a positive impact on the ATCO productivity.
1d	**R/T communication time** Availability of automated switching of AGL and the related "Follow-The-Greens" procedures is expected to result in less R/T communication time when giving taxi instructions. This supports the ATCO in being efficient, thus has an indirect link to Cost Efficiency KPA.
1e	**Taxi time variability** Availability of AGL may have an impact on taxi time variability, however, the exact direction of the change is not yet established.
1f	**Starts and Stops while taxiing, Fuel and Time** Availability of AGL may result in less stops and starts while taxiing, if the ATCO is sufficiently engaged in finding more optimal taxi routes, optimised fuel consumption and taxi time.
1l	**Usability** The system functionalities and the HMI has the potential to support ATCO's work as the system will take on the conflict detection and resolution tasks by automatically switching the TCL and Stop bars. Reduction in workload is hypothesized, however, only when trust in the system is established. Safety nets like CMAC and CATC can help ATCO's in the management of the traffic. However, intuitive route editing functionality is imperative, and also a correct sequencing logic should be included in the system. Those impacts are related to Safety (SAF) and Human Performance (HP) KPA.
1g 1i	**Controller / Pilot misunderstanding** The expected increase of situation awareness of the flight crew, as well as the reduction of route deviation occurrences, are linked to a reduction of ATCO / pilot misunderstanding. The described impacts are linked to the Safety (SAF) and Human Performance (HP) KPA and also on Operational Efficiency.
1h 1j	**Guidance of Mobiles on taxiways and aprons** Automated switching of TCL and stop bars will guide mobiles more efficiently and expeditiously on the airport surface. The AGL is only switched on in front of mobiles

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	that are moving instead of on all equipped taxiways regardless of traffic movements. The improved guidance is expected to have a positive impact on both Safety (SAF) and Human Performance (HP) KPAs
1k 1m	**Conflicting situations** The automated switching of AGL will de-conflict converging and opposing traffic. This expects to have an impact on both Safety (SAF) and Human Performance (HP) KPAs and also on Operational Efficiency.
1n 1o	**Workload** The reduction of R/T communication time, and the increased ATCO productivity will have a direct impact on workload, which is linked to Human Performance (HP). The decrease of the workload has also a link to Operational and Cost Efficiency (i.e., the number of flights to be handled/hour may increase due to the workload and R/T reduction). Obviously the new technology tested by the Solution has a real impressive added value to help and to increase the improvement in traffic management by the ATCOs on duty, during unusual weather situation with reduced capacity on the airfield, and so it allows the direct improvement in ATCO productivity due to additional number of aircraft handled within the same operational scenario, when compared with the Reference. Reduction in workload is hypothesized, however, only when trust in the system is established, even if it has been validated by multiple SESAR Solutions and validation Exes tested on different ECAC Airports
1p 1r	**Traffic flow** Reduction in the frequency of stops and starts while taxiing and route deviation should result in a more efficient and smoother traffic flow. This would be further supported if the solution was to positively impact taxi variability, and in traffic management by the ATCOs. Overall, the optimised traffic flow would have an impact on Operational Efficiency KPA and on Cost Efficiency KPA (i.e. with smooth traffic flow the ATCO may take on more flights /hour.)

13 Appendix C

13.1 Applicable deployment locations

The following table reports the applicable deployment locations (14 Very Large and 18 Large) for the OI steps AO-0222-B, according to the SESAR Airport OE [14].

Airport	APT Sub-OE	Number of movements (2018)
Frankfurt/Main	Very large	511.773
Amsterdam	Very large	510.966
Paris	Very large	488.038
London	Very large	477.464
Istanbul	Very large	455.660
München	Very large	410.301
Madrid	Very large	409.455
Barcelona	Very large	335.521
Roma	Very large	307.873
London	Very large	283.804
Kloten	Very large	271.348
Kastrup	Very large	265.977
Oslo	Very large	257.638
Wien	Very large	256.343
Stockholm	Large	243.690
Dublin	Large	232.449
Paris	Large	232.369
Zaventem	Large	229.847
Istanbul	Large	225.606
Palma De Mallorca	Large	220.242
Düsseldorf	Large	218.429
Lisboa	Large	217.946
Spata Attiki	Large	211.139
Manchester	Large	201.110
London	Large	200.252
Varese	Large	194.355
Vantaa	Large	192.291
Warsaw	Large	187.263
Antalya	Large	186.004
Berlin	Large	185.269
Genève	Large	180.255
Prague	Large	150.961
Frankfurt/Main	Very large	511.773
Amsterdam	Very large	510.966
Paris	Very large	488.038
London	Very large	477.464
Istanbul	Very large	455.660

Airport	APT Sub-OE	Number of movements (2018)
München	Very large	410.301
Madrid	Very large	409.455
Barcelona	Very large	335.521
Roma	Very large	307.873
London	Very large	283.804
Kloten	Very large	271.348
Kastrup	Very large	265.977
Oslo	Very large	257.638
Wien	Very large	256.343
Stockholm	Large	243.690
Dublin	Large	232.449
Paris	Large	232.369
Zaventem	Large	229.847
Istanbul	Large	225.606
Palma De Mallorca	Large	220.242
Düsseldorf	Large	218.429
Lisboa	Large	217.946
Spata Attiki	Large	211.139
Manchester	Large	201.110
London	Large	200.252
Varese	Large	194.355
Vantaa	Large	192.291
Warsaw	Large	187.263
Antalya	Large	186.004
Berlin	Large	185.269
Genève	Large	180.255
Prague	Large	150.961

Table 22: SESAR Solutions PJ.02-W2-21.4 Deployment airports

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