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Cost Benefit Analysis for Surveillance Performance Monitoring (SPM) Tools for Cooperative Sensors (ADS-B, WAM, MLAT) (TRL6)

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00.01.02	02/11/2022	Released	All authors	Version approved from 2021 updated after TRL6 Gate from October 2022 (latest template, few more explanations)

PJ.14 W2 I-CNSS

SURVEILLANCE PERFORMANCE MONITORING (SPM) TOOLS FOR COOPERATIVE SENSORS (ADS-B, WAM, MLAT)

This CBA is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 874478 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document provides the Cost Benefit Analysis (CBA) related to the deployment of the SESAR technological solution PJ.14-W2-84e that has been matured through validation activities at TRL6 level. CBA objectives, scope and cost benefit analysis have been provided in accordance with CBA programme guidance and in close collaboration with PJ.19-04 (incl. Eurocontrol's CBA experts) considering the solution type (technological solution) and specificities.

This SESAR solution is attached to the OI step POI-0061-SUR (Surveillance performance monitoring for cooperative sensors) and is covering the enablers CTE-S07a (Coop. sensor SPM Tool – ER & TMA) and CTE-S07b (Coop. sensor SPM Tool – Surface).

The key deployment locations are TMA/En-route operations (for ANSPs) and Surface operations (for Airport Operators).

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1 Executive Summary

Communications, Navigation and Surveillance (CNS) systems provide the invisible and often unappreciated infrastructure which is essential for Air Traffic Management. CNS enables efficient navigation and safe separation in all phases of flight.

In Surveillance, several SESAR solutions will be developed to enhance, harmonize, and integrate cooperative and emerging non-cooperative sensors, advanced multi-sensors data fusion capabilities, security related functionality together with the methods and tools for Surveillance Performance Monitoring. This is in line with a performance-based Surveillance (PBS) approach.

The performance assessment tools and methods for emerging Surveillance technologies (MLAT, WAM, ADS-B) are currently not aligned with the evolution of the emerging standards that follow the performance-based approach. The main objective of the technological solution PJ.14-W2-84e is therefore to enable a harmonized performance monitoring for the cooperative sensors. Such monitoring will seek to identify degradation trends early, using both off-line and quasi-real time processes.

The stakeholders potentially impacted/concerned by the deployment of this SESAR solution are:

- ANSP (TMA and En-route OEs),
- Airport Operators (Surface OE),

These stakeholders will receive the benefits described in this document (§4) thanks to the technological evolution introduced by this solution. Key benefits are:

- Cost efficiency,
- Increased automation,
- Increased trustworthiness of the performance assessments.

As part of the CBA-work, the Sol.84e project-team has developed a pre-CBA Model (Excel-file "CBA_Template_20210827_Clean.xlsx") to gather all the information and assumptions related to the Reference and Solution Scenarios, and convert them into quantitative input feeding the CBA-model provided by the SJU. ***Using this approach, the Net Present Value calculated by the CBA-model is 6,4 M€ (--> ANSP 4,1 M€ and Airports 2,3 M€).***

Regarding the payback year: as the delta between the ground implementation costs in the Solution Scenario and the Reference Scenario is negative (i.e. higher ground costs expected in the Reference Scenario), ***the payback year is actually from the start of deployment, i.e. 2023***. In other words, the main benefits of this Solution are what we can call the "avoided costs". ***By deploying the harmonized SPM-tools, the stakeholders will still have to invest, but they will invest less than with the current approach of deciding for a suitable SPM tool. Moreover, they will benefit from several trustworthy (and harmonized) SPM-tools defined and accepted by a larger community involving ANSP's and***

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industry via the SESAR project, and also take advantage of the Quasi-Real Time functionality both technically[1] (= flexible monitoring) and economically (= reduction of operating costs).

The main uncertainties/limitations identified in this CBA are mainly linked to 2 of the assumptions made at ECAC level to build the analysis:

- the number of Surveillance sensors (WAM, ADS-B, MLAT) deployed in the scenarios by 2030,
- the amount of time - in average - spent by ATSEP-resources to test the tools (= pre-implementation and implementation phases) and to carry out the performance assessments (= post-implementation phase).

These 2 assumptions have therefore a significant impact on the level of confidence of the CBA. Their influences on e.g. the NPV has been investigated as part of the sensitivity analysis (§8), as well as the impact of the discount rate on the NPV. ***The main observation is that the NPV always remains positive, which is a very good indication that the stakeholders can expect a profit and should consider moving forward with the investment***.

[1] The technical benefit has been translated in monetary terms in the pre-CBA Model when estimating/assessing the time spent by an ATSEP on a performance assessment with and without the Quasi-Real Time functionality (Configuring, Monitoring, Analyzing and Reporting).

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2 Introduction

2.1 Purpose of the document

This document provides the Cost Benefit Analysis (CBA) related to the deployment of the SESAR technological solution PJ.14-W2-84e that has been matured through validation activities at TRL6 level. CBA objectives, scope and cost benefit analysis have been provided in accordance with CBA programme guidance and in close collaboration with PJ.19-04 (incl. Eurocontrol's CBA experts) considering the solution type (technological solution) and specificities.

2.2 Scope

The CBA period is up to 2043, so fully covering the major key dates of the Solution (start of deployment in October 2023, ie. 3 years before IOC as assumption, and October 2030 as FOC). The geographical scope is the entire ECAC-region, and the main stakeholders are Airport Operators and ANSPs.

2.3 Intended readership

The intended audience of this document is:

- PJ.14-W2-84f: to share assumptions and methodology that could be applicable to the end-to-end part,
- PJ.19-04 project: having a particular interest on CBA outcomes.**Structure of the document**

This document is organized as follows:

- Chapter 1 Executive summary,
- Chapter 2 Introduction: general introduction, scope, and purpose of the document. This chapter also provides the glossary of terms, acronyms and terminology used in this document,
- Chapter 3 CBA objectives and scope,
- Chapter 4 provides the identified benefits,
- Chapter 5 provides the overall cost assessment,
- Chapter 6 provides the CBA model,
- Chapter 7 provides the CBA results,
- Chapter 8 provides the sensitivity and risk analysis,
- Chapter 9 provides the recommendations and next steps,
- Chapter 10 provides the reference and applicable documents.**Background**

This Solution is the direct continuation of the Solution PJ.14-04-01 task 1 which reached TRL4 during Wave 1. In W2 PJ.14-04-01 task 1 coping with the Cooperative sensors and PJ.14-04-01 task 2 coping with the Non-Cooperative sensors were combined to PJ.14-W2-84e. However, the Non-Cooperative Sensors were dropped from the solution and are now out of PJ.14-W2-84e scope (impacted by Covid-19). Rather than a formal and quantitative CBA, PJ.14-04-01 developed and delivered a qualitative

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High-Level Economic Appraisal at the end of the previous phase, in agreement with the SJU (see Appendix E in the TVALR D11.1.070 [12]). The conclusions and remarks of the document are still considered applicable.

2.6 Glossary of terms

Term	Definition	Source of the definition
Baseline scenario	A point of reference. The Scenario at a specific date to be used in the validation in order to perform measurements from a well-known and consistent origin. The Baseline year has been set as 2012, which is in line with the start point of the Performance Ambitions defined in the ATM Master Plan and in line with performance validation targets defined in PJ19.04	*SESAR 2020 Performance Framework*
Capital Expenditure	Capital expenditures (Capex) are funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment.	*Investopedia*
Cost benefit analysis	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 the total costs associated with taking that action.	*Investopedia*
Operational expenditure	An operational expenditure (Opex) is an expense a business incurs through its normal business operations.	*Investopedia*
Net Present Value	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.	*Investopedia*
Reference scenario	To measure the performance impact of a SESAR Solution, at least two different situations must be assessed and compared: a Reference Scenario and a Solution Scenario. One situation should be a scenario that does not have the concept element (the reference scenario) and, then, a second situation that equals the first except	*SESAR 2020 Performance Framework* *TVALP Template guidances*

	that it includes the new concept element (the Solution scenario). The descriptions of the reference scenario(s) and of the solution scenario(s) can include, depending on the scope of the validation exercise, airport information, airspace information, traffic information, etc. The reference scenario is matched in time with the solution scenario but DOES NOT include the SESAR solution(s) that is the subject of the validation. The only difference between the solution and the reference scenario is that the former includes the SESAR solution(s) that is the subject of the validation.	
Sensitivity analysis	Sensitivity analysis determines how different values of an independent variable affect a particular dependent variable under a given set of assumptions. In other words, sensitivity analyses study how various sources of uncertainty in a mathematical model contribute to the model's overall uncertainty. This technique is used within specific boundaries that depend on one or more input variables.	*Investopedia*
Solution scenario	See Reference scenario	*SESAR 2020 Performance Framework* *TVALP Template guidances*

Table 1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
ADS-B	Automatic Dependent Surveillance - Broadcast
ANSP	Air Navigation Service Provider
ATM	Air Traffic Management
ATSEP	Air Traffic Safety Electronics Personnel
AU	Airspace Users

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CAPEX	Capital expenditure
CBA	Cost Benefit Analysis
CNS	Communication, Navigation and Surveillance
ECAC	European Civil Aviation Conference
EATMA	European ATM Architecture
FOC	Full Operational Capability
FTE	Full-time equivalent
INTEROP	Interoperability Requirements
IOC	Initial Operational Capability
KPA	Key Performance Area
KPI	Key Performance Indicator
MLAT	Multilateration
NPV	Net Present Value
OE	Operational Environment
OI	Operational Improvement
OPEX	Operational expenditure
OSED	Operational Service and Environment Definition
QRT	Quasi Real Time
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SPM	Surveillance Performance Monitoring
SPR	Safety and Performance Requirements
SUR	Surveillance
TMA	Terminal Manoeuvring Area
WAM	Wide Area Multilateration

Table 2: List of acronyms

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3 Objectives and scope of the CBA

3.1 Problem addressed by the solution

This document provides the Cost Benefit Analysis (CBA) related to the deployment of the SESAR technological solution PJ.14-W2-84e that has been matured through validation activities at TRL6 level.

The deployment of the SPM-tools developed by this Solution would enable a more trustworthy[2] performance monitoring of the emerging cooperative sensors (WAM, ADS-B, MLAT). Such monitoring will seek to identify degradation trends early, using both off-line and quasi-real time processes.

The main purpose of this CBA is to facilitate and support better informed decision-making for key investment decisions related to the SESAR technological solution PJ.14-W2-84e. This is achieved by:

- identifying all costs and benefits per stakeholders,
- quantifying in economic terms the costs and benefits,
- calculating the economic value of the project,
- making a cash flow projection,
- Identifying the factors/assumptions having the most influence on the results.

3.2 SESAR Solution description

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.14-W2-84e - Surveillance Performance Monitoring Tool for Cooperative Sensors	POI-0061-SUR	Surveillance performance monitoring for cooperative sensors	Fully	EATMA (No applicable SPR-INTEROP/OSED have been identified)

Table 3: SESAR Solution PJ.14-W2-84e Scope and related OI steps

[2] Increased trustworthiness achieved through the alignment of the SPM-tools to the applicable standards (e.g. EUROCAE) and the verified harmonization between the SPM-tools agreed by a larger community involving ANSP's and industry via the SESAR project.

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OI Steps ref.	Enabler[3] ref.	Enabler definition	Enabler coverage	Applicable stakeholder	Source reference
POI-0061-SUR	CTE-S07a	En-route/TMA Cooperative Sensor Surveillance	Fully	ANSP	EATMA (No applicable SPR-INTEROP/OSED have been identified)
POI-0061-SUR	CTE-S07b	Airport Surface Cooperative Sensor Surveillance	Fully	Airport Operators	EATMA (No applicable SPR-INTEROP/OSED have been identified)

Table 4: OI steps and related Enablers

The following table provides an overview on the unique Validation Target allocated to this solution by PJ.19-04. The information depicted in this table is:

- if the related KPA is directly or indirectly impacted by this solution,
- if the validation target is being evaluated during validation activities,
- if the validation target is being evaluated during CBA activities,
- limitations concerning both validation and CBA activities.

Validation target	Direct/Indirect impact	Validation activities	CBA activities	Limitations
Technology Cost per flight	Direct impact (CEF3, medium impact expected)	Not measured during validation activities	Evaluated during CBA activities	Strong assumptions made at ECAC level to build the CBA (see §8 Sensitivity analysis)

Table 5: SESAR Solution PJ.14-W2-84e validation targets

3.3 Objectives of the CBA

This document provides the Cost Benefit Analysis (CBA) related to the deployment of the SESAR technological solution PJ.14-W2-84e that has been matured through validation activities at TRL6 level. The main purpose of this CBA is to facilitate and support better informed decision-making for key investment decisions. This is achieved by:

- identifying all costs and benefits per stakeholders,
- quantifying in economic terms the costs and benefits,
- calculating the economic value of the project,

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

- making a cash flow projection,
- Identifying the factors/assumptions having the most influence on the results.

3.4 Stakeholders[4] 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	TMA and En-route OEs	Invest and enjoy benefits in operations.	Provide inputs, participate to the brainstorms on elaboration of assumptions, review the results	Yes, on both costs and benefits
Airport Operators	Surface OE	Invest and enjoy benefits in operations.	Not involved	Yes, on both costs and benefits

Table 6: SESAR Solution PJ.14-W2-84e CBA Stakeholders and impacts

3.5 CBA Scenarios and Assumptions

The Reference and Solutions Scenarios considered for this CBA are summarized in the following sub-sections. Since Sol.84e is a Technological Solution, the involved scenarios are not derived from any SPR-INTEROP/OSED but built upon several specific assumptions made by the Sol.84e project-team.

The complete list of assumptions (incl. the source/technique used) is available in the pre-CBA Model (Excel-file “CBA_Template_20210827_Clean.xlsx”).

3.5.1 Reference Scenario

The Reference Scenario can be summarised as follows:

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

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- 3 to 5 SPM tools are developed in parallel and independently (by industry),
- The tools are supporting the latest EUROCAE standards,
- Quasi-Real Time functionality (QRT) is not developed.

3.5.2 Solution Scenario

The Solution Scenario can be summarised as follows:

- 2 SPM tools are developed within SESAR (Thales & Eurocontrol),
- The tools are supporting the latest EUROCAE standards,
- Quasi-Real Time functionality (QRT) is developed.

3.5.3 Assumptions

As previously written, the complete list of assumptions (incl. the source/technique used) is available in the pre-CBA Model (Excel-file "CBA_Template_20210827_Clean.xlsx") and converted into quantitative input feeding the CBA-model provided by the SJU.

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4 Benefits

For this Solution, the benefits are equivalent to the “negative” costs. The only KPI identified is CEF3. Rather than showing the result for Year N, Year N+x and Year N+y, in the table below (which would not be reader-friendly) the results are depicted in the Capex-Opex charts extracted from the CBA-model and inserted in §7.

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Performance Framework KPA[5]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year N	Year N+x	Year N+y
Cost Efficiency	ANS Cost efficiency	**CEF2** Flights per ATCO-Hour on duty	Nb	ATCO employment Cost change	€/year	N/A	N/A	N/A
				Support Staff Employment Cost Change	€/year	N/A	N/A	N/A
				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	6,4 M€ discounted 17,4 M€ undiscounted		
	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

[5] 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[5]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year N	Year N+x	Year N+y
		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	N/A	N/A	N/A
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
		CAP2 En-route throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
	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
		Diversions	% and # movements	Cost of diversions	€/year	N/A	N/A	N/A

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Performance Framework KPA[5]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year N	Year N+x	Year N+y
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	N/A	N/A	N/A
	Fuel Efficiency	**FEFF2** CO2 Emissions	Kg CO2 per movement	CO2 Costs	€/year	N/A	N/A	N/A

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Performance Framework KPA[5]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year N	Year N+x	Year N+y
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

Table 7: Results of the benefits monetisation per KPA

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5 Cost assessment

The main users of the SPM-tools are the ANSPs (WAM and ADS-B performance assessments for En-route and TMA) and the Airport Operators (MLAT and ADS-B performance assessments for Surface). There is currently no figure depicting the number of licenses per ECAC country, and no forecast for the next years. The number of licenses will in any case be highly dependent on:

- the capability of the tools (limited number of SPM tools for Surface),
- the choice made by each single ANSP and Airport Operator to buy a license or not,
- the fact that several Airport Operators may choose to delegate the performance assessment of their sensors to the ANSPs,

In the context of this CBA, the assumption made is that the number of licenses per country in the ECAC region is in average 5 (= 4 for Airport Operators + 1 for ANSP), both in the Reference scenario and the Solution scenario. The investments costs and annual operating costs are calculated per stakeholder (i.e. ANSPs and Airport Operators).

5.1 ANSPs costs

3 categories of costs have been identified and estimated for the ANSPs: the pre-implementation costs, the implementation costs and the operating costs.

5.1.1 ANSPs cost approach

The cost figures were obtained using expert judgment (from ANSPs, SUR-Industry partners and SUR-Community). Several "brainstorms" were organized to define a reasonable set of assumptions having a direct impact on the costs (e.g. no. of SPM tool licenses needed, no. of sensors available, ATSEP-time to analyse the tools and carry out the performance assessments, ATSEP-FTE, …).

5.1.2 ANSPs cost assumptions

As previously written, the complete list of assumptions is available in the pre-CBA Model (Excel-file "CBA_Template_20210827_Clean.xlsx") and converted into quantitative input feeding the CBA-model provided by the SJU.

5.1.3 Number of investment instances (units)

One of the assumptions of this CBA is that an average of 5 SPM-tool licenses would be bought in each ECAC-country: 1 for the national ANSP and 4 for the Airport Operators. ANSPs would mainly use the SPM-tools for the performance assessments in TMA and En-route environments (WAM, ADS-B), while Airport Operators would focus on Surface environment (MLAT, ADS-B Surface).

5.1.4 Cost per unit

The figures at ECAC level provided in this section are the ones calculated in the pre-CBA Model (Excel-file "CBA_Template_20210827_Clean.xlsx", spreadsheet DELTA) and used as direct input to the CBA-model provided by the SJU (parameters "***Ground Costs - MEUR***" and "***Ground Change in operating costs (M€, annual)***" for Scenario 1 in the spreadsheet Sol_Info).

For ANSPs, the "delta" at ECAC level when comparing the Solution and the Reference Scenario is:

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- overall investment costs (= pre-implementation + implementation): -204695 €, i.e. higher ground costs expected in the Reference Scenario,
- annual operating costs: -703728 €, i.e. higher operating costs expected in the Reference Scenario.

As the assumption is that each ANSP of the ECAC region would buy a license (= 44 ANSPs in total), the cost per ANSP, or cost per unit would then be:

- overall investment costs (= pre-implementation + implementation): -4652 €,
- annual operating costs: -15994 €.

5.2 Airport operators costs

3 categories of costs have been identified and estimated for the Airport Operators[6]: the pre-implementation costs, the implementation costs and the operating costs.

5.2.1 Airport operators cost approach

The cost figures were obtained using expert judgment (from ANSPs, SUR-Industry partners and SUR-Community). Several "brainstorms" were organized to define a reasonable set of assumptions having a direct impact on the costs (e.g. no. of SPM tool licenses needed, no. of sensors available, ATSEP-time to analyse the tools, ATSEP-FTE, …).

5.2.2 Airport operators cost assumptions

As previously written, the complete list of assumptions is available in the pre-CBA Model (Excel-file "CBA_Template_20210827_Clean.xlsx") and converted into quantitative input feeding the CBA-model provided by the SJU.

5.2.3 Number of investment instances (units)

One of the assumptions of this CBA is that an average of 5 SPM-tool licenses would be bought in each ECAC-country: 1 for the national ANSP and 4 for the Airport Operators. ANSPs would mainly use the SPM-tools for the performance assessments in TMA and En-route environments (WAM, ADS-B), while Airport Operators would focus on Surface environment (MLAT, ADS-B Surface).

[6] It's reasonable to say that the way an ATSEP would use the tools (time for each phases of the assessment, methodology) is expected to be similar for ANSP and Airport operators. It would of course have been beneficial to get input from the Airport operators, for instance regarding the forecasted number of Surface sensors to be deployed by 2035, but it would not have significantly impacted the cost figures and the overall quality of the document. Moreover, the lack of Airport Operator input and more globally the risk of low reliability of the inputs are covered by the sensitivity analysis, especially in section 8.3 which is going even further the guidelines of the CBA (as recommended by PJ.19).

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5.2.4 Cost per unit

The figures at ECAC level provided in this section are the ones calculated in the pre-CBA Model (Excel-file "CBA_Template_20210827_Clean.xlsx", spreadsheet DELTA) and used as direct input to the CBA-model provided by the SJU (parameters "***Ground Costs - MEUR***" and "***Ground Change in operating costs (M€, annual)***" for Scenario 1 in the spreadsheet Sol_Info).

For Airport Operators, the "delta" at ECAC level when comparing the Solution Scenario and the Reference Scenario is:

- overall investment costs (= pre-implementation + implementation): -818780 €, i.e. higher ground costs expected in the Reference Scenario,
- annual operating costs: -320028 €, i.e. higher operating costs expected in the Reference Scenario.

As the assumption is that 4 Airport Operators per ECAC region would buy a license (= 4 x 44 Airports in total), the cost per Airport Operator, or cost per unit would then be:

- overall investment costs (= pre-implementation + implementation): -4652 €,
- annual operating costs: -1818 €.

5.3 Network Manager costs

No costs involved.

5.3.1 Network Manager cost approach

No costs involved.

5.3.2 Network Manager cost assumptions

No costs involved.

5.3.3 Network Manager cost figures

No costs involved.

5.4 Airspace User costs

No costs involved.

5.4.1 Airspace User cost approach

No costs involved.

5.4.2 Airspace User cost assumptions

No costs involved.

5.4.3 Number of investment instances (units)

No costs involved.

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5.4.4 Cost per unit

No costs involved.

5.5 Military costs

No costs involved.

5.5.1 Military cost approach

No costs involved.

5.5.2 Military cost assumptions

No costs involved.

5.5.3 Number of investment instances (units)

No costs involved.

5.5.4 Cost per unit

No costs involved.

5.6 Other relevant stakeholders

No further stakeholders.

5.7 Cost mechanism summary

This section provides a summary of how the data in the previous sections is used to feed the CBA-model. For both the Ground Costs (= investment) and the Annual Operating Costs, the figures depicted in the following tables are the difference between the costs in the Solution Scenario (SOL) and the costs in the Reference Scenario (REF). The 2nd column is the cost per unit, and the last column the cost at ECAC level.

Stakeholder	Cost per-unit (Delta btw. SOL & REF)	x	Deployment Locations	=	Ground Costs (Delta btw. SOL & REF)
ANSP (TMA, En-route)	- 4652 €	x	1 ANSP x 44 countries	=	- 204695 €
Airport Operator (Surface)	- 4652 €	x	4 airports x 44 countries	=	- 818780 €

Table 8: SESAR Solution PJ.14-W2-84e Difference between REF and SOL scenarios for Ground costs

Stakeholder	Cost per-unit (Delta btw. SOL & REF)	x	Deployment Locations	=	Annual Operating Costs (Delta btw. SOL & REF)
ANSP (TMA, En-route)	- 15994 €	x	1 ANSP x 44 countries	=	- 703728 €
Airport Operator (Surface)	- 1818 €	x	4 airports x 44 countries	=	- 320028 €

Table 9: SESAR Solution PJ.14-W2-84e Difference between SOL and REF scenarios for Annual Operating Costs

6 CBA Model

The pre-CBA Model ***"CBA_Template_20210827_Clean.xlsx"*** and the CBA model"***s7.2.11_for_S84e_20210827.xlsm***" are included here

CBA_Template_2021 0827_Clean.xlsx

s7.2.11_for_S84e_20 210827.xlsm

6.1 Data sources

The data used to build the CBA consist mainly of several assumptions and/or expert-judgements captured and recorded during specific brainstorming sessions, especially:

- The estimation of ATSEP-time for testing the tools and carrying-out the performance assessments,
- The average number of SPM tool licences in the ECAC area (for ANSPs and Airport Operators),
- The average number of sensors available in a system of sensors (consulting also external expertise such as the Network Surveillance User Group),
- The estimation of the number of sensors deployed in the ECAC area by 2030 (consulting also external expertise such as the Network Surveillance User Group).

The data sources are recorded in the pre-CBA Model (Excel-file "CBA_Template_20210827_Clean.xlsx") and converted into quantitative input feeding the CBA-model provided by the SJU. The confidence in the expert-judgements is pretty high, with a group of 5 to 8 skilled representatives from ANSPs (ENAIRE, COOPANS, NavPortugal) and from the industrial partners developing the tools (Thales, Eurocontrol, Indra).

Remark: the pre-CBA Model has been developed in close collaboration with PJ.19-04, including several review-meetings with their CBA experts who developed the CBA-model used by all SESAR-Solutions.

This CBA identifies and takes into account the main uncertainties of the project (= linked to the strongest assumptions) by using ranges for uncertain input data in the sensitivity analysis:

- the number of sensors in the ECAC region compared to the forecast in 2030 → range +/- 20% applied,
- the average time spent by ATSEP-resources to test the tools (= pre-implementation and implementation phases) and to carry out the performance assessments (= post-implementation phase) → ranges +/- 25% and +/- 50% applied.

To estimate the ATSEP annual employment costs for one full-time equivalent (FTE) in the ECAC area, the figures from the EUROCONTROL Standard Inputs for Economic Analyses, Ed.9.0 from December 2020 [13] are used.

7 CBA Results

The following tables and figures are extracted from the CBA-model and depict the most relevant results for this CBA.

Tables 10 and Table 11 are summarizing the overall investment costs and the benefits up to 2043, when a discount rate of 8% is applied and without any discount rate respectively.

Figure 1 and Figure 2 are presenting the yearly Opex/Capex results up to 2043, without any discount rate and when a discount rate of 8% is applied respectively.

The payback year is actually from the start of deployment, i.e. 2023. In other words, the main benefits of this Solution are what we can call the "avoided costs". By deploying the harmonized SPM-tools, the stakeholders will still have to invest, but they will invest less than with the current approach of deciding for a suitable SPM tool.

S84e - 2022-2043 (discount rate 8%) (M€)				
	NPV	Capex	Opex	Benefits
ANSP	+4,1	-0,1	-4,0	0,0
Airports	+2,3	-0,5	-1,8	0,0
Overall	**+6,4**	**-0,7**	**-5,8**	**0,0**

Table 10: SESAR Solution PJ.14-W2-84e Investment costs and Benefits discounted

S84e - 2022-2043 (undiscounted) (M€)				
	Net Benefits	Capex	Opex	Benefits
ANSP	+11,5	-0,2	-11,3	0,0
Airports	+5,9	-0,8	-5,1	0,0
Overall	**+17,4**	**-1,0**	**-16,4**	**0,0**

Table 11: SESAR Solution PJ.14-W2-84e Investment costs and Benefits undiscounted

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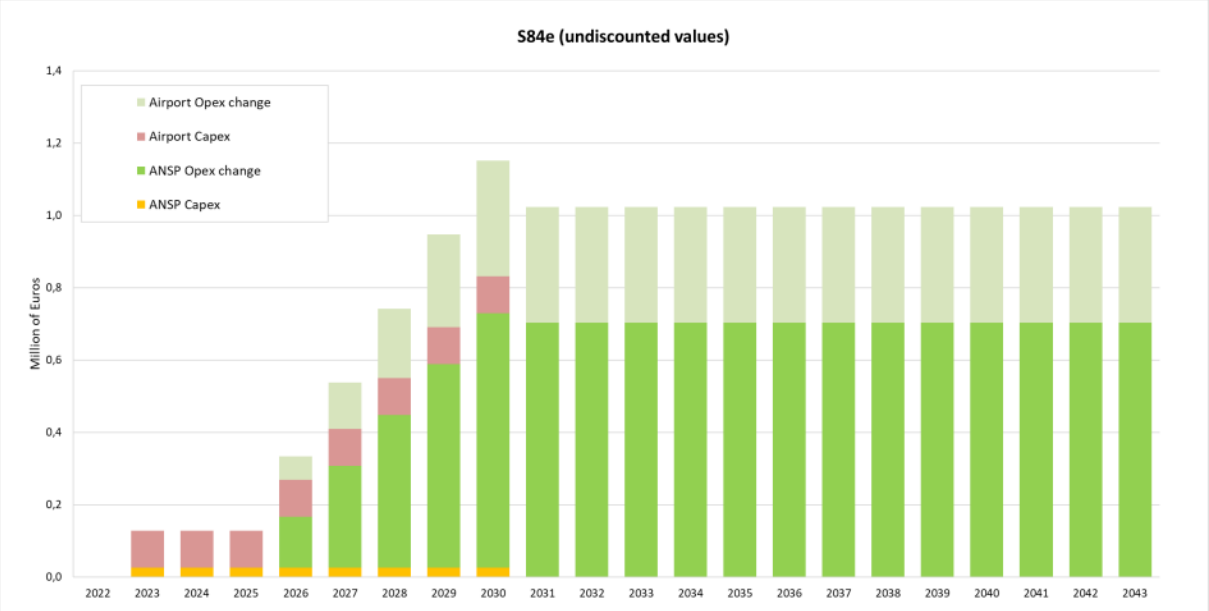

Figure 1: SESAR Solution PJ.14-W2-84e Opex-Capex undiscounted

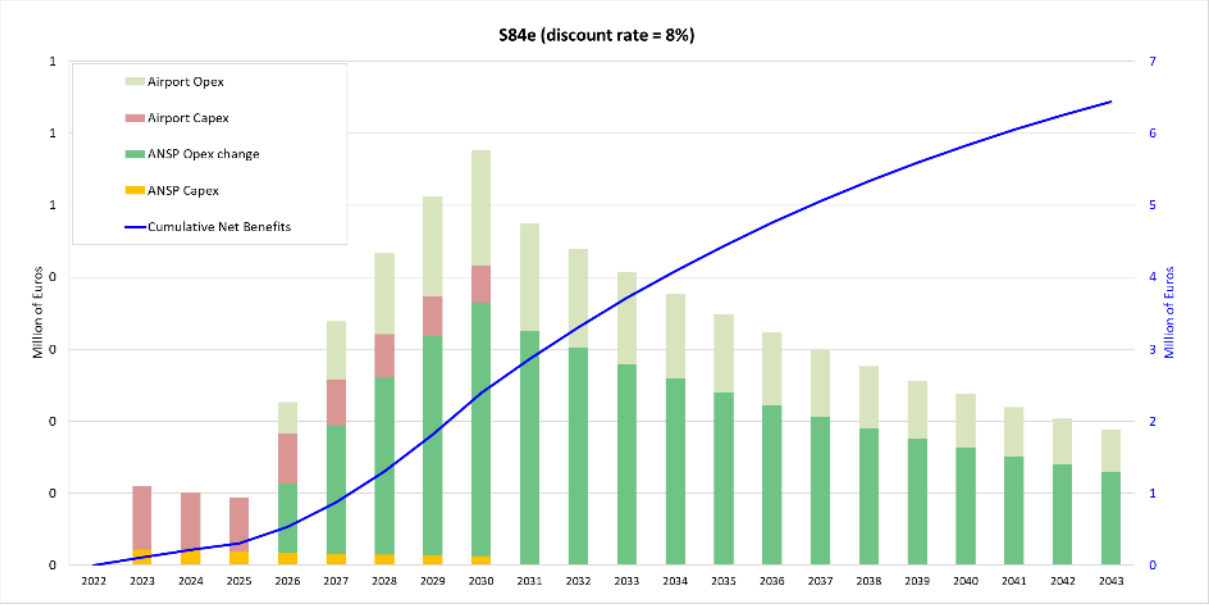

Figure 2: SESAR Solution PJ.14-W2-84e Opex-Capex discounted

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8 Sensitivity and risk analysis

8.1 Influence of the discount rate on NPV

The following graph is extracted from the CBA-model and depicts the impact of the Discount rate on the NPV (in M€). The NPV remains positive - which is good indication that the stakeholders can expect a profit - and is following linearly the Discount Rate (approx. -2 M€ every time it's increased by 2%).

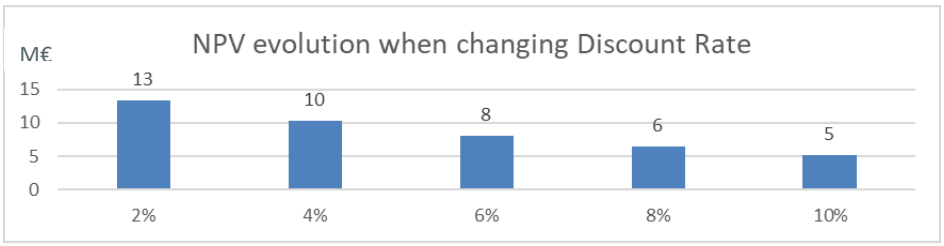

Figure 3: SESAR Solution PJ.14-W2-84e NPV and Discount Rate

8.2 Variation of the input to the CBA-model[7]

The following graphs are also extracted from the CBA-model and depict the impact of a variation of the input to the model (input variations +/- 25% and +/- 50%) on the Ground Opex/Capex.

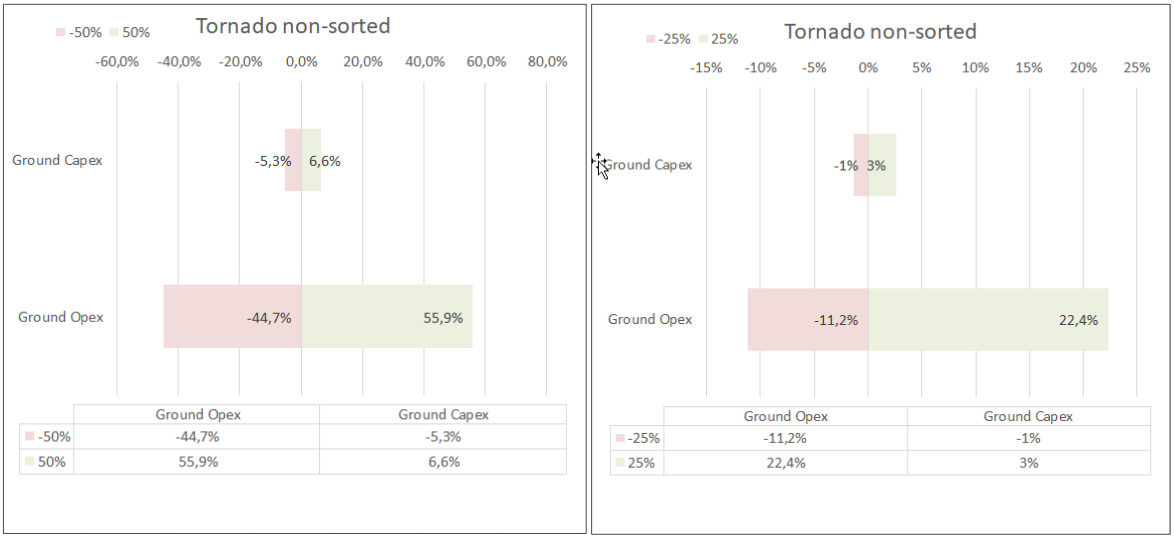

Figure 4: SESAR Solution PJ.14-W2-84e Input variations

[7] The input to the model are the "Ground Costs - MEUR" and "Ground Change in operating costs (M€, annual)" in the spreadsheet Sol_Info (cell G33 to cell H34) from the CBA-model calculated in the Pre-CBA model (spreadsheet "DELTA" in CBA_template_20210827). In section 8.3, the variation was not applied on these overall Ground Costs and Operating costs, but directly on the 2 major assumptions of the CBA (number of sensors and ATSEP-time) to see their actual impact on the Ground Costs and Operating Costs (as recommended by PJ.19).

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8.3 Influence of the number of sensors and of the ATSEP-time

As this CBA is built upon several assumptions, the approach chosen for the sensitivity analysis is to "play" with the strongest assumptions and see their individual impact/influence on e.g. the NPV. The main uncertainties are:

- the number of sensors in the ECAC region compared to the forecast in 2030 → range +/- 20% applied,
- the average time spent by ATSEP-resources to test the tools (= pre-implementation and implementation phases) and to carry out the performance assessments (= post-implementation phase) → ranges +/- 25% and +/- 50% applied.

Remark: these 2 "parameters" can be adjusted in the spreadsheet DELTA of the pre-CBA Model (Excel-file "CBA_Template_20210827_Clean.xlsx"), triggering a re-calculation of the costs. The results are then imported in the CBA-model provided by the SJU (parameters "***Ground Costs - MEUR***" and "***Ground Change in operating costs (M€, annual)***" for Scenario 1 in the spreadsheet Sol_Info).

The figures from the next sub-sections show that these 2 assumptions have a significant impact on the level of confidence of the CBA. Nevertheless, the NPV remains always positive, which is a very good indication that the stakeholders can expect a profit and should consider moving forward with the investment.

8.3.1 Influence of the number of sensors

The following tables depict the impact of the number of sensors deployed in the ECAC area on the main CBA-figures (NPV for discounted, Net Benefits for undiscounted):

NPV (DISCOUNTED) (M€)	-20% sensors	Baseline	+20% sensors
ANSP	+3,3	+4,1	+4,9
Airports	+2,0	2,3	+2,7
Overall	**+5,3**	**+6,4**	**+7,6**
Variation	**-17%**	**-**	**+19%**

Table 12: SESAR Solution PJ.14-W2-84e Impact of the number of sensors (discounted)

Net benefits (UNDISCOUNTED) (M€)	-20% sensors	Baseline	+20% sensors
ANSP	+9,2	+11,5	+13,7
Airports	+4,9	+5,9	+7,0
Overall	**+14,1**	**+17,4**	**+20,7**
Variation	**-19%**	**-**	**+19%**

Table 13: SESAR Solution PJ.14-W2-84e Impact of the number of sensors (undiscounted)

8.3.2 Influence of the ATSEP-time

The following tables depict the impact of the ATSEP-time on the main figures (NPV for discounted, Net Benefits for undiscounted). ATSEP-resources are involved in the pre-implementation, and implementation phase when choosing/assessing the tools, and also in the post-implementation phase as main users of the SPM-tools:

NPV (DISCOUNTED) (M€)	-50% ATSEP-time	-25% ATSEP-time	Baseline	+25% ATSEP-time	+50% ATSEP-time
ANSP	+2,0	+3,1	+4,1	+5,1	+6,1
Airports	+1,2	+1,8	+2,3	+2,9	+3,5
Overall	**+3,2**	**+4,8**	**+6,4**	**+8,0**	**+9,7**
Variation	**-50%**	**-25%**	**-**	**+25%**	**+50%**

Table 14: SESAR Solution PJ.14-W2-84e Impact of the ATSEP-time (discounted)

Net benefits (UNDISCOUNTED) (M€)	-50% ATSEP-time	-25% ATSEP-time	Baseline	+25% ATSEP-time	+50% ATSEP-time
ANSP	+5,7	+8,6	+11,5	+14,3	+17,2
Airports	+3,0	+4,5	+5,9	+7,4	+8,9
Overall	**+8,7**	**+13,1**	**+17,4**	**+21,8**	**+26,1**
Variation	**-50%**	**-25%**	**-**	**+25%**	**+50%**

Table 15: SESAR Solution PJ.14-W2-84e Impact of the ATSEP-time (undiscounted)

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9 Recommendations and next steps

The main benefits of this Solution are what we can call the "avoided costs". ***By deploying the harmonized SPM-tools, the stakeholders will still have to invest, but they will invest less than with the current approach of deciding for a suitable SPM tool. Moreover, they will benefit from several trustworthy (and harmonized) SPM-tools defined and accepted by a larger community involving ANSP's and industry via the SESAR project, and also take advantage of the Quasi-Real Time functionality both technically (= flexible monitoring) and economically (= reduction of operating costs)***.

The main uncertainties/limitations identified in this CBA are mainly linked to 2 of the assumptions made at ECAC level to build the analysis:

- the number of Surveillance sensors (WAM, ADS-B, MLAT) deployed in the scenarios by 2030,
- the amount of time - in average - spent by ATSEP-resources to test the tools (= pre-implementation and implementation phases) and to carry out the performance assessments (= post-implementation phase).

These 2 assumptions have therefore a significant impact on the level of confidence of the CBA. Their influences on e.g. the NPV has been investigated as part of the sensitivity analysis (§8), as well as the impact of the discount rate on the NPV. ***The main observation is that the NPV always remains positive, which is a very good indication that the stakeholders can expect a profit and should consider moving forward with the investment***. No further work on this CBA is deemed necessary.

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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[8];

[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]SESAR 2020 Performance Framework Ed 01.00.01 from 20 Dec 19

[12] D11.1.070 PJ14-04-01 T02 TVALR ed00.01.02.docx

[13] EUROCONTROL Standard Inputs for Economic Analyses, Ed.9.0 from December 2020

[8] 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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11 Appendix

Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs, source reference ***Error! Reference source not found.***

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

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

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