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PJ.10-W2 PROSA

SEPARATION MANAGEMENT AND CONTROLLER TOOLS

This Cost Benefit Analysis, CBA, is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 874464 under European Union's Horizon 2020 research and innovation programme.

Abstract

Automatic Speech Recognition or ASR, as it is known in short, is the technology that allows users to utilize their voices to speak with a computer interface in a way that allows converting human speech into texts, extract the information within, and use this knowledge in different applications. The ASR enabled applications can provide a solution to significantly reduce ATCOs workloads and increase ATM efficiency.

Considering the continuous growth of air traffic, ASR is a technology that can help the controller to carry out their task in a more efficient way.

SESAR Solution PJ.10-W2-96 ASR deals with new methods of controller interaction with the Human Machine Interface (HMI), applying mature technologies from other domains to ATM. This will increase controller productivity, reduce workload, reduce stress level and enable the use of SESAR advanced tools, safely facilitating performance-based operations.

This document aims at presenting the Cost Benefits analysis of the Automatic Speech Recognition function at technology readiness level (TRL) 6.

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1 Executive Summary

SESAR Solution 96 ASR deals with new methods of controller interaction with the Human Machine Interface (HMI), applying mature technologies from other domains to ATM. This will increase controller productivity, reduce workload, reduce stress level and enable the use of SESAR advanced tools, safely facilitating performance-based operations.

Automatic Speech Recognition or ASR, as it is known in short, is the technology that allows users (e.g. controllers) to utilise their voices to speak with a computer interface in a way that allows converting human speech into texts, extract the information within, and use this knowledge in different applications. The ASR enabled applications, can provide a solution to significantly reduce ATCOs workloads and increase ATM efficiency.

Considering the continuous growth of air traffic, ASR is a technology that can help the controller to carry out their task in a more efficient way.

The document analyses the Solution proposed by the PJ.10-W2-96 ASR in economic terms, comparing the costs expected to implement Automatic Speech Recognition (ASR) commands in the Controller Working Position (CWP) with its potential monetary benefit, as the positive result of the Stakeholders investment.

The CBA analyses the benefits identified within the solution and the costs that the stakeholders, ANSPs, need to perform to implement the solution. Finally, the outcome at ECAC level in three different scenarios is analysed with an assumption that half of the ACC will incorporate the technology in their premises. Not all the functionalities studied in S96 are analysed in this CBA as their benefits are not able to be monetised following the SESAR approach model.

Only one stakeholder has been identified as the one that needs to perform an investment to implement the solution but also receives the benefits. The stakeholder is the Air Navigation Service Providers, ANSPs.

All the scenarios have a positive Net Present Value, NPV, which indicates that the solution provides economic benefits for the stakeholder:

- Scenario 1 that aggregates all the use case analysed: has a NPV of €690M and a breakeven year in 2032;
- Scenario 2 that analyses the use of ASR to identify flights has a NPV of €180M and a breakeven year in 2035;
- Scenario 3 that analyses the use of ASR to prefill radar label has a NPV of €380M and a breakeven year in 2033.

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), In other words, the expected benefit gain through controllers productivity increase cost savings easily covers the costs of deploying and operating ASR across the ECAC region over the period of the CBAT.

2 Introduction

2.1 Purpose of the document

The document analyses the Solution proposed by the PJ.10-W2-96 ASR in economic terms, comparing the costs expected to implement Automatic Speech Recognition (ASR) commands in the Controller Working Position (CWP) with its potential monetary benefit, as the positive result of the Stakeholders investment. This kind of analysis will be provided with a detailed CBA in order to assess the economic feasibility of solutions and to help compare different alternatives.

The CBA is produced using the Reference Methodology as provided by SESAR guidelines on the CBAs, specifically: the Project Handbook[1]; Methods to assess Costs and monetize Benefits [3], and the cost Analysis Model [4], among other documents

2.2 Scope

The document provides the cost benefit analysis to the SESAR solution PJ.10-W2-S96 ASR at TRL6 level.

The focus is to assess the economic impact of implementing Automatic Speech Recognition by converting human speech into texts that can provide a solution to significantly reduce ATCOs workloads and increase ATM efficiency.

The operation improvement and technical enabler addressed according to EATMA [10] are:

- **POI-0055-SDM** "**Improving controller productivity by Automatic Speech Recognition (ASR) at the ER/APP CWP/HMI"** ATCOs will be supported by introducing innovative human machine interaction such as Automatic Speech Recognition. The goal is to automatically support certain tasks of the ATCO, which are either not performed at all or performed manually in today's ER APP systems / CWPs.
- **ER APP ATC 180 Controller productivity enhancements by Automatic Speech Recognition at the ER/APP CWP/HMI.** Introduction of new automated functions for Automatic Speech Recognition at the CHMI Management ER/APP for improving the controller productivity.

TIMEFRAME SCOPE

The CBA for PJ.10-W2-96 ASR solution was calculated for the years from 2022 to 2043, assumption indicated in [15]

According to EATMA [10]:

POI-0055-SDM has as Initial Operational Capability, IOC date 31/12/2029 and Full Operational Capability, FOC, 31/12/2033 with initial deployment date 31/12/2027.

These dates are common for all the environments where the Operational Improvement step can be deployed. These dates imply that the implementation period will start on 2028 and benefits realisation date will start on 2030 with a build up to full operational benefits by 2034.

GEOGRAPHIC SCOPE

The geographical scope covers the European Civil Aviation Conference (ECAC) countries. The target Operational Environments of SOL.96 ASR covers En-Route and TMA/approach with all the possible complexity: Very High, High, Medium and Low.

The planned exercises have been performed in the following Operational environment:

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- **En-route** Medium complexity
- **Approach/TMA** Medium complexity

The CBA will extrapolate validation results from the Exercises to the other target En-Route and TMA Operating Environment complexity with the next assumption:

- **Assumption#1 the same benefits will be achieved in the new environments.**

2.3 Intended readership

Belonging to a SESAR Technological solution, this CBA is of interest for all enabled SESAR ATM Solutions focusing on defining improved operational processes based on Human machine interface:

- **SESAR 2020 PJ.10-W2-96 ASR** consortium members in order to be aware of activities and methods being used to allow for coherency, consistency and comparability of the validation results through all Solution 96 activities.
- **ER4 HAAWAII project** members, so that they know what the expectations from industry to research are.
- **SESAR JOINT UNDERTAKING (SJU)** as SESAR 2020 Programme coordinator.
- **SESAR 2020 PJ.19 Content Integration** that aims at assuring coherency, consistency, and comparability of the validation results throughout all SESAR2020 Solutions.
- Representatives of civil stakeholders: **ANSPs** as possible investors.
- **SESAR 2020 Solution PJ.05-W2-97.1** consortium members, in order to have a common and shared view on technologies related to the use of ASR on the CWP HMI.
- **ANSPs** that are interested in implementing the ASR technology within their ACCs.

2.4 Structure of the document

The CBA Document is structured in the following chapters or paragraphs as indicated in the index:

- **Section 1** provides the executive summary;
- **Section 2** provides the overall scope, time horizon, intended audience, structure of the document, background, glossary of terms and acronyms;
- **Section 3** presents the objectives and scope of this CBA, provides a description of the PJ.10-Solution 96 ASR and the problem addressed by this Solution, identifies the main stakeholders impacted and describes the different scenarios compared in the CBA;
- **Section 4** provides a view on the overall contribution to Key Performance Indicators 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 Solution and presents the results of the cost assessment per stakeholder group;
- **Section 6** provides a description of the CBA model and the sources of data used to build the CBA Model;
- **Section 7** provides the CBA results;
- **Section 8** includes sensitivity analysis;
- **Section 9** includes Recommendations and next steps;
- **Section 10** includes the references and applicable documents.
- **CBA Model** used to quantify estimated costs and benefits for this CBA is provided as a supporting document and will be part of the Annexes of the CBA Report.

2.5 Background

ASR in ATM domain matured in Wave 1 in PJ16-04 up to TRL-4 and enabled the definition of rules for transformation of a sequence of ATC words into ATC concepts. No CBA was developed in the project.

Coordination with the CBA under development in PJ.05-W2-S97 dealing with the use of ASR on the tower CWP was performed.

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*
Operational Improvement (OI)	An OI is a new or modified capability of the ATMS which introduces performance benefits in terms of Capacity, Efficiency (cost, time, fuel), Environment, Safety and Security. An OI is implemented by means of one or more Enablers which upgrade an existing capability (basic building block of the ATMS) or create a new one.	SESAR

Table 1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
ACC	Area Control Centre
AG	Attention Guidance
AI	Artificial Intelligent
ANSP	Air Navigation Service Provider
APP	Approach
ASR	Automatic Speech Recognition
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATM	Air Traffic Management
CAP	Capacity
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CEF	Cost Efficiency
CHMI	Controller HMI

CWP	Controller Working Position
DAC	Dynamic Airspace Configuration
EATMA	European ATM Architecture
ECAC	European Civil Aviation Conference
ER	En- Route
EXE	Exercise
FC	Flight Crew
FEFF	Fuel Efficiency
FOC	Final Operational Capability
HC	High complexity (airport)
HMI	Human-Machine Interface
HP	Human Performance
IOC	Initial Operational Capability
KPI	Key Performance Area
LC	Low complexity (airport)
OPEX	Operational Expenditure
PAR	Performance Assessment Report
PIRM	Programme Information Reference Model
S3JU	SESAR3 Joint Undertaking (Agency of the European Commission)
SESAR	Single European Sky ATM Research Programme
SOD	Start Of Deployment
TMA	Terminal Manoeuvring Area
TRL	Technology Readiness Level
TS	Technical Specification
TVALP	Technical Validation Plan
TVALR	Technical Validation Report
UC	Use Case
VH	Very High
VHC	Very High Complexity

Table 2: List of acronyms

3 Objectives and scope of the CBA

3.1 Problem addressed by the solution

With increased levels of flights, new concepts and tools, exploration of new Human- Machine Interface, HMI, and interaction technologies to support controllers in their tasks is necessary. Solution 96 ASR investigates automatic speech recognition, and the impact that this new interaction mode has on controllers' productivity and performance and safety of operations. It integrates this new technology in Approach/TMA and En-Route environments.

The objective of PJ.10-W2-96 ASR is the development of ASR technology with a view to reduce the workload of air traffic controllers and increase the efficiency of air traffic management. To date, it is a technology that lacks accuracy, with errors in message transcription and no clear procedure for the Air Traffic Controller, ATCo, to confirm or cancel the sending of the message.

ASR speech form ATCo and/ or pilot utterances are recognized and transformed into text. This text is further analysed to extract relevant information. Several commands can be recognised from the controller-pilot spoken dialog, and they can be directly presented (and input) on the Controller HMI, CHMI, instead of manually inputting them into the system. Highlighting of aircraft upon callsign pronunciation from the ATCo or Flight Crew, FC, is also considered, as well as the use of functions in the CWP such as visualisation of sectorisation changes and 3D navigation. Artificial intelligence (AI) and machine learning algorithms are required for speech recognition engine training.

3.2 SESAR Solution description

SESAR Solution PJ16.4 ASR in Wave 1 matured ASR in ATM domain up to TRL-4 and enabled the definition of rules for transformation of a sequence of ATC words into ATC concepts (so called ontology). This ontology will be developed further and prepared for standardization.

In Wave 2 ASR operates also on real life data and the objective is to reach TRL-6. As most input comes from the ATCo-FC spoken dialog, ASR is the appropriate technology to reduce ATCO's workload by directly filling the command masks and radar labels using the spoken commands instead of manually inputting them into the system. This requires integration of artificial intelligence (AI) and machine learning algorithms. Identification of aircraft, user-friendly and intuitive operation will increase controller productivity.

The solution operates in a TMA and En-Route environments and ATCos are the end users. HMI prototypes will be developed in order to present the results of the speech recognition (identification of aircraft, user-friendly and intuitive operation etc.) in the best way to the controllers. The solution takes into account current operations and/or future operational concepts still under development and scope of other SESAR Solutions.

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.10-W2-96 ASR (Automatic Speech Recognition)	POI-0055-SDM	Improving controller productivity by Automatic Speech Recognition	Fully	TVALP [12]

		(ASR) at the ER/APP CWP/HMI		

Table 3: SESAR Solution 96 ASR Scope and related OI steps

OI Steps ref.	Enabler[1] ref.	Enabler definition	Enabler coverage	Applicable stakeholder	Source reference
POI-0055-SDM	ER APP ATC 180	Controller productivity enhancements by Automatic Speech Recognition at the ER/APP CWP/HMI	Required Full coverage	ANSP Industry	TVALP [12]

Table 4: OI steps and related Enablers

3.3 Objectives of the CBA

The purpose of this document is to develop a quantitative Cost Benefits Analysis, given the objective to reach the **TRL6** status of the Solution. The CBA will compare the costs and benefits of the solution (at ECAC network level), considering the costs for all actors involved and all the benefits expected by the capacity increase, fuel efficiency, reduction in the number of ATCos etc, ATCo's workload reduction for the whole ATM system. The solution impact at regional level will be used to measure the results at ECAC network area. The output should be the NPV overall and per stakeholder group, sensitivity and risk analysis, CBA model report and recommendation.

The CBA conducted for PJ.10-W2-96 ASR gives an overview of the application of the ASR system applied for the UCs detailing the results of the enhanced speech recognition system and its contribution to the whole solution. The goal is to validate the reduction in the workload of ATCos and the increase in the efficiency of Air Traffic Management through the improvement of the ASR system.

The CBA assesses whether the benefits of the deployed Solution are expected to exceed the costs over the CBA time horizon. Then, the CBA results can be used to support the decision to move to the next stage of life cycle.

As well as technical and user feasibility, the TVALP [12] identifies that the validation exercises are expected to demonstrate:

- Increase in situational awareness of ATCos
- Reduction of ATCos workload
- Increased ATCos efficiency and productivity
- Decrease of Human error
- Increased or maintained level of Safety

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

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3.4 Stakeholders[2] identification

The main stakeholders of solution 96 ASR are the ANSPs which will be the ones to perform the investment and the Airlines that will benefit from the outcome.

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	En-Route/approach. High, medium, low complexity	Costs: ANSP will have to invest in the upgrade of systems with ASR. Invest in training of ATCOs Benefits: from ATCOs increase efficiency, productivity, and situational awareness	Collaboration in cost and benefits assessment	Implementation costs: 240M/170M€ Operating costs: 28M€/year Benefits: $CEF2_{sc1}$: +3.21% $CEF2_{sc2}$: +1.17% $CEF2_{sc3}$: +1.95%
Airport Operators	Civil/Military	Costs: No costs identified	-	Benefits not monetized
Network Manager	Network	Costs: No costs identified	-	Benefits not monetized
Scheduled Airlines (Mainline and Regional)	Airspace User	Costs: No costs identified Benefits: Fuel efficiency	-	Benefits not monetized
Business Aviation – Fixed Wing	Airspace User	Costs: No costs identified Benefits: Fuel efficiency	-	Benefits not monetized
General Aviation	Airspace User	Costs: No costs identified Benefits: Fuel efficiency	-	Benefits not monetized
Military – Airborne	Airspace User	Costs: No costs identified Benefits: Fuel efficiency	-	Benefits not monetized
Military – Ground (WOC)	Airspace User	Costs: No costs identified	-	Benefits not monetized
Other impacted	No Impact foreseen	-	-	Benefits not monetized

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

stakeholders (ground handling, weather forecast service provider, NSA….)	imputable to PJ10-W2-S96			

Table 5: SESAR Solution SOL 96 ASR CBA Stakeholders and impacts

3.5 CBA Scenarios and Assumptions

This CBA considers the standalone deployment of Solution PJ.10-W2-96 ASR. This means that the full costs for the enablers are included in the CBA even if they will enable other Solutions[3] too.

The CBA Solution Scenario (green box in Figure 1: CBA Scenario Overview) considers the situation where the Solution OI Steps are already integrated at all deployment locations across ECAC. The CBA Reference Scenario (orange box in Figure 1: CBA Scenario Overview) describes the same future situation, but assuming that Solution PJ.10-W2-96 ASR is not deployed. However, for the CBA Reference Scenario is considered that all deployment locations comply with the necessary pre-requisites to deploy the Solution, including all improvements from SESAR Wave 1. The CBA reflects the delta (difference) between the CBA Reference and Solution Scenarios (i.e., between the orange and green boxes in Figure 1: CBA Scenario Overview).

Relevant costs include costs sustained for all actors involved, for training, for technological installation as well as capital and operational costs etc.

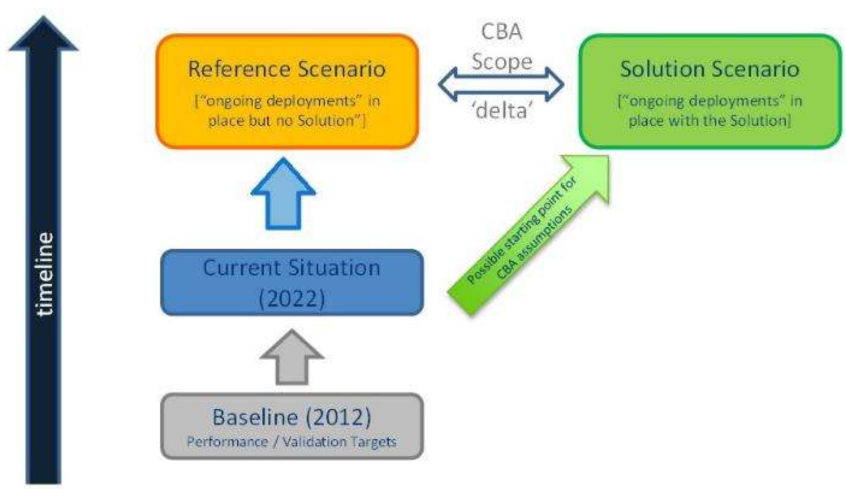

Figure 1: CBA Scenario Overview

[3] Issues of double counting will need to be addressed by PJ19/PJ20 when considering the deployment of multiple solutions.

3.5.1 Reference Scenario

The CBA **Reference** Scenario is the baseline against which the costs and benefits of S96 ASR are compared. The reference scenario represents the operational situation *without* ASR. In the timeframe of the CBA, 2023 to 2043, and as such includes the SJU CBA Common assumptions [9] regarding, for example, traffic volumes by sub-Operating Environment.

3.5.2 Solution Scenario

The Solution Scenario includes the deployment of the use cases, UC, listed in Table 6 . The complete description of each use case is available at the S96 ASR Technical Specification,[13].

Use Case	Use Case Title	En-Route	Approach/ TMA	En-Route-DAC
#3.1	Highlight of callsigns on the CWP from pilot utterances.	X	X	
#3.2	Highlight of callsigns on the CWP from controllers utterances.	X	X	
#3.3	Annotation of controllers commands.	X	X	
#3.4	Pre-filling of commands in the CWP	X	X	
#3.5	Voice commands for highlighting an upcoming sectorization change in the CWP			X
#3.6	Voice commands for highlighting the fights that will be affected by an upcoming sectorization change in the CWP			X
#3.7	Voice commands for navigating the 3D visualization of the air space in the CWP			X
#3.8	Prefilling of Datalink commands	X		

Table 6: UC addressed in S96 ASR

Next assumptions are done in respect to the CBA deployment scenarios:

- Where possible, each use case will be deployed separately and analysed in the CBA.
- Aggregated scenarios: If ASR is deployed in an En-route sector UC. 1, 2, 3, 4, and 8 will be deployed. The reasoning behind: the cost comes mainly from the development and integration of an ASR prototype. The investment differences on implementing one or all the use cases are negligible in the cost approach performed by ranges, while all the benefits could be counted on. In En-route environment prefilling of datalink commands (UC.8) will be dominant over voice commands (UC.4), but both UC are complementary as both communication means will coexist in the future.
- Aggregated scenarios: If ASR is deployed in an En-route with dynamic configuration sectors UC. 5, 6, and 7 will be deployed as well as UC. 1, 2, 3, 4, and 8. The reasoning behind: the cost

comes mainly from the development and integration of an ASR prototype. The investment differences on implementing one or all the use cases are negligible in the cost approach performed by ranges, while all the benefits could be counted on. → The case where ASR is deployed on a DAC but no ASR is deployed is possible but out of the scope of this CBA as it is centred on the full exploitation of the ASR possibilities.

- Aggregated scenarios: If ASR is deployed in an approach/TMA sector UC. 1, 2, 3, 4, and 8 will be deployed. The reasoning behind: the cost comes mainly from the development and integration of an ASR prototype. The investment differences on implementing one or all the use cases are negligible in the cost approach performed by ranges, while all the benefits could be counted on. In approach/TMA environment over voice commands (UC.4) will be dominant over prefilling of datalink commands (UC.8), but both UC are complementary as both communication means will coexist in the future.
- Not all the ANSP will deploy the ASR functionality. One intermediate scenario will be selected:
    - Intermediate deploy scenario: **half of the ACC will implement the functionality.**

3.5.3 Assumptions

Next assumptions apply to this CBA:

- SJU CBA common assumptions, [9], are applicable. The document contains assumptions regarding, for example, average fuel burnt per TMA, and flight movements per Sub Operational Environment and year.
- Deployment of the solution across ECAC is distributed evenly over a four-year period starting in Initial Operational Capability to the Full Operational Capability dates.
- Benefits will start to be noted two years after the implementation of the solution. It coincides with the IOC.
- The model has used a discount rate of 8%.
- En-route ACCs that will deploy DAC will be based on the assumptions performed at Project PJ.09–W2 Solution 44 'Dynamic Airspace Configuration'.
- Cost and Benefits of the solution scenario must be seen as a delta from the reference scenario.
- It is assumed that all targeted ANSP/ACCs will support the same kind of estimated benefits.
- The performance baseline will be 2022.
- Operating Environment category. Exercises take place in medium complexity environments. The benefits obtained for these environments are directly applicable in all the operational environments.

Timeframe considered for the CBA

Timeframe of the CBA is from 2022 to 2043. This assumption is aligned with the latest template of the SESAR CBA template available [15]. Within the CBA, the Solution is deployed when the assigned Stakeholders have deployed the required enablers and the system is operational and providing benefits. There are three key dates for the CBA lifecycle:

- Start of Deployment (SOD): is the date on which the deployment of the Solution starts, meaning that the first costs are beginning to be incurred. It is set at 31/12/2027. Deployment will take four years.

- Initial Operational Capability (IOC): is the date on which the benefits ramp-up starts. From this point, there are some remaining costs to be invest, but the benefits of the solution are beginning to be seen. It is set at 31/12/2029.

- Full Operational Capability (FOC): is the date on which deployment ends, so investments also stop. However, the Solution will still be providing benefits until the end date of the CBA W2 timeline. It is set at 31/12/2033.

Based on the above table and the schedule:

- ✓ Investment costs are spread equally between the Start and the End of Deployment dates (a duration of 4 years from 2028 to 2031), with a resultant deployment profile of:

2028	2029	2030	2031
25%	25%	25%	25%

Table 7: Deployment Profile

- ✓ Full benefits will start in the IOC in the Deployed ACCs.

- ✓ Operating Costs will start at the IOC and will continue until the rest of the CBA Timeframe.

Note: PJ.10-W2-97 TRL4 ASR CBA, [19], has been used as reference in several sections due to the similarities of the technology addressed. The S97 CBA considers Benefits will start being counted at the OE where the Technological enablers are fully deployed, immediately: IOC and SOD start the same year. The solution is TRL4 and does not have these dates described in EATMA [10]. This CBA will follow EATMA data for S96 ASR and test in the sensitivity analysis the different approach.

Geographical scope considered for the CBA

The ASR solution can be deployed in all the ACC and TMA regardless of their complexity. The scenario will assume that only half of the ACC in each category will deploy it.

4 Benefits

The present section provides information regarding the expected benefits taking into account the Validation Targets, [14], the BIMs as described in the TVALP, [12], the outcomes collected in the TVALR, [18], and the initial version of the PAR, [17].

It is based on the approach followed by Attention Guidance, the other technology solution in S96. i.e PJ.10-W2-96 AG *TRL6* CBA *[20].*

4.1 Identification of benefits

4.1.1 Validation targets

The Validation Targets expected from SESAR PJ10-W2-96 ASR according to PJ19 [14]

- **SAF:** Safety
- **FEFF1**: Fuel Efficiency.
- **CEF2:** ATCO productivity.
- **CEF3:** Technology cost.
- **HP:** Human Performance

SOL. CODE	SAF	FEFF1	TEFF1	CAP3	CAP1	CAP2	PRD1	PUN1	CEF2	CEF3	HP
PJ.10-W2-96 ASR	ISI	1	N/I	N/I	N/I	N/I	N/I	N/I	3	3	YES

Table 8: S96 Validation Targets

The Performance Expectations specified in S96 TVALP [12] are the following:

SESAR Solution ID	KPI	Performance Expectation
PJ.10-W2-96 ASR	SAF	No direct impact on safety, but HP improvements might be achieved with indirect impact on safety (e.g. workload, situational awareness and human error).
	FEFF1	Low impact in flight efficiency. Aircraft will be able to improve route efficiency due to higher throughput linked to ATCO productivity and human performance in TMA.
	CEF2	Increased Cost Efficiency optimization for ANSP due to technological Enablers that will increase the efficiency in ATC.
	CEF3	Impacted by the outcome of the CBA. No impact is expected to be measured by the exercises.
	HP	ASR will support the controllers in several different UC. It is anticipated that the system will maintain or improve situational awareness, reduce human error and improve job satisfaction. Workload is anticipated to be decreased supporting ATCOs to reach goals efficiently and effectively. Roles and responsibilities, team composition and communication remain unchanged. Operating procedures will be adapted to the new HMI.

Table 9: Solution 96 ASR Performance Expectations

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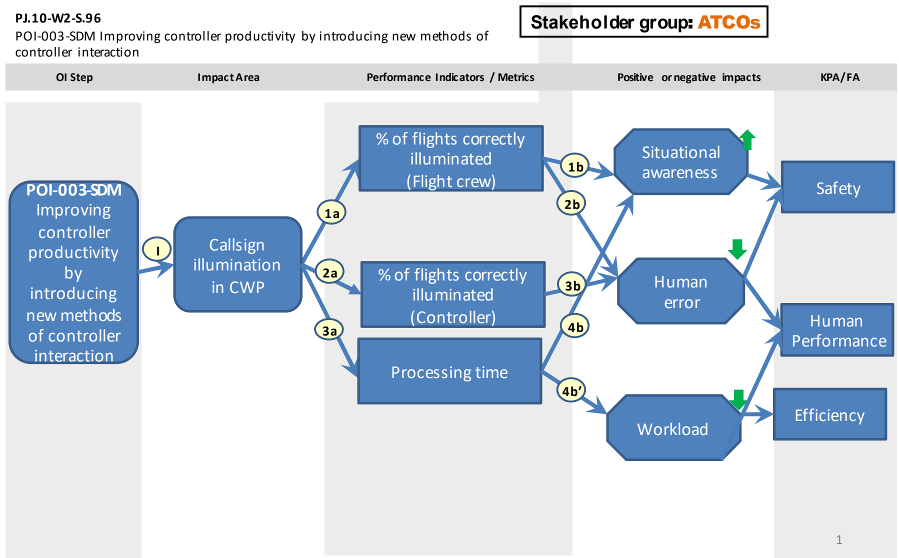
4.1.2 Benefit impact Mechanism

The Benefit and Impact Mechanisms (BIMs) for each operational improvement as described in S96 TVALP [12] are presented in Figure 2 below, following. Efficiency is identified as CEF2.



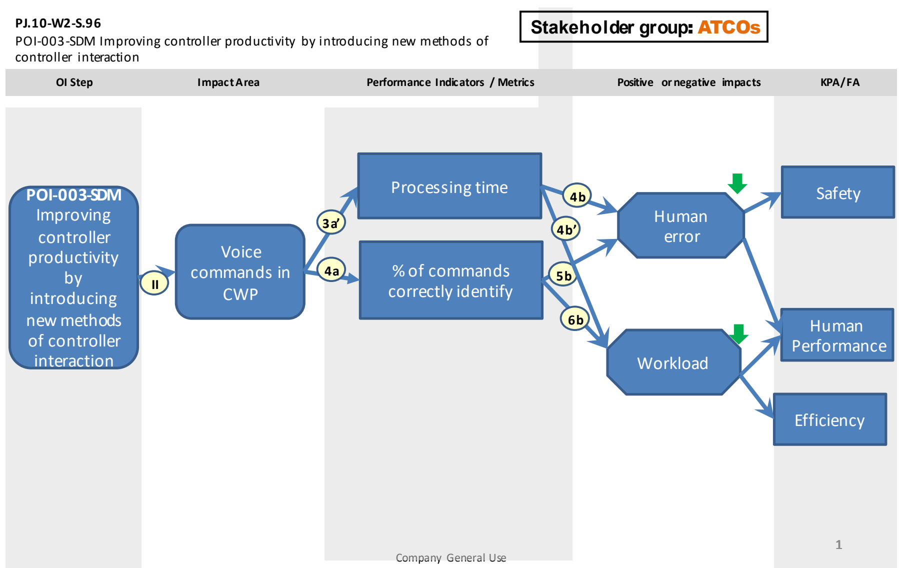


Figure 2: Benefits mechanism for POI-003-SDM

4.1.3 Performance metrics

Based on the benefits mechanisms presented in Figure 2, the following ***Cost efficiency*** performance metric was identified, representing the main expected measurable benefit deriving from the deployment of solution SESAR PJ.10-W2-96 ASR:

- ***CEF2 Flights per ATCO-Hour on duty***: As the result of the deployment of the Solution PJ.10-W2-96 ASR, an increase in the number of flights per ATCO hour may be observed. In the long-term this may potentially allow that a given number of ATCOs will be able to handle a substantially higher number of flights when , compared with the reference case. This improvement would lead to a reduction in ATCO employment costs for the provision of ANS services to a given number of flights.

4.1.4 Validation exercise and Performance assessment results

The final version of the Technological Validation Report [18] and initial Performance assessment report [17] provided evidence for the effectiveness of ASR deployment during the validation exercises performed. The documents however did not provide suitable quantitative data allowing the direct financial assessment of the benefits of ASR in terms of FEFF1, CEF3 or CEF2. There were no assessment results nor extrapolation of performance in the area of Cost efficiency. Thus an indirect approach has been adopted to measure the benefits through workload.

Therefore, the benefits obtained in Human Performance in terms of workload reduction results have been used. Table 10: S96 WL benefits per UC summarises the outcome regarding WL (in percentage) per exercise and addressed use case:

<table>
<tr><th>Use Case</th><th>Use Case Title</th><th>EXE-01</th><th>EXE-02</th><th>EXE-03</th><th>EXE-05</th></tr>
<tr><td>#3.1</td><td>Highlight of callsigns on the CWP from pilot utterances.</td><td></td><td></td><td rowspan="2">WL: -6%</td><td></td></tr>
<tr><td>#3.2</td><td>Highlight of callsigns on the CWP from controllers utterances.</td><td>WL acceptable</td><td></td><td></td></tr>
<tr><td>#3.3</td><td>Annotation of controllers commands.</td><td>-</td><td>-</td><td>N/A</td><td>-</td></tr>
<tr><td>#3.4</td><td>Pre-filling of commands in the CWP</td><td>WL acceptable</td><td>WL: -10%</td><td></td><td></td></tr>
<tr><td>#3.5</td><td>Voice commands for highlighting an upcoming sectorization change in the CWP</td><td>-</td><td>-</td><td>-</td><td rowspan="3">WL acceptable</td></tr>
<tr><td>#3.6</td><td>Voice commands for highlighting the fights that will be affected by an upcoming sectorization change in the CWP</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>#3.7</td><td>Voice commands for navigating the 3D visualization of the air space in the CWP</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>#3.8</td><td>Prefilling of Datalink commands</td><td>WL acceptable</td><td></td><td></td><td></td></tr>
</table>

Table 10: S96 WL benefits per UC

Taking into account these results:

- This CBA will not analyse the benefits from UCs 3, 5, 6, 7 and 8 as they cannot be monetised with current SESAR CBA model.

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The benefits on WL reduction from Using UC 1, 2 and 4 can be estimated as independent and will be added. **Providing a total workload reduction of 16% that is rounded to 15% if all the UC are implemented.** Although this approach could be considered initially as optimistic, it should be considered that there are other benefits as improved situational awareness that are not being monetarised.

Using the SESAR Performance Framework [7], this workload reduction was converted into a productivity gain with the following formula to calculate a corresponding potential productivity change:

$$\textbf{\textit{Increase in productivity}}\ (\%) = \left(\frac{\mathbf{1}}{\mathbf{1} - \frac{\mathbf{0.75} \times \textbf{\textit{workload reduction}}}{\mathbf{2}}} - \mathbf{1} \right) \times \mathbf{100}$$

Note that in the formula above the workload reduction is expressed as a decimal fraction (i.e. 10% = 0.1).

The calculated ATCO productivity increase per ACC is, Table 11:

Implementation scenario	Implemented UC	WL reduction	ATCO productivity increase
Scenario 1	Aggregated	15%	6%
Scenario 2	UC .1 and UC 2	6%	2%
Scenario 3	UC 4	10%	4%

Table 11: S96 CEF2 benefits per ACC and Implementation Scenario

4.1.5 Extrapolation to ECAC wide

From the aggregation assumptions for 2035 that appear in annex1 of the common assumptions document [9],the contribution total ENR traffic from the Sub-operating Environment affected by the operational concept are shown in Table 12.

ID	Sub-OE	Year	Value	Comment
ER-VHC-2035	Very High Complexity	2035	31.3	Contribution to total En-Route traffic from the specific sub-OE
ER-HC-2035	High Complexity ER	2035	27.98%	
ER-M-2035	Medium Complexity	2035	37.89%	
ER-L-2035	Low complexity	2035	2.80%	

Table 12: Values extrapolation at ECAC level

To extrapolate the benefits ECAC wide, next assumption apply:

- The WL reduction is the same in all the operating environments:

$$\Delta CEF2_{ECAC} = \Delta CEF2_{LOCAL} \cdot Traffic_{SubOE}$$

The increase in productivity measured by the validation activities is measured evenly in all the OE that sum the 100% of ECAC traffic and therefore, the increase in productivity at ECAC level per scenario is the same as presented in Table 11 **if the solution is deployed in all the ACC**.

- Intermediate scenario deployment: **half of the ACC** in each Operational Environment deploys the solution.

$$\Delta CEF2_{ECAC} = \Delta CEF2_{LOCAL} \cdot Traffic_{SubOE}/2$$

Implementation scenario	Implemented UC	ATCO productivity increase Half ACC
Scenario 1	All ASR UC	2.98%
Scenario 2	UC 1and UC 2	1.17%
Scenario 3	UC 4	1.95%

Table 13: S96 CEF2 benefits per ACC and Implementation Scenario

4.2 Calculation of solution benefits

In this CBA, the benefits in ***CEF2 Flights per ATCO-Hour on duty*** are quantified.

Performance Framework KPA[4]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit
Cost Efficiency	ANS Cost efficiency	**CEF2** Flights per ATCO-Hour on duty	Nb	ATCO employment Cost change	€/year

Table 14: Results of the benefits monetisation per KPA

The CEF2 aims to assess the impact of the introduction of the fade out algorithm on ATCO productivity in En-route and TMA airspaces.

ATCO productivity is monetised in the CBA through the number of flights that can be managed by the controller per hour on duty. When a Solution decreases controller workload[5] then additional flights

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

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

can be managed with the same number of controllers, all else remaining equal. Therefore, the forecast traffic growth can be handled with a smaller increase in controller numbers than if the Solution was not deployed.

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

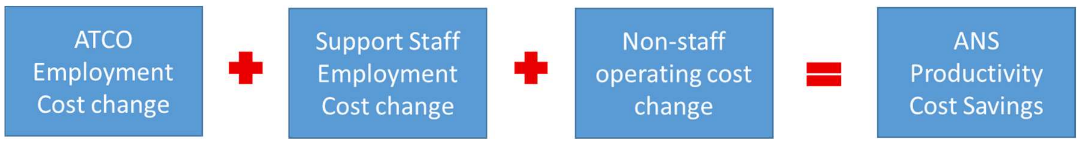

Figure 3: Monetisation mechanism for ATCO Productivity

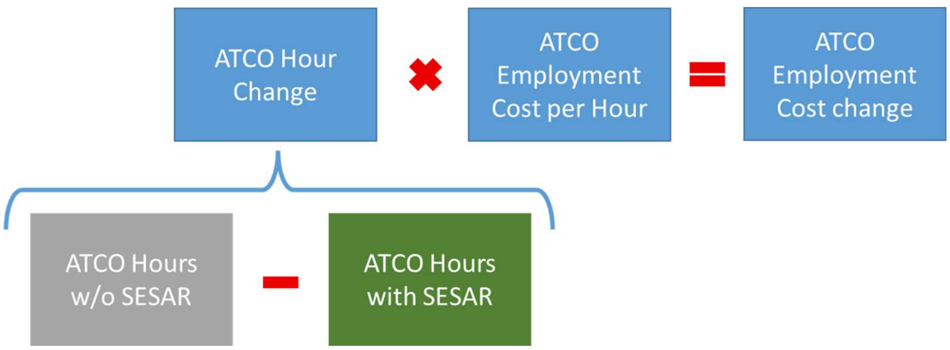

Figure 4: Monetisation mechanism for ATCO Employment Cost change

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

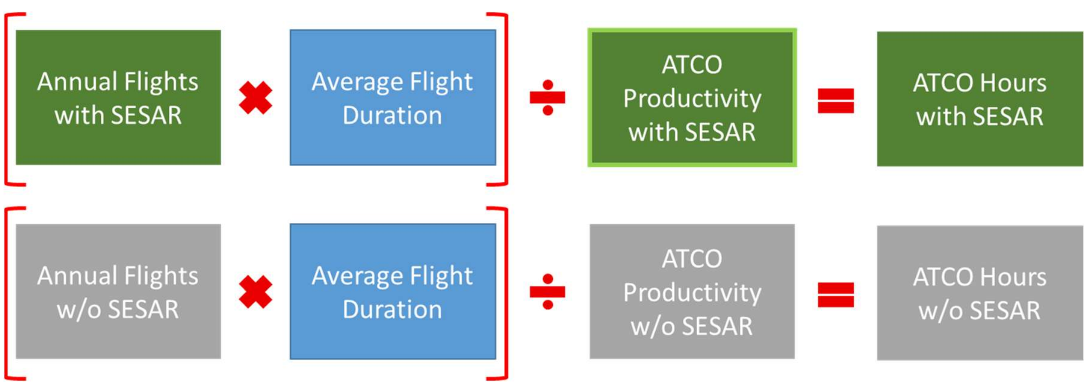

Figure 5: Monetisation mechanism for ATCO hours with and w/o SESAR

The (undiscounted) monetary value of ATCO Productivity (i.e., fewer additional controllers are needed to handle the increased traffic) is presented in Table 15[6].

Scenario	ANSP Benefits (Undiscounted M€)	Delta staff Operating costs		
		2030	2036	2043
Scenario 1: aggregated implementation of UC 1, 2 and 4	3140	45	255	290
Scenario 2: implementation of UC 1, 2	1250	15	100	115
Scenario 3: implementation of UC 4	2070	30	170	190

Table 15: Results of the benefits monetisation per CEFF2

[6] Note that the aggregated UC is not exactly the sum of the independent UC as the WL estimation was rounded. This approach aligns with the assumptions performed in the following sections where a rounded approach has been followed when possible.

5 Cost assessment

5.1 ANSPs costs

Given the nature of the Solution, the Stakeholders involved in the analysis of the costs considered for all UCs analysed in the Solution can be limited to ANSPs.

The CBA needs to consider the investment costs of acquiring the systems as well as the project management involved with installation, testing, transition periods, developing and documenting procedures, training costs, etc. (i.e. everything needed to get the system operational).

It is also necessary to assess the impact on Operating costs during the CBA timeframe. For example, what is the impact on maintenance costs or ongoing training – will they increase, decrease or remain stable.

5.1.1 ANSPs cost approach

Three costs groups have been considered during the CBA, following the recommendations in [3]:

1. *Pre-Implementation Costs*: all costs that need to be used up to define the needs, to develop solutions (R&D), to decide which solution best serves the needs. These are costs already incurred in the SESAR Development Phase and therefore not included in the cost assessment;
2. *Implementation costs*: are incurred during the implementation period. They include one-time implementation estimated costs, one-off implementation estimated costs and ground/space estimated costs that require capital replacement over time.
3. *Operating costs*: routine costs. Costs that will incur every year in order to assure the running and maintenance of the delegation procedures in addition to normal operation.

Cost Item	One-off or routine cost	Cost assessors
Installation/Commissioning	One-off	ANSPs
Certification	One-off	ANSPs
Initial Training	One-off	ANSPs
Project Management	One-off	ANSPs
Administrative estimated costs	One-off	ANSPs
Yearly Equipment maintenance	Operating cost	ANSPs
Controllers training	Operating cost	ANSPs
Licences	Operating cost	ANSPs
Project Management and administrative cost	Administration	ANSPs

Table 16: Overview of ANSPs cost items

Several possibilities and multiple architecture options exist that could support the implementation of the solution.

As presented previously Solution 96 ASR is applicable to all En-route and Approach/TMA environment complexity. Although traffic volume and associated workload may not be sufficiently high at low complexity airspace to need the ASR functions, other considerations such us having a common CWP and training for all their controllers may justify deployment.

5.1.2 ANSPs cost assumptions

A certain number of assumptions have been taken for the ANSPs estimated costs assessment:

- The **ANSP costs are extracted from the CBA of PJ.05-W2-S97 TRL 4 ASR**, [19] solution that analyses the cost of an ASR for Airports. Some costs have been estimated using stakeholder judgment.. It is assumed that both implementations will be similar in En-route/TMA and Airport. The text will indicate where a difference is introduced.
- ANSPs have electronic flight strips and datalink communication in the CWP already deployed or will deploy them independently of Sol 96 ASR. Thus, only the cost directly related to the update of the CWP due to speech recognition is computed.
- Implementation occurs in a 4-year transition period, where total estimated costs have been spread equally.
- No other pre-requisite or enabler is necessary to develop the solution.
- Investment is performed per ACC.
- There are no significant difference in the implementation in a TMA and an En-route Operational environment.

5.1.3 Number of investment instances (units)

The number of En route and/or TMAs ACCs in ECAC have been collected from SESAR PJ20 analysis of EN-route and Terminal Airspace OE, [21]. En-Route and TMA have been grouped together per complexity. Following the assumption only half of them in each category will implement ASR. Table 17 presents the instances where the implementation will take place.

En-route/TMA ACCs			
VH	H	M	L
4	6	17	8

Table 17: Number of investment instances – ANSPs

5.1.4 Cost per unit

An extrapolation from the ACC-based estimation done is needed to cover all ACCs present in ECAC where the Solution is going to be deployed. The results of such extrapolation are collected in Table 25.

Previously identified cost is now decomposed and calculated. Rather than a single figure, a range with probable values is used.

Implementing costs:

- Acquisition, installation, configuration, testing/certification and setting to work ASR **infrastructure equipment** comprising the hardware/software platform required for the ASR functionality and connection/integration to CWPs. It is assumed that:
  - implementation is per ACC;
  - All CWP in the ACC will have the ASR implemented

- the infrastructure architecture may be based on either physical servers associated with each CWP or centralised in a virtualised server environment7;
  - includes back up/failure provision; and
  - is compliant to any required technical standard.

- Acquisition, installation, configuration, testing/certification and setting to work of **ASR related functions** for the CWPs. This includes the set up and configuration of the AI/ML algorithms using locally recorded pilot/ATCO voice command exchanges.

In accordance with SESAR CBA guidance (STELLAR FAQ_CBA_v4_ (1_1)) the overall scales of costs are estimated rather than the individual aspects. The cost driver is:

__Cost of AI/ML ASR Tool__] + [__Cost of Licence for use of Tool__] (source: Stakeholder Judgement), where:

- **Cost of AI/ML ASR Tool** = Cost of infrastructure [acquisition + installation + configuration + testing and certification to applicable standards + operational deployment] and integration with existing CWP systems.
  Assumed to be the same for all OEs, **unlikely to be less than €350K, unlikely to be more than €700K with a median value of €500K** (source: S97 Stakeholder judgement)
  Cost of licence of use = Cost of licence for use of AI/ML functions for each CWP. Assumed to be valid for a period of 10 years.
- Assumed to be the same for all OEs, and is unlikely to be less than €80K, **unlikely to be more than €120K with a median value of €100K**. (source: S97 Stakeholder judgement)

Item	Unlikely <€K	Median €K	Unlikely >€K
	For all ACC OEs		
AI/ML ASR Tool	350	500	700
License for Use	80	100	120
Total	430	600	820

Table 18: ASR Tool Costs - Implementation

- **Training for controllers UC 3, 4 and 8 and aggregated scenarios**: Initial training is assumed to be a total of 5 days comprising 2 days for classroom/simulator training (a theoretical session of 2 hours for each day and the rest of the 5 hours with practical exercises) including a qualification test at the end of the training period and 3 days On-the-job training. (Source: S97 Stakeholder Judgement).

The cost is assumed to comprise three elements:

- the cost of a classroom/simulator training course to the ANSP (which may be provided by a third-party provider or could be "internal charging" to an in-house provider);

[7] For the purposes of this CBA, the range of costs presented for the AI/ML platform is considered to cover either architecture

- the cost of the ATCOs attending the classroom/simulator training (which could be regarded as the additional cost of employment for the additional training days or as the opportunity cost for the time they are not available for operational duty); and,
- the cost of On-the-job training ("internal charging" to an in-house provider) following ATCO attendance at the classroom/simulator course.

The cost driver is:

*[**Cost of Classroom/Simulator Course** * **# of courses**] + [**Cost of an ATCO attendance** * **# of ATCOs] + [Cost of OJT Training * # of ATCOs]*** where:

- ***Cost of Classroom/Simulator Course*** = [# of days in training course * cost of training day], where:
  - ✓ Number of days in training course is 2 (*source: Stakeholder Judgement*)
  - ✓ cost of training day, based on 3 trainers (supporting theory, simulation runs and ATCO guidance) + simulation facility + materials.
    - If externally provided it is unlikely to be less than €2K, median €6, unlikely to be more than €10K per day i.e., €4K, €12K and €20K for a 2-day course (*source: Stakeholder Judgement*)
    - If internally provided, assume based on cost recovery[8] of personnel providing the training i.e., Cost of ATCO (#ATCO Hours/Day (8) * ATCO Cost/Hour (€119[9]) * # of Trainers (3)) = €2.856 per day, total of €5.7K for a two-day course, however this does not include preparation of materials, simulators etc. and therefore is only a component of the course. (*Source: Stakeholder Judgement and CBA template, [15]*)
  - ✓ Therefore, Cost of training course is considered to be between €4K and €20K with a median value of €12K
- ***# Of Courses*** [10]= [# ATCOs / # of ATCOs at each training session], where:
  - ✓ # ATCOs is 265 for Very High/High complexity, 121 for Medium complexity and 50 for Low complexity (*source: Expert judgment + Annex 7 table 0.7 of EUROCONTROL (2019) - ATM Cost-Effectiveness (ACE), [22]*)
  - ✓ # of ATCOs at each training course is 12 (*source: Stakeholder Judgement*)
  - ✓ Therefore, # of Courses is 22 for Very High/High, 10 for Medium, 4 for Low.
- ***Cost of an ATCO attendance*** = [# ATCO training days * # ATCO Hours/Day * ATCO cost/hour], where:
  - ✓ # of ATCO training days is 2 (*source: Stakeholder Judgement*)
  - ✓ # of ATCO Hours/Day is 8 (*source: SESAR common assumptions*)
  - ✓ ATCO cost/hour is €119 (*source: CBA template[15]) for day is €952*
  - ✓ Therefore, Cost of an ATCO attendance is €1.904K

[8] The cost of the additional training tasks for ATCO dedicated training personnel or those removed from operational duties to provide training

[9] This cost has been extracted from the latest CBA template. It differs from the data in S97 CBA that estimates a 131€/h

[10] The number of ATCos per ACC and per course is different for S96 and S97

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- ***# of ATCOs*** = ATCOs is 265 for Very High/High complexity, 121 for Medium complexity and 50 for Low complexity.
- ***Cost of OJT Training***, assumed to be internally provided and therefore is cost recovery of personnel providing the training. i.e. Cost of ATCO (#ATCO Hours/Day (8) * ATCO Cost/Hour (€119) * # of Trainers (1)) = €952K/day (*source CBA template [15])*. For each trainer it is assumed that between 1 and 3 days per ATCO are required with a median of 2 day (*source: Stakeholder Judgement*).

Item	Unlikely <€K	Median €K	Unlikely >€K
Very High/High Complexity			
Cost of Training Course	90	264	440
Cost of ATCO Attendance	505	505	505
Cost of OJT	250	505	760
Total (VH/H)	840	1270	1700
Medium Complexity			
Cost of Training Course	40	120	200
Cost of ATCO Attendance	230	230	230
Cost of OJT	115	230	350
Total (M)	385	580	780
Low Complexity			
Cost of Training Course	16	50	80
Cost of ATCO Attendance	95	95	95
Cost of OJT	50	95	140
Total (L)	160	240	320

Table 19: ASR Training Costs (ATCO) – Implementation UC 3, 4 and 8 and aggregated scenarios

- ***Training for controllers UC 1, 2, 5, 6 and 7***: Initial training is assumed to be a total of 1 day comprising 1 day for classroom/simulator training (a theoretical session of 2 hours for each day and the rest of the 5 hours with practical exercises) including a qualification test at the end (*Source: Exercises feedback, [18]*).

  The cost driver is:

  *[**Cost of Classroom/Simulator Course** * **# of courses**] + [**Cost of an ATCO attendance** * **# of ATCOs**]* where

  - ***Cost of Classroom/Simulator Course*** = [# of days in training course * cost of training day]: Cost of one day training course in simulator is considered to be between €2K and €10K with a median value of €6K.

- ***# Of Courses*** = [# ATCOs / # of ATCOs at each training session], does not vary regarding the precious calculation: # of Courses is 22 for Very High/High, 10 for Medium, 4 for Low.
- ***Cost of an ATCO attendance*** = [# ATCO training days * # ATCO Hours/Day * ATCO cost/hour],
    - ✓ # of ATCO training days is 1 (*source: Exercises feedback, [18]*).
    - ✓ # of ATCO Hours/Day is 8 (*source: SESAR common assumptions, [15]*)
    - ✓ ATCO cost/hour is €119*, for day is €952/day* (*Source: Stakeholder CBA template, [15]*
    - ✓ Therefore, Cost of an ATCO attendance is €952/day
- ***# of ATCOs*** = ATCOs is 265 for Very High/High complexity, 121 for Medium complexity and 50 for Low complexity (*source: Expert judgment + Annex 7 table 0.7 of EUROCONTROL (2019) - ATM Cost-Effectiveness (ACE), [22]*).

Item	Unlikely <€K	Median €K	Unlikely >€K
Very High/High Complexity			
Cost of Training Course	45	130	220
Cost of ATCO Attendance	250	250	252
Total (VH/H)	300	385	472
Medium Complexity			
Cost of Training Course	20	60	100
Cost of ATCO Attendance	115	115	115
Total (M)	135	175	215
Low Complexity			
Cost of Training Course	8	24	40
Cost of ATCO Attendance	50	50	50
Total (L)	60	70	90

Table 20: ASR Training Costs (ATCO) – Implementation UC 1, 2, 5, 6 and 7

- **Project management**, update of local manuals and procedures, certification and validation and general **administration** in relation to the installation of ASR AI/ML functionality at Enroute/TMA centre.

.

With regards to certification[11] and validation aspects it is estimated, based on similar activities in the past, that this would be equivalent of 2 Administrative staff over a period of a week (i.e., a total of 10 working days). The cost driver is, therefore:

[Cost of Certification/Validation] = [Cost of Admin per day * # of days] * # of Admin Staff, where:

- ***Cost of Admin staff (2022)*** is €75839 per year (*source: CBA template [15]*)
  Each staff works 11 months with an average of 20 days per month (H2020 Personnel cost estimation [23]). Cost Admin staff per day is 344,7€
- # of days is 5
- # of Admin Staff is between 1 and 3 with mean of 2

The median cost of Certification/Validation is, therefore, is 3.4K.

It is not possible to provide a detailed breakdown of the remaining project management, documentation and general administration one-off costs due to relative immaturity of the Solution. A range of bundled values have been determined based on the experience of implementing similar technological advances (e.g., 30 days of operational staff time for PM and manuals/procedures updates). There is no difference due to complexity of the ACC. (*source: S97 Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very High/High/Medium /Low complexity			
Certification/Validation	2	3	5
PM, Documentation, Admin	75	100	150
Total	80	103	155

Table 21: ASR Certification/PM Costs - Implementation

In summary, the estimated One-Off costs for Solution 96 ASR are shown in the following table for ACC/TMA Environment Complexity Very High/High (VH/H), Medium (M) and Low (L).

Cost Item	Short description	Median Cost VH/H	Median Cost M	Median Cost L	Source
Training	All the training and staff costs related to the use of ASR UC 3, 4, 8 and aggregated	€1270K	€580K	€240K	Stakeholder judgement
	All the training and staff costs related to	€385K	€175K	€70K	

[11] Although the method to calculate the cost of certification/validation is the same as in S97. The outcome greatly differs due to the source used for the cost for admin staff

	the use of ASR UC 1, 2, 5, 6, 7				
Administrative costs	All the administrative costs related to the acquisition, installation, configuration and testing of ASR and associated functions	€100K	€100K	€100K	Stakeholder judgement, SESAR common assumptions and standard references
ASR AI/ML Installation, Commissioning and licence	Installation and configuration costs. Initial Test and evaluation	€600K	€600K	€600K	Stakeholder judgement
TOTAL	UC 3, 4, 8 and aggregated	***€1980K***	***€1285K***	***€940K***	
TOTAL	UC 1, 2, 5, 6, 7	***€1908K***	***€880K***	***€775K***	

Table 22: ASR Implementation Costs Summary

Operating costs:

- **Yearly equipment maintenance,** hardware equipment replacement Installation & Commissioning as needed.

Infrastructure replacement.

It is assumed that:

- the ASR Tool is subject to a five-year periodic one-off cost (@5% of original costs) to include provision of updates and patches etc. (*source: S97 Stakeholder judgement*)
- the License of Use is renewed every ten years @120% of original costs (*Source: S97 Stakeholder judgement*)

Item	Unlikely <€K	Median €K	Unlikely >€K
For all OEs			
ASR Tool	15	25	35
License renewal	100	120	145
Total	115	145	180

Table 23: ASR Infrastructure Costs - On-going

In summary, the estimated One-Off costs for Solution 96 ASR are shown in the following table for ACC/TMA Environment Complexity Very High/High (VH/H), Medium (M) and Low (L).

Cost Item	Short description	Median Cost VH/H	Median Cost M	Median Cost L	Source
ASR Tool update and patch costs	5-year replacement Installation and configuration costs.	€25K	€25K	€25K	Stakeholder judgement
ASR Use licence	10-year renewal of licence	€120K	€120K	€120K	Stakeholder judgement
TOTAL	***5-year ASR Tool***	***€25K***	***€25K***	***€25K***	
	10-year Licence	***€120K***	***€120K***	***€120K***	

Table 24: ASR Operating/On-going Costs Summary

5.1.5 Cost per unit

Cost category	ACC (En-Route and TMA)			
	Very High	High	Medium	Low
Deployment Option 1: UC 3, 4, 8 and aggregated				
Pre-Implementation Costs	N/A	N/A	N/A	N/A
Implementation costs	***€1980K***	***€1980K***	***€1290K***	***€940K***
Operating costs	€145K	€145K	€145K	€145K
Deployment Option 2: UC 1, 2, 5, 6, 7				
Pre-Implementation Costs	N/A	N/A	N/A	N/A
Implementation costs	***€1090K***	***€1090K***	***€880K***	***€775K***
Operating costs	€145K	€145K	€145K	€145K

Table 25: ASR Costs per unit Summary

As previously explained, each OE covers both En-route and TMA OE in the category.

5.1.6 Total Cost ECAC

Taking into account the number of units per category that will implement the solution, Table 17, and the costs per unit per operational environment detailed in Table 25. The total cost ECAC wide are presented in Table 26.

Scenario	Implementation costs	Operating costs
Scenario 1: aggregated	€243.0 M	€28.4 M
Scenario 2: UC 1 &2	€196.6 M	€28.4 M
Scenario 3: UC 4	€243.0 M	€28.4 M

Table 26: ECAC cost per scenario

5.2 Airport operators costs

In the BIMs, as defined in the Solution PJ.10-W2-S96 ASR TVALP [12]-, Airport operators have not been identified as required to invest this solution, so they do not have associated costs in this CBA.

5.3 Network Manager costs

In the BIMs, as defined in the Solution PJ.10-W2-S96 ASR TVALP [12]-, the Network Manager has not been identified as required to invest this solution, so they do not have associated costs in this CBA.

5.4 Airspace User costs

In the BIMs, as defined in the Solution PJ.10-W2-S96 ASR TVALP [12]-, Airspace users have not been identified as required to invest this solution, so they do not have associated costs in this CBA.

5.5 Military costs

In the BIMs, as defined in the Solution PJ.10-W2-S96 ASR TVALP [12]-, Military have not been identified as required to invest this solution, so they do not have associated costs in this CBA.

5.6 Other relevant stakeholders

In the BIMs, as defined in the Solution PJ.10-W2-S96 ASR TVALP [12]-, No other stakeholders have been identified as required to invest this solution, so they do not have associated costs in this CBA.

6 CBA Model

PJ.10-W2-96
SESAR2020 Cost Bene

6.1 Data sources

Cost Inputs

The sources for the Solution PJ.10-W2-S96 ASR costs has been obtained from partners within the Solution and information available in the CBAs from PJ.05-W2-97 TRL4 [19] ASR part, and PJ.10-W2-S96 AG TRL 6 [20].

Benefit Inputs

The source for the benefit calculation inputs are the initial Performance Assessment Results from Solution PJ.10-W2-S96 ASR [17] and TVALR [18].

Other Input Parameters

The data sources for the non-Solution specific CBA Model parameters are referenced in the various input's sheets of the CBA Model with details provided in the sheet 'Source of Reference'. These are all part of the Common Assumptions [9]. Additionally, the rest of parameters have been obtained from CBA reference documentation.

7 CBA Results

SESAR Solution PJ.10-W2-96 ASR provides a new human machine interaction mode for the controller based on speech recognition. Several possible use cases have been identified in the solution, and this CBA aims to provide a quantified value of the possible benefits.

The beneficiaries of the solution are the ANSP that benefit from the improvement in Controller efficiency. They are also the only stakeholder that need to invest in the solution.

The model has used a discount rate of 8%. The discount rate used to calculate the Net Present Value (NPV) can be interpreted as the interest on invested money (from a project or a savings account) or as the interest charged on borrowing money (to fund an investment).

Three different scenarios have been evaluated in the present CBA. A summary of the outcome is presented in Table 27.

The NPV is for the timeframe of the CBA 2002 to 2043.

Scenario	NPV (€M's)	Breakeven Year
Scenario 1: aggregated implementation of UC1, 2 and 4	690	2032
Scenario 2: implementation of UC1 and 2	179	2035
Scenario 3: implementation of UC4	380	2033

Table 27: ECAC CBA Model outcome for Sol 96

The following graphs present a summary of the cash flow for each scenario in terms of costs, benefits and the cumulative net benefits.

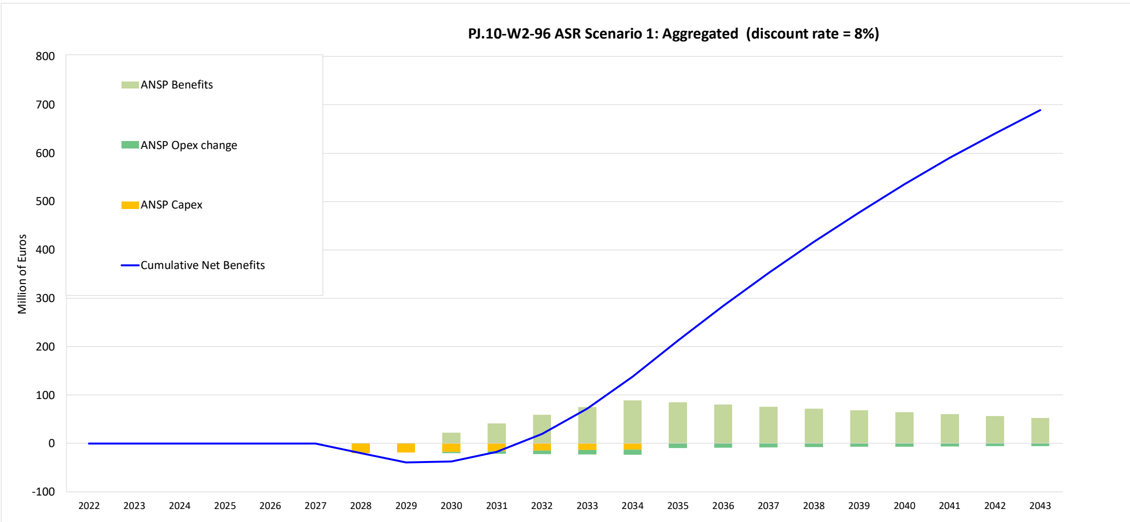

Figure 6: Sol 96. Scenario 1 ECAC-wide Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), the solution that combines all the UC shows a positive NPV (€690M), and that breakeven is achieved in 2032, i.e. 2 years following IOC. In other words, the expected benefit gain through CEF2 cost savings easily covers the costs of deploying and operating ASR across the ECAC region over the period of the CBAT.

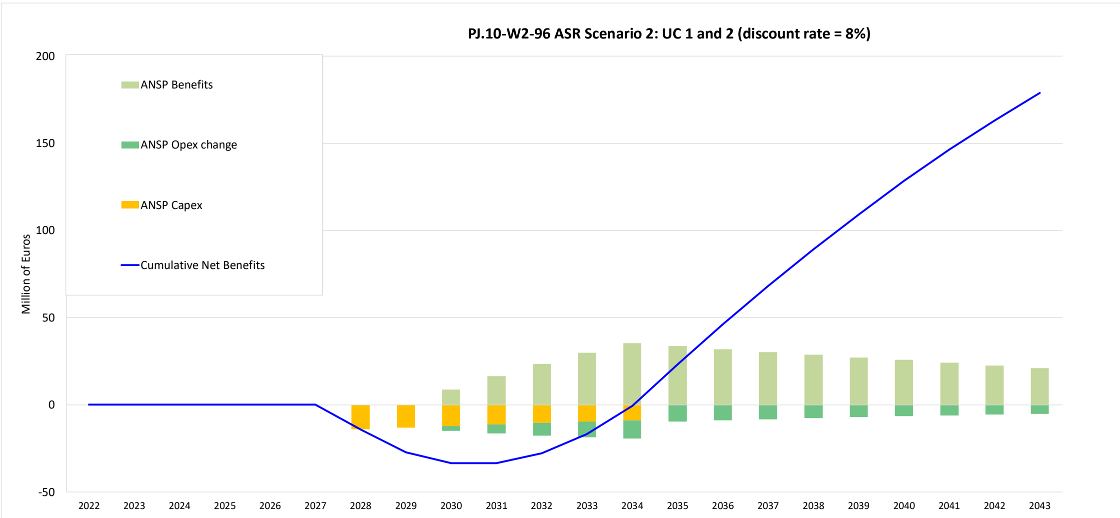

Figure 7: Sol 96. Scenario 2 ECAC-wide Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), the solution that combines UC 1 and UC 2, identification of callsigns from FC and ATCo utterances, shows a positive NPV (€180M), and that breakeven is achieved in 2035, i.e. one years after FOC In other words, the expected benefit gain through CEF2 cost savings easily covers the costs of deploying and operating ASR across the ECAC region over the period of the CBAT.

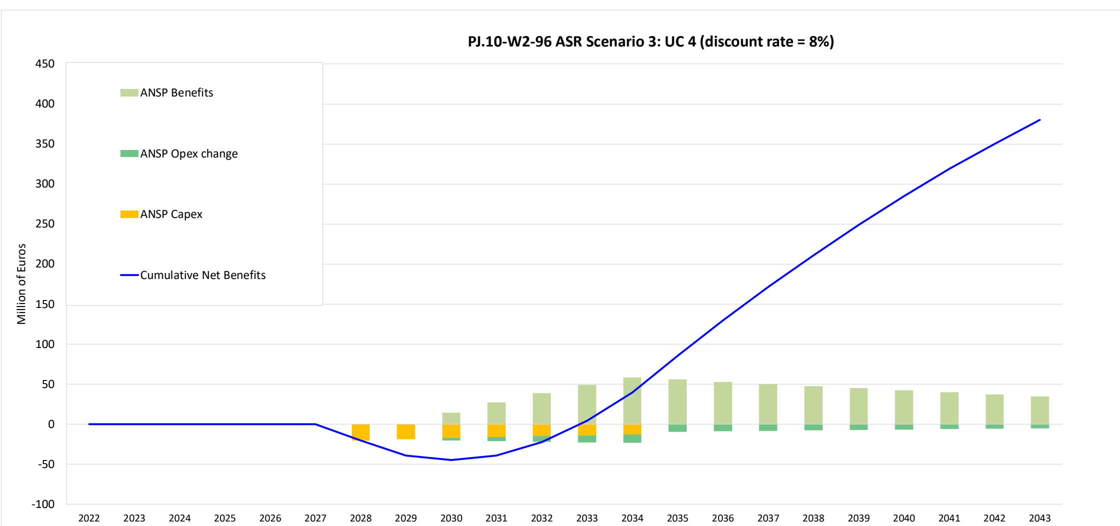

Figure 8: Sol 96. Scenario 3 ECAC-wide Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), the solution that implements UC 4, prefilling of radar labels, shows a positive NPV (€380M), and that breakeven is achieved in 2033, i.e. 3

years after IOC. In other words, the expected benefit gain through CEF2 cost savings easily covers the costs of deploying and operating ASR across the ECAC region over the period of the CBAT.

8 Sensitivity analysis

Sensitivity analysis is a systematic method for examining how the outcome of benefit-cost analysis This section details the sensitivity analysis performed for Solution PJ.10-W2-96 ASR. The analysis aims to determine the impact that variations in costs, benefits or the discount rate would have on the CBA results. The scenarios explored are the following:

1) Sensitivity to Benefits' reduction/ increase
2) Sensitivity to Costs' increase
3) Sensitivity to Deployment Start and Initial operational Capability dates
4) Sensitivity to discount rate reduction

Sensitivity to Benefits' reduction /increase

This subsection contains an analysis of the impact that a reduction in benefits expected has in the overall CBA results. This study seeks to illustrate a possible scenario in which benefits are not as high as anticipated (for whatever reason) and results are impacted somehow. In this case, a reduction of benefits to the half is considered.

It also analysed the outcome if the benefits increase in a 50%. Taking into account that some of the ASR UC studied in the solution have not been able to be monetised in this CBA, the increase of benefits it is not an unlikely scenario, the operating cost would not vary, and the ground cost would increase but not significantly.

Table 28 gathers the impact that this reduction would have in the NPV. The NPV is significantly reduced by between 65% and 100%%. Where the margin in the baseline scenario is large, the NPV remains positive, in the worst case, there is no NPV benefit.

An increase in the benefits impacts equally the outcomes, and an increment in the benefits, which according to the TVALR it is a likely scenario if prototypes are improved and thoroughly training is provided, will equally impact the benefits between a 65 and a 100%.

Scenario	Sensitivity Scenario	Benefits	NPV (M€)	Change
Scenario 1	Baseline	CEF2: +3.21%	690	-
	Benefits reduced by 50%	CEF2: +1.60%	240	**-65%**
	Benefits increased by 50%	CEF2: +6.43%	1130	**+64%**
Scenario 2	Baseline	CEF2: +1.17%	180	**-**
	Benefits reduced by 50%	CEF2: +0.59%	0	**-100%**
	Benefits increased by 50%	CEF2: +2.36%	360	**99%**
Scenario 3	Baseline	CEF2: +1.95%	380	**-**
	Benefits reduced by 50%	CEF2: +0.97%	85	**-78%**
	Benefits increased by 50%	CEF2: +3.90%	960	**+77%**

Table 28: Impact of benefit change on NPV

A tornado diagram is not included as there is only one benefit.

Sensitivity to Costs' increase

This subsection contains the analysis of how the doubling of costs would impact the overall NPV. It tries to reflect a possible situation where costs are exceeded and cause a negative impact on the results.

Table 29 gathers the impact that this reduction would have in the NPV. The NPV is impacted but not as much as if benefits are decreased. As presented in the table all the scenarios remain with a positive NPV. With a reduction of benefits between 22 and 59%.

In the scenarios with high Ground costs, CAPEX, the influence of doubling of the cost is greater than an increase in the operational costs, OPEX.

The outcome of both analyses performed if necessary, ensuring higher benefits can justify higher costs.

Scenario	Sensitivity Scenario	Cost (M€)	NPV (M€)	Change
Scenario 1	Baseline Capex	243	690	-
	Ground Capex increased by 100%	486	520	**-25%**
	Baseline Opex	28	690	**-**
	Ground Opex increased by 100%	57	540	**-22%**
Scenario 2	Baseline Capex	180	180	**-**
	Ground Capex increased by 100%		100	**-47%**
	Baseline Opex	28	180	
	Ground Opex increased by 100%	57	70	**-59%**
Scenario 3	Baseline Capex	243	380	**-**
	Ground Capex increased by 100%	486	210	**-45%**
	Baseline Opex	28	380	
	Ground Opex increased by 100%	57	230	**-40%**

Table 29: Impact of costs on NPV

Sensitivity to 1 Deployment Start and Initial operational Capability dates

As previously presented, S97 CBA considered that benefits can start as soon as the ASR technology is deployed in the ACC which is in line with expert feedback. This section analyses one scenario where the scenario 3 has the same IOC and Deployment date, 2030. All the other parameters remain unchanged.

Table 30 presents the comparison of both scenarios. The NPV presents a 10% difference, and the benefits starts two years earlier.

Scenario	NPV (€M's)	Breakeven Year
Baseline Scenario 3: implementation of UC 4. SOD 2028	380	2033
Scenario 4: implementation of UC4. SOD 2030	420	2031

Table 30: ECAC CBA Model outcome for SOD sensitivity analysis

The figure below presents the discounted Cash flow for the new scenario.

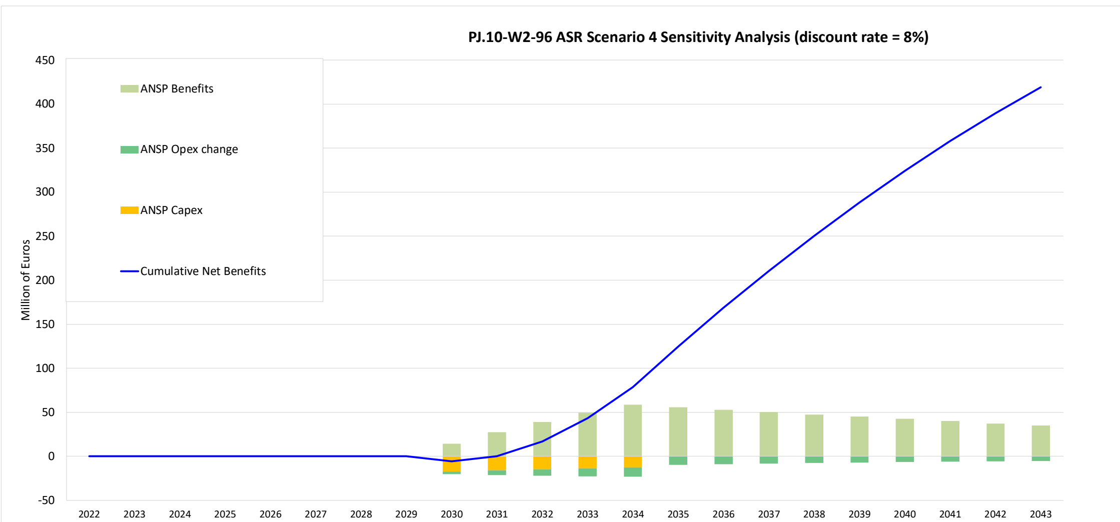

Figure 9: Sol 96. Scenario 4 ECAC-wide Discounted Cash Flow

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The sensitivity analyses indicate that the influence of benefits variation on NPV is lower if there are benefits since the SOD. The influence of costs is also lower in scenario 4, and the influence of operating cost is higher than the deployment cost.

The outcome of this sensitivity analyses is a recommendation to provide training to controllers as soon as possible to be able to gather more benefits and decrease the influence of unwanted factors

Scenario	Sensitivity Scenario	Benefits	NPV (M€)	Change
Scenario 3	Baseline	CEF2: +1.95%	380	-
	Benefits reduced by 50%	CEF2: +0.97%	90	**-78%**
	Benefits increased by 50%	CEF2: +3.90%	960	**+77%**

Scenario 4	Baseline	CEF2: +1.95%	420	-
	Benefits reduced by 50%	CEF2: +0.97%	130	**-70%**
	Benefits increased by 50%	CEF2: +3.90%	710	**+70%**

Table 31: Impact of benefits on NPV in scenarios 3 and 4

Scenario	Sensitivity Scenario	Cost (M€)	NPV (M€)	Change
Scenario 3	Baseline Capex	243	380	-
	Ground Capex increased by 100%	486	209	**-45%**
	Baseline Opex	28	380	
	Ground Opex increased by 100%	57	230	**-40%**
Scenario 4	Baseline Capex	243	240	-
	Ground Capex increased by 100%	486	310	**-27%**
	Baseline Opex	28	240	
	Ground Opex increased by 100%	57	270	**-36%**

Table 32: Impact of costs on NPV in scenarios 3 and 4

Sensitivity to discount rate reduction

The discount rate is used to determine the present value of future cash flows, so reducing the discount rate reduces the difference between the value of money today and its value in the future.

Next figures show that **using a lower discount rate increases the NPV** in all the scenarios.

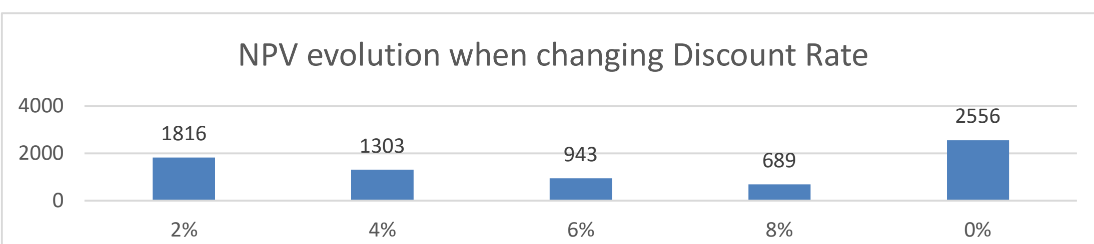

Figure 10: Impact of discount rate on NPV on Scenario 1

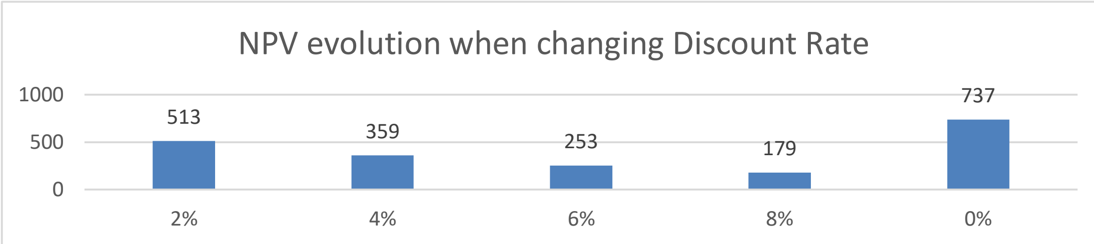

Figure 11: Impact of discount rate on NPV on Scenario 2

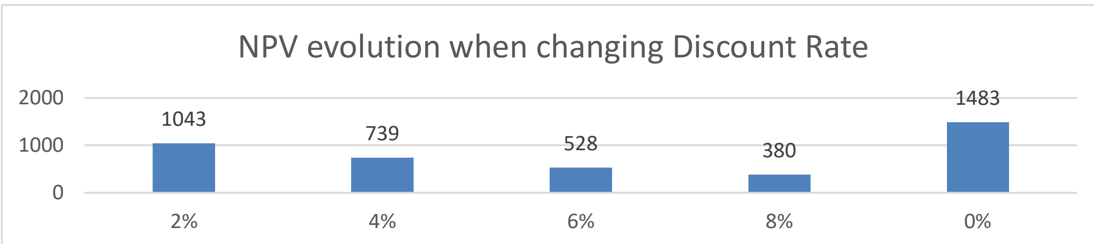

Figure 12: Impact of discount rate on NPV on Scenario 3

9 Recommendations and next steps

The CBA presented has been based on the outcomes of the exercises performed within the solution. Sol96 ASR exercises were performed in medium complexity En-Route and TMA operational environments but the CBA has assumed that the benefits can be directly extrapolated to the high and low complexity. Future research could be focused on confirming this assumption.

The exercises addressed different UC and the numeric outcomes have been very variable between them, depending on the Use Case addressed and the maturity of the prototype. The variation ranges from workload slightly increased but still within acceptable limits to workload improved in 6%. Further investigation to collect data is highly recommended.

The CBA sensitivity analysis indicates that the outcome is highly dependent on the benefits. An increase in the benefits which, according to the TVALR it is a likely scenario if prototypes are improved and thoroughly training is provided to controllers, will greatly impact the NPV.

The analysis has assumed a deployment scenario were only half of the ACC implement the solution. Taking into account the sensitivity analysis on benefits and cost, having more ACCs implementing the solution will positively improve the NPV. One possible CBA analysis not currently performed, is developing and scenario where it is assumed that when an ANSP deploys the solution, it is deployed in all its ACC.

One exercise measured the possible improvement in Fuel efficiency. Aircraft may be able to improve route efficiency due to higher throughput in TMA linked to ATCO productivity and human performance. The outcome was not conclusive. Further investigation is needed to confirm the positive or no impact of the ASR technology. A possible benefit should be included in the CBA increasing the cost.

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[12];

[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] S2020 D4.0.30 – PJ.19 CI Common assumptions; ed 01.00.00, September 2019

[10] European ATM Master Plan Portal https://www.atmmasterplan.eu/ ; Data set 23

[11] PJ19.04: Performance Framework (2019

[12]SESAR 2020 – D4.1.035-PJ.10-W2 Sol.96 ASR intermediate TVALP - Part I, ed 00.01.00. Nov 2020

[13]SESAR 2020 - PJ.10-W2-96 ASR-TRL6 Intermediate TS/IRS, ed 00.02.00, May 2021

[14] SESAR 2020 D4.0.1 PJ19-W2: Validation Targets - SESAR2020 Wave 2 & Wave 3, ed 00.01.00 May 2021

[15]SESAR Cost Benefit Analysis Single Solution (Wave 2) ed s7.3.1. October 2021

[16] PJ.19 - En-route & Terminal Airspace Operational Environments (April 2019)

[17] PAR_PJ10-W2.SOL.96 ASR PAR_00.00.04

[18] SESAR D4.1.095-PJ.10-W2-96 ASR-TRL6 TVALR. Ed 00.01.00 .Feb 2023

[19] SESAR D3.1.071 PJ.05-W2-97 TLR4 CBA Ed 10.00.01. 28 Oct 2022

[20] SESAR D4.2.80 -PJ10-W2-96 AG TLR6 Final CBAT Ed 00.01.00. 19 Dec 2022

[21] SESAR 2020 PJ20 En-route & Terminal Airspace OEs_April 2019 Version

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

[22]*EUROCONTROL (2019) - ATM Cost-Effectiveness (ACE)*

[23]https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home

11 Appendix

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

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

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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 CO_2 emissions			(FEFF2)	CO_2 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 33: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs

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