INDUSTRIAL RESEARCH

SESAR SOLUTION PJ06.01: COST BENEFIT ANALYSIS (CBA) FOR V3

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Copyright Statement

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SESAR SOLUTION PJ06.01: COST BENEFIT ANALYSIS (CBA) FOR V3

This Cost Benefit Analysis report is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 734129 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document provides the Cost Benefit Analysis (CBA) at V3 level for **SESAR Project PJ06.-01 - Optimized traffic management to enable Free Routing in high complexity environments**.

This document was developed to identify and agree the main elements and assumptions that have been used in the development of the CBA Model; identify impacted stakeholders groups and propose countries and ANSPs for the deployment scenario approach with options in term of Operational Improvements (OIs) and Enablers (ENs) implementation; Provide a mechanism of the potential estimated costs of the Solution for Air Navigation Service Providers (ANSPs); Provide a description, assessment and monetisation of the benefits per different impacted KPA.

Benefits are based on a data driven approach. Validation results provided evidence on the flight efficiency benefit but were not sufficient to quantify and extrapolate benefits among ACCs or ANSPs, due to the validation technique (RTS) which is limited to local environment. Hence, it was decided to build the model based on analysis of historical data. The performance indicators used are KEA and KEP, the key performance indicators measuring the level of horizontal En-route flight inefficiency in actually flown trajectories and filed flight plans respectively over a period of 12 months. Other sources of data used are the Network Manager Fast Time Simulations developed in previous maturity level validation exercises (and extrapolation coming from PJ.06-01 V3 PAR.

Estimated costs have been derived using a bottom-up approach starting from inputs at Enabler Level (provided by partner ANSPs) and going to the extrapolation using earmarked FDPs investments declared by ANSPs in ACE Report.

Therefore, the CBA calculations and the NPV (2040) of 797 M€ results are consolidated in this CBA V3 covering the timeframe 2019-2040. They provide a realistic approach to the real benefits of implementing PJ.06-01 Solution at the identified ACCs.

Table of Contents

List of Tables

List of Figures

1 Executive Summary

This report[1] contains the Cost Benefit Analysis (CBA) of **SESAR Project PJ06.-01 - Optimized traffic management to enable Free Routing in high and very high complexity environments** for the V3 Phase.

The PJ.06-01 Solution builds on work initiated in SESAR 1 with Solution#32 and #33 which is about to be partially implemented through the PCP Implementing Regulation (EU) No 716/2014. However, PJ.06-01 scope is more limited than Free Route as defined in PCP since partially addresses AOM-0505 and is limited to high and very high complexity environments. In addition and in parallel, there is PJ.06-02 solution that targets improved management of Free Route in Lower airspace. The Solution aims to:

- Optimize traffic management to enable Free Routing in high complexity environments
- Provide a description of high complexity cross-border Free Routing environment in upper airspace (at the 31/12/2026 timeframe as per PCP AF#3)
- Improve Aircraft-to-Aircraft Separation Provision and Air Traffic Flow / Complexity Management (in the frame of Integrated Network Management) to enable Free Routing operations in upper airspace in high complexity cross-border environments (with minimum structural limits to manage airspace and demand complexity)
- Enable airspace users to plan flight trajectories without reference to a fixed route network or published directs within high and very high-complexity environments so they can optimise their associated flights in line with their individual operator business needs or military requirements.

From a benefit modelling point of view, PJ.06-01 and PJ.06-02 could be seen as a single project since free route is expected to be in all ECAC and in all environments. Hence, CBA approach and model are common to both solutions and coordination has been ensured through frequent contact and discussion with PJ.06-02 members and task leaders. This CBA team and authors are also in charge of producing PJ.06-02 V2 CBA.

Benefits have been assessed based mainly on a data driven approach through the use of KEA and KEP actual and future values (so-called targets) supported by results from both PJ.06-01 Validation Exercises and performance assessment of the solution. The estimated costs (capital expenditures and in operating estimated costs) have been assessed through the contact with Air Navigation Service Providers and earmarked investments from ACE Report. They provide a consolidated approach to the estimated costs and benefits of the PJ.06-01 Solution.

All consolidated benefits have been quantified in the V3 CBA, and the results show that the PJ.06-01 Solution would bring significant benefits to the Airspace Users and great improvement of the network

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

performance. Some potential benefits such as the vertical flight efficiency have not been monetized because no evidences could be gathered that would justify so.

With a limited amount of estimated costs required, 846 M€ (undiscounted) spread over the period 2025 – 2028 and 2030-2033, the solution could expect to obtain a rapid return on investment. The overall benefits (3,869 M€ undiscounted) are significantly higher than the overall estimated costs and at the end of the time horizon the overall net savings are 395 M€ undiscounted and 79 M€ discounted at 8% (yearly saving in 2040). The breakeven point is obtained at the 2030 for the base scenario.

When looking at the overall results of the PJ.06-01 CBA, the NPV is positive with a gain estimated at 797 M€ (with an 8% discount rate). This result is supported by flight efficiency benefits evidenced in Validation Exercises and Fast Time Simulations performed by the Network Manager (further explained in 3.5.1.1). In addition, expert judgement also defined how to estimate extrapolation ECAC wide in 2035 and CBA results result to be aligned but always more conservative than high-level approach.

Nevertheless when looking at the PJ.06-01 FOC i.e. in 2036, the CBA shows that the annual benefits (379 M€ undiscounted) are a lot higher than the additional operating estimated costs generated by the Basic and Advanced Solutions (24 M€ in 31/12/2035). The Solution provides an annual net savings of +354 M€ undiscounted. It is expected that those annual net savings would be even higher with all potential benefits estimated.

As a conclusion of this economic study, it can be confirmed that the implementation of PJ.06-01 will obtain a positive overall NPV meaning the project is feasible in economic terms. Moreover, those results and the short-term payback period (5 years after IOC) decrease the risk level of the PJ.06-01 for potential investors.

It is important to note that this CBA has only taken the consideration that PJ.06-02 is deployed in parallel, but does not consider influence of other SESAR2020 solutions. This is done in the PAGAR report at program level, where relationships between solutions are assessed.

Recommendations for the interpretation of the CBA results are provided in section 9 of this report.

2 Introduction

2.1 Purpose of the document

This document provides the Cost Benefit Analysis (CBA) for **SESAR Project PJ.06-01 - Optimized traffic management to enable Free Routing in high and very high complexity environments** for the V3 level.

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

This CBA has been developed to identify and agree on:

- The deployment scenario approach for the Solution;
- The assumptions related to the Solution and Reference Scenarios;
- The stakeholders impacted by the Solution, i.e. those who will support the deployment and operating estimated costs and those who will benefit from the Solution;
- The cost elements to be assessed for each stakeholders' group considering the operating environments where the Solution is expected to provide benefits, as defined in the deployment scenario approach and in the SESAR Solution PJ.06-01 SPR-INTEROP/OSED for V3 final document [20];
- The mechanisms to quantify the benefits, based on the BIMs (Benefit and Impact Mechanisms) developed in the OSED task and presented in the Annex 1 of the SESAR Solution PJ.06-01 SPR-INTEROP/OSED for V3 final document [20].

This V3 CBA provides a consolidated evaluation of the overall estimated costs at Solution level and per affected stakeholder. At this stage, estimated costs for ANSPs and benefits for Airspace Users have been quantified and monetised in the CBA. This has been done based on the gathering of inputs from project partners and their correspondent extrapolation to estimate the impact on the rest of EU stakeholders, thanks to ad-hoc developed models. The overall results have been thoroughly reviewed internally and externally to PJ.06 (involving SDM, Airspace Users, SESAR CBA CoP) and we are confident they provide the most faithful estimation on the potential estimated costs and benefits of the Solution, based on the available data as of the day of writing this report.

The results of the CBA have been partially confirmed by the results captured during validation exercises in this phase and by PAR extrapolation ECAC wide using expert judgement assumptions.

2.2 Scope

In accordance with the OSED, the scope of the PJ.06-01 CBA includes all the benefits generated by the OI Step AOM-0505 according to two evolutionary scenarios for implementation of its associated enabler:

- Basic Solution (with IOC in 31/12/2026) including enablers:

  - ER ATC 78
  - ER ATC 129 (baseline MTCD)
  - ER ATC 91
- Advanced Solution (with IOC 31/12/2035) including enablers:
  - ER ATC 157
  - ER ATC 157b (latest Enabler 31/12/2035)
  - PRO-046b

The operating environments considered for deployment of both versions of the solutions are exclusively High and Very High Complexity Airspaces, extended to Cross-border implementations.

The Dataset 20 Draft | EATMA V13.0 Draft | MP L3 Plan 2019 [13] was used as a Reference, but the IOC/FOC dates seem to be unrealistic (too late) taking into account the nature of the solution and current deployment status. Based on agreement with partners, it was decided to align them with the most recent EATMA database.

Consequently, we have not taken into account the initial deployment of FRA, following the EU provision of implementing FRA above FL310 in the ICAO EUR region as of 1 January 2022, mandated under AF#3 by PCP Regulation 716/2014. An advanced continuation of the implementation is reflected in the analysis through the implementation of a PJ06.01 “Basic Solution”, which has been considered compliant with the mandate, therefore its corresponding estimated costs and benefits could be at least partially attributable to PCP provisions for FRA in HC and VHC Airspaces in Europe. However, since in the CBA investments are made later in time, they are independent of PCP activity.

The benefits in terms of KEP and KEA reduction observed with initial deployments of DCT and FRA across Europe since 2014 (e.g. in Hungary, Italy, Austria, etc.), have been fully reflected in the model and extrapolated to other ACCs based on their complexity and estimated future evolution. The author recommends to refer to PJ19.04-D4.4 Performance Framework (2018) section “A.4.4 SES Performance Scheme for Environment” within Environment KPA if the reader is not familiar with this metrics.

Figure 1 below qualitatively presents the projected evolution of benefits (measured though KEP and KEA indicators as further explained in section 3.5.1.1) based on a stepped approach for implementation of FRA. The basic Solution has been considered sufficient to implement FRA in HC and VHC mostly at ACC level, while the advanced Solution allows its cross-border extension.

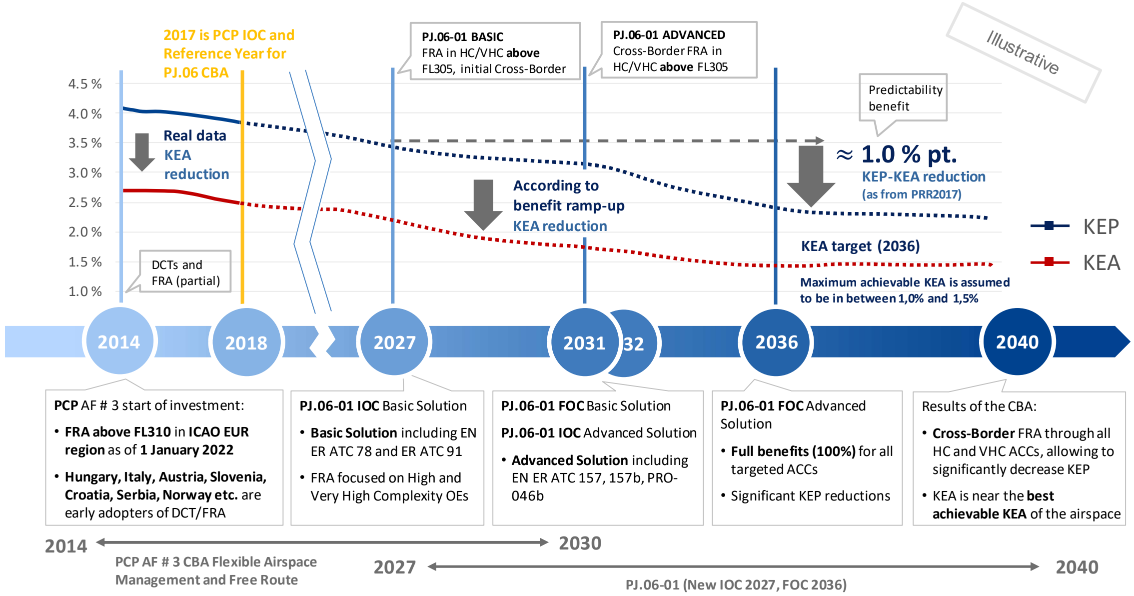


Figure 1 ***PJ.06.01 CBA builds upon the current FRA as implemented under PCP and projects KEA and KEP values based on expected benefits***

Benefits and estimated costs that could result from interdependencies with other S2020 Solutions (different from PJ.06-01) are not considered in this analysis, which is an aspect tackled by SESAR2020 PJ.19-4 in the frame of Performance Assessment consolidation and Gap Analysis. Therefore the CBA provides the estimated costs and benefits of the PJ.06-01 Solution in a consolidated manner considering the deployment (benefits) of PJ.06-01 solution.

2.2.1 Identification of stakeholders

CBA results are presented at the aggregated overall level and individually from the viewpoint of the impacted stakeholder groups, i.e. the stakeholders that will have to invest and will mainly benefit from the Solution:

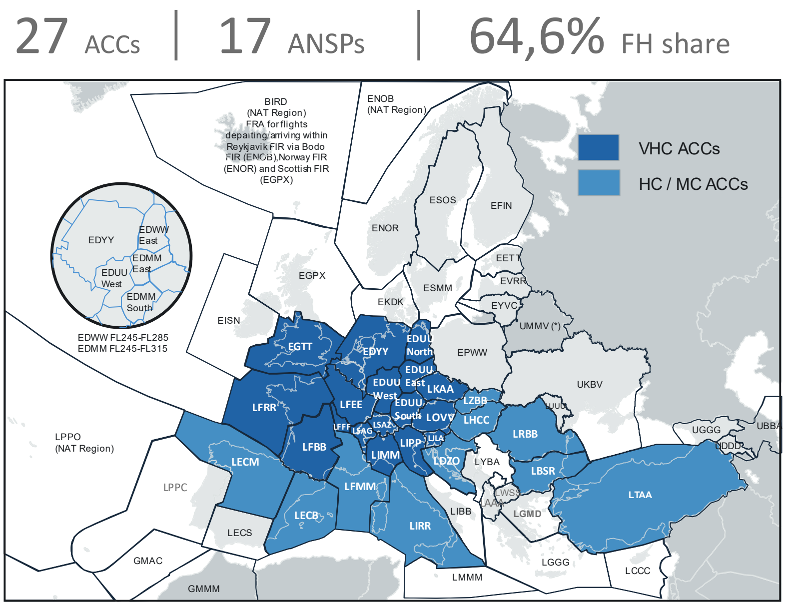
- ANSPs, in particular the ones providing ATC services in High and Very High Complexity ACCs within ECAC area, or specifically targeted Medium Complexity ACCs that are close to High Complexity, or are key for high volume of traffic crossing them.
- Airspace Users, Commercial Air Traffic operating under IFR in High and Very High Complexity ACCs within ECAC area, or specifically targeted Medium Complexity ACCs that are close to High Complexity, or are key for high volume of traffic crossing them.

2.2.2 Geographical scope

The SESAR 1 Direct Routing (part of Free Route concept) concept was generic and applicable to all levels of complexity ACCs in ECAC. On the other hand, Free routing (i.e. where not all DCT are published) was only researched to medium complexity. That’s why PJ.06-01 filled the gap in En-Route an in high and very high complexity, seeking for V3 maturity level. PJ.06-01 project addresses to optimize Free Routing in high and very high complexity airspace above FL305, from a very congested ACC to less congested but with more interacting flights, according to the definition of complexity for ER Operating Environments adopted in SESAR [29].

High and very high complexity ACCs are the ones with values of traffic complexity above 6. The CBA includes additionally some ACCs that are currently medium complexity (2017) but can potentially become high complexity airspace in the coming years mainly due to traffic growth and complexity of new traffic flows. They have been included because the complexity forecast and OEs classification list extracted from [29] is conservative and is more realistic to consider that for instance Barcelona or Madrid ACCs will implement. Otherwise, currently medium complex Mixed OE ACCs (e.g. Madrid and Barcelona) and medium complex ANSP (e.g. ENAIRE) would not have any high or very high implementation in 2035 (SESAR 2020 FOC) and this does not seem realistic.

This deployment scenario approach is a consolidated proposal and the list of targeted countries/ACCs is detailed Appendix 1 - List of PJ.06-01 targeted ACCs.



Operational Environment	Traffic Complexity Score 2025
Maastricht UAC	16.98
Geneva ACC	14.53
London ACC	13.56
Karlsruhe UAC	13.50
Zurich ACC	11.68
Reims ACC	10.02
Paris ACC	9.89
Padova ACC	9.22
Wien ACC	8.41
Ljubljana ACC	8.14
Milano ACC	8.06
Praha ACC	8.00
Bordeaux ACC	7.60
Bratislava ACC	7.34
Brest ACC	7.30
Prestwick ACC	7.26
Budapest ACC	7.25
Munchen ACC	7.07
Marseille ACC	6.55
Sarajevo ACC	6.47
Zagreb ACC	6.35
Barcelona ACC	5.72
Ankara ACC	5.50
Sofia ACC	5.29
Madrid ACC	4.99
Bucuresti ACC	4.82
Roma	4.44

Figure 2 Traffic complexity per ACC according to OEs classification by PJ20, forecasted for 2025 [29]

The reason why CBA considered complexity forecasted by 2025 is because it is the closer data we have to the IOC (31/12/2026) and it is the start year for investments (2 years before IOC, so beginning 2025)

2.2.3 Time horizon

The Solution and Reference Scenarios consider a 21-year period for the analysis of all potential estimated costs and benefits, from 2019 to 2040. Investments start in 2025, 2 years before the first benefits can be accounted (31/12/2026) following CoP recommendations (between 2 and 3 years before IOC). Although the deployment of most of the Operational Improvements of the Solution could be at different years, the CBA time horizon has been aligned with the latest version of the Common assumptions for CBAs document maintained by PJ19 [12].

2.3 Intended readership

The intended readership for this document includes:

- PJ.06-01 Solution Members,
- All other PJ.06 Project Members,
- SESAR Programme Management,
- PJ.19, as Content Integration Project,
- PJ.20, as Master Plan Maintenance project.
- The key stakeholders targeted by the Solution, i.e.

  - **Airspace Users** who will be directly impacted by the implementation of Free Routing operations obtaining benefits from savings in distance, time and thus fuel consumptions and CO^2 emissions;

  - **ANSPs** who will benefit from improved predictability thanks to more stable trajectories while at the same time enhancing the use of conflict detection tools.

2.4 Structure of the document

This report is structured as follows:

- **Section 1** provides the executive summary;
- **Section 2** provides the overall scope, time horizon, intended audience, structure of the document, background, glossary of terms and acronyms;
- **Section 3** presents the objectives and scope of this CBA, provides a description of the PJ.06-01 Solution 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 and risk analysis;
- **Section 9** includes Recommendations and next steps;
- **Section 10** includes the references and applicable documents.
- **Appendix 1** is the list of high & very high complex ACCs to whom the solution is addressed.
- **Appendix 2** is an appendix that provides the mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs.

- **CBA Model** used to quantify estimated costs and benefits for PJ.06.01 is provided as a supporting document and will be part of the Annexes of the CBA Report.

2.5 Background

The PJ.06-01 Solution builds on work produced during SESAR 1 program in AF#3 “Free Route”. This constitutes the baseline for the R&D work to be performed within the PJ.06-01 Solution and the baseline for the CBA. Work in this Operational Focus Area (OFA) culminated with:

- Solution #32 (Free Route through the use of Direct Routing);
- Solution #33 (Free Route through Free Routing for Flights both in cruise and vertically evolving above a specified Flight Level);

No previous dedicated CBA activity has been performed in SESAR 1 related solutions. As Free Route Airspace is part of the PCP Family AF#3 (3.2.1 Upgrade ATM systems DCTs and FRA, 3.2.3 Implement DCTs, 3.2.4 Implement FRA), it is included in the PCP CBA developed for the PCP implementation phase. Although the level of granularity of the data used for PCP CBA is too coarse and has not been considered useful for this CBA.

2.6 Glossary of terms

Term	Definition	Source of the definition
Benefit	A Benefit is the positive value of the return on investment to (some or all) stakeholders.	*SESAR 16.06.06 - Methods to Assess Estimated costs and Monetise Benefits for CBAs (D26, Edition 00.02.02, July 2016)*
Benefit and Impact mechanism	A Benefit and Impact Mechanism: • Is a cause-effect description of the impacts of the Solution proposed by the project; Describes and identifies all relevant impacts, whether positive or negative, that the project Solution is expected/ shown to provide.	*PJ.06-01 OSED-SPR V3*
Cash Flow	Cash flow is the difference between the cash inflows and outflows related to the project during the time horizon in which they occur.	*SESAR 16.06.06 - ATM CBA for Beginners, D26-01, October 2014*
Cost	A Cost is the monetary value of an investment used up to produce or acquire the benefit.	*SESAR 16.06.06 - Methods to Assess Estimated costs and Monetise Benefits for CBAs (D26, Edition 00.02.02, July 2016)*

Cost Benefit Analysis	Process of quantifying estimated costs and benefits of a decision, program, or project (over a certain period), and those of its alternatives (within the same period), in order to have a single scale of comparison for unbiased evaluation.	*Business Dictionary (Web Finance Inc.)*
Cost mechanisms	Cost mechanisms are a description of the potential estimated costs of the project broken down into relevant cost categories (e.g. investment, operating).	*SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014*
Discount Rate	Discount Rate is a way to capture the time value of money. This is a percentage that represents the increase in the amount of money needed or estimated to keep the same value as one year ago.	*SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014*
Initial Operational Capability	Initial Operational Capability is the state archives when a capability is available in its minimum usefully deployable form. In other words, it identifies the start of benefits and the benefit ramp-up period.	*16.06.06-D68-New CBA Model and Method 2015- Part1 of 2*
KEA	KEA is a key performance indicator measuring the level of horizontal en-route flight inefficiency in actually flown trajectories over a period of 12 months. Used in the Single European Sky (SES) Performance Scheme.	*https://ansperformance.eu/definition/kea/*
KEP	KEP is a key performance indicator measuring the level of horizontal en-route flight inefficiency in filed flight plans over a period of 12 months. Used in the Single European Sky (SES) Performance Scheme.	*https://ansperformance.eu/definition/kep/*
Net Present Value	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.	*Investopedia*
NPV Risk Profile	NPV Risk Profile is the range of values the NPV of the project might take along with the associated cumulative probabilities.	*SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014*
Sensitivity Analysis	Sensitivity refers to the impact one given input to the model has on the overall NPV.	*SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014*

Stakeholder	Stakeholders are organizations and entities who will have to pay for or will be impacted by the project directly or indirectly.	*SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014*
Time Horizon	Time horizon refers to a definite time period during which all cost and benefits related to a given project occur.	*SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014*
Time Value of Money	Time Value of Money means that the same (nominal) amount of money received at different points in time has different value	*SESAR 16.06.06, ATM CBA for Beginners, D26-01, October 2014*

2.7 List of Acronyms

Acronym	Definition
ACC	Area Control Centre
AF	ATM Functionality
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Services
AU	Airspace User
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CBA	Cross Border Area
DCT	Direct Routing
ER	En-Route
EATMA	European ATM Architecture (eATM portal)
ECAC	European Civil Aviation Conference
EFF	Efficiency
FAB	Functional Airspace Block
FEFF	Flight Efficiency KPI
FRA	Free Route Airspace

EN	Enabler
ENV	Environment
FOC	Full Operational Capability
FPL	Flight Plan
FRA	Free Route Airspace
HC	High complexity
IFR	Instrument flight rules
IOC	Initial Operational Capability
KEA	Key performance Environment indicator based on Actual trajectory
KEP	Key performance Environment indicator based on last filed flight Plan
KPA	Key Performance Area
KPI	Key Performance Indicator
LC	Low complexity
MC	Medium Complexity
NPV	Net Present Value
OE	Operating Environment
OFA	Operational Focus Area
OI	Operational Improvement
OPEX	Operating Expenditure
OSED	Operational Service and Environment Definition
PCP	Pilot Common Project
PAR	Performance Assessment Report
PRED	Predictability KPI
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SPR	Safety and Performance Requirements
TMA	Terminal Manoeuvring Area
VHC	Very High Complexity

3 Objectives and scope of the CBA

3.1 Problem addressed by the solution

There are various FRA initiatives undergoing currently in Europe, offering different implementations of Free Route Airspace. In general, Free Route Airspace initiatives in Europe aim to eliminate the need to follow fixed ATS-routes and allows aircraft to fly trajectories that are more efficient between a pre-defined set of navigation points. Compared to previously available explicit direct routing options, Free Route Airspace further improves demand predictability and flight efficiency and helps increasing flexibility with a view to balancing demand and capacity. FRA is expected to bring significant benefits to the airlines, through straighter flight profiles, burning less fuel and ultimately reducing aviation operating estimated costs and environmental footprint. Actual KEP and KEA data from PRU repository demonstrates that ANSPs that are "early-movers" with Free Route have already experienced improvements in terms of flight efficiency. Obviously improvements could be due to other reasons, and that is why the Validations in PJ.06-01 should provide evidence on the benefits.

To unlock the full benefits, aircraft need to access free routing along the full length of their flight path. Cross Border Free Route Airspace will allow even more optimal planning, as users will not be forced to deviate from the optimum track. The greater the area, the greater the potential benefit.

As stated in the OSED [20], Solution PJ.06-01 takes as input previous Free Route Solutions (brought to a V3 maturity level in SESAR 1):

- Solution #32: Free Route through the use of Direct Routing
- Solution #33: Free Route through the use of Free Routing for Flights both in cruise and vertically evolving above a specified Flight Level.

According to the applicable version of EATMA, the Solution PJ.06-01 is related to #32 but OI has only as predecessor the AOM-0501 which was linked only to #33. It should however be noted that these Solutions are not a pre-requisite for Solution PJ.06-01, as Solution #32 does not need to be deployed prior to the Solution PJ.06-01 in high and very high complexity environments (it is only a possible Free Route Solution in the transition phase before Free Routing implementation) and Solution #33 (related to Free Routing in low to medium complexity environments) is not directly applicable to the same operating environment than the Solution PJ.06-01.

Solution PJ.06-01 is contributing to the improvement of air traffic management at local ATC level to enable Free Routing in En-route high and very complexity ACCs and eventually cross-border. Solution PJ.06-01 is considered as an enabler to the achievement of AF#3 as prescribed by Regulation (EU) N° 716/2014 for the deployment of Free Route at least above FL305 in the ICAO EUR region as from 31/12/2026.

3.2 SESAR Solution description

The Solution PJ.06-01 is contributing to the improvement of air traffic management at local ATC level to enable Free Routing in En-route high and very high complexity cross-border environments. Although contributing to support the deployment of Free Routing operations beyond low and medium complexity environments, the Solution is not targeting unrestricted free routing operations, but aims at enabling safe and efficient operations in Free Routing Airspace (FRA) with minimum structural constraints as far as practicable while maintaining the required level of safety and capacity in the airspace.

In the applicable version of EATMA the rationale of AOM-0505 states that "…for full performance achievement high and very high complexity environments require further support for conflict detection and resolution by ATC. Demand and Capacity Balancing, including INAP function, would also bring additional performance benefits." These expectations come within the scope of the Solution PJ.06-01, apart from DCB aspects at local level (through the INAP function) which are not addressed.

Full implementation of wide cross-border Free Routing Airspace in all complexity En-route environments will require further improvements that are beyond the scope of the Solution PJ.06-01.

SESAR Solution ID	OI Steps ref. (coming from the Integrated Roadmap)	OI Steps definition (coming from the Integrated Roadmap)	OI step coverage	Comments on the OI step title / definition
PJ.06-01 Optimized traffic management to enable Free Routing in high complexity environments	**AOM-0505** — Free Routing for Flights both in cruise and vertically evolving within high and very high complexity environments in Upper En Route airspace	Free routing operations allow the airspace user to plan and re-plan a route according to the user-defined segments within significant blocks of Free Route Airspace (i.e. multiple FIR AOIs (areas of interest) or FABs) within high and very high traffic complexity environments where airspace reservations are managed in accordance with AFUA principles.	Partially (Key Feature addressed by PJ.06-01 is Advanced Air Traffic Services; AU/FOC/WOC and NM operations are part of the operational environment of the Solution, but not in scope of the Solution	Current maturity level is V3

Table 1: SESAR Solution PJ06.01 Scope and related OI steps

Next table summarises the enablers addressed by the solution and comments on the Enabler are directly extracted from OSED [20].

Enabler[2] ref.	Enabler definition	Enabler coverage	Applicable stake-holder	Comments on the Enabler / definition
Baseline				

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

ER ATC 129 — Upgrade FDP and provide Controller Tools to provide assistance to ATC Planning for Preventing Conflicts in En-Route Airspace	Upgrade FDP and provide Controller Tools to provide assistance to ATC Planning for Preventing Conflicts in ER – baseline + PCP	Required Coverage: full	ANSPs	This enabler is the pre-SESAR baseline enabler for ATC support tools. ***This enabler is a required enabler of both the OI Step AOM-0505 and the Solution PJ.06-01.***
Basic Solution				
ER ATC 78 — Update FDP to support 4D trajectory direct segments in free routing airspace beyond local AoR	Update related systems (FDPSs) to support 4D trajectory direct segments in free routing airspace and support at ATC level the planning and execution of RBT/MBT across ACC/FIR/FAB and multiple AoRs. The 4D trajectory is the planned trajectory calculated by the ground system. Updates to the 4D trajectory can be shared between ATC units to support decision making processes and operational procedures. 4D Trajectory data exchange will support coordination and transfer between units and extend beyond local AoR across the AoI. 4D Trajectory data exchange (ground-ground) can be achieved by use of OLDI or IOP. Request on frequency between sector and request traffic skipping sectors (different time, different FL...) are possible.	Required Coverage: full	ANSPs	This enabler aims at updating Flight Data Processing (FDP) related systems to support 4D trajectory direct segments in Free Routing Airspace, and support at ATC level the planning and execution of RBT/MBT across ACC/FIR/FAB and multiple AoRs. It is essential to support ATS in cross-border Free Routing Airspace of high and very high complexity.
ER ATC 91 — ATC System Support for Advanced Conformance Monitoring in En-route Airspace	Enhance conformance monitoring approaches, associated algorithms and controller HMI functions to support advanced conformance monitoring in an en-route environment. The monitoring aids functionality is extended to monitor downlinked aircraft parameters such as selected	Required Coverage: full	ANSPs	This enabler (which IOC date is in 2016) is a SESAR 2020 baseline enabler brought in V3 maturity in SESAR 1 in the scope of Solution #33.

	flight level, vertical rate, and selected heading for conformity with the flight clearance.			
Advanced Solution (optional enablers)				
ER ATC 157 - Enhanced ATC System Support to the Tactical Controller for Conflict Detection and Resolution in En-Route	Conflict Management is updated to integrate conflicts derived from multiple trajectory types in order to detect sector entry, in-sector, and exit conflicts, as well as conflicts for aircraft on open clearances or deviating from their planned trajectory. Resolution is assisted by indicating available and occupied levels and allowing the user to probe for conflicts on a what-if trajectory. Controller HMI is upgraded to provide the conflict information for the tactical controller.	Optional Coverage: full	ANSPs	This enabler is a SESAR 2020 baseline enabler brought in V3 maturity in SESAR 1 in the context of Solution #27. These enhanced ATC functionalities (with "what-if" and "what-else" probing of ATC clearances) are nice to have to support separation provision in Free Routing environments of high and very high complexity.
ER ATC 157b - Enhanced ATC System Support the Planning Activity for Conflict Detection and Resolution in En-Route	Conflict Management is updated to integrate conflicts derived from multiple trajectory types in order to detect sector entry, in-sector, and exit conflicts, as well as conflicts for aircraft on open clearances or deviating from their planned trajectory. Resolution is assisted by indicating available and occupied levels and allowing the user to probe for conflicts on a what-if trajectory. Controller HMI is upgraded to provide the conflict information for the planning activity.	Optional Coverage: full	ANSPs	This enabler is envisaged to achieve V3 maturity in SESAR 2020 in the context of the Solution PJ.10-02a and the Solution PJ.06-01 with regard to Free Routing environment. These enhanced ATC functionalities, which goes beyond the baseline support tools for ATC Planning (cf. enabler ER APP ATC 129), are nice to have to support separation provision in Free Routing environments of high and very high complexity.

PRO-046b — ATC Procedures for Using Advanced System Assistance to Medium Term Conflict Detection and Resolution		Optional Coverage: Partial	ANSPs	This enabler is nice to have to support the ATCOs in managing conflicts in FRA of high and very high complexity using advanced Conflict Detection Tools (cf. enablers ER APP ATC 157 and ER ATC 157b).

Table 2: OI steps and related Enablers

3.3 Objectives of the CBA

The objective of the V3 CBA is to provide a consolidated assessment of the estimated costs and benefits of deploying Solution PJ.06-01 in the ACCs that have been identified in the deployment scenario approach (see section 2.2.2). This CBA will assess whether the benefits of the deployed Solution are expected to exceed the estimated costs over the CBA time horizon.

Only benefits for Airspace Users in terms of flight efficiency and predictability have been monetised in the CBA, in full alignment with the Benefit Impact Mechanisms described in the OSED [20]. It was not possible to assess or monetise other potential benefits for other stakeholders (e.g. for the ANSPs) due to lack of evidences.

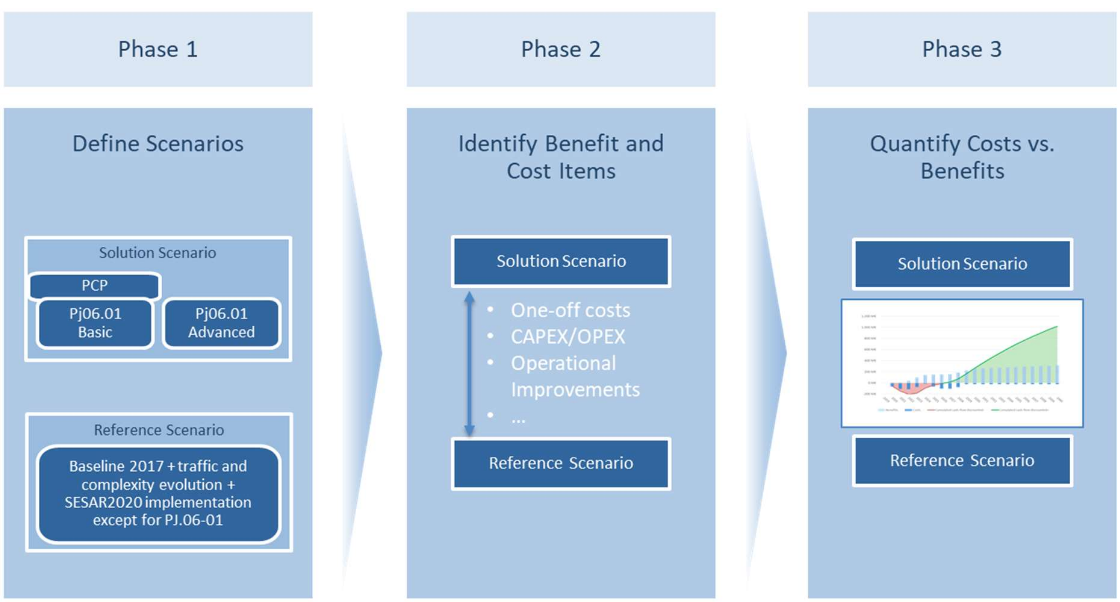


Figure 3 PJ.06-01 CBA development phases

This V3 Cost Benefit Analysis will help in building an assessment of whether the PJ.06-01 Solution is worth deploying from an economic perspective for the involved stakeholders. It should also help in adjusting the deployment scenario approach and find the best option in terms of OIs/ENs implementation. To this aim, this V3 CBA provides accurate results of expected benefits and estimated costs for the stakeholders.

3.4 Stakeholders 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	- High and Very High complexity ACCs - Medium complexity ACCs that will become High or Very High Complexity in the coming years e.g. en-route ANS, High Complexity ACCs	- Invest in the acquisition or upgrade of systems to enable Free Routing - Invest in the training of ATCOs for both basic and advanced solutions	Skyguide, DSNA and ENAV have estimated ANSPs estimated costs and benefits. LFV has estimated training estimated costs.	Estimated costs have been quantified and monetised in the CBA. Estimated costs are mainly related to training (less than 1 week) and acquisition of new systems or upgrade of the existing ones. Operating estimated costs of those systems. Changes in the current procedures that would generate no additional estimated costs compared to current level of operating expenditures.
Airport Operators	No Impact foreseen imputable to PJ06.01			
Network Manager	No Impact foreseen imputable to PJ06.01			
Scheduled Airlines (Mainline and Regional)	Concerns mainly the flights in implementing ACCs	- Fuel efficiency improved thanks to more direct routes, thus reduction in flight time and in fuel consumption - CO2 emissions reduced thanks to improved fuel efficiency - Fuel efficiency improved thanks	Air France (AFR) and Lufthansa (DLH) have estimated AUs benefits by providing inputs, validating assumptions, and reviewing results.	Benefits have been quantified and monetised in the CBA.

		to improved predictability, allowing to better plan the route and upload less fuel - Fuel efficiency improved thanks to uploading less fuel - CO2 emissions improved for both fuel efficiencies above mentioned		
Business Aviation	Not explicitly analysed, but included in IFR traffic for the estimation of network benefits			
Rotorcraft	No Impact foreseen imputable to PJ06.01			
General Aviation IFR	Not explicitly analysed, but included in IFR traffic for the estimation of network benefits			
General Aviation VFR	No Impact foreseen imputable to PJ06.01			
Military – Airborne	No Impact foreseen imputable to PJ06.01			
Military – Ground	No Impact foreseen imputable to PJ06.01			
Other impacted stakeholders	No Impact foreseen imputable to PJ06.01			

Table 3: SESAR Solution PJ.06-01 CBA Stakeholders and impacts

3.5 CBA Scenarios and Assumptions

The CBA results refer to the difference between a Solution Scenario and a Reference Scenario. The Reference Scenario is taken as from historical data in 2017, since this is considered before any implementation of FRA project comparable to PJ.06-01. Although since 2014 a number of early adopters of DCT/FRA can be found among European ANSPs (e.g. Hungary, Italy, Austria, Slovenia, Croatia, Serbia, Norway etc.), the corresponding operational impact is considered as not imputable to PJ06.01 and therefore included in the Reference Scenario.

The ATS route network as published on 31/12/2017 is then frozen, and the traffic is projected to future until 2040, which is the end year of the CBA.

From 01/01/2018 (i.e. the Target date for PCP to have DCT implemented) to 31/12/2026 (i.e. the IOC for the basic Solution implementation of PJ06.01), no other changes than the traffic increase are taken into account for the Reference Scenario.

Then 31/12/2026 is taken as the initial implementation date for PJ06.01 (i.e. the Basic Solution through EN ER ATC 78 and 91). Therefore, 31/12/2026 is considered as the starting year of the Solution Scenario. The CBA covers the period until 2040, by projecting traffic growth according to STATFOR forecasts, estimated costs and benefits in the Solution Scenario through a Gaussian ramp-up function.

The CBA uses a delta approach, i.e. the Solution Scenario identifies all the additional elements that will have to be put in place on top of what is assumed to be deployed in the Reference Scenario, which does not include the whole operational improvements imputable to PCP, but only the part implemented until year 31/12/2017. The estimated costs and benefits of the additional elements to that reference year are considered in the CBA.

The role of SESAR R&D in this area is to demonstrate that tangible benefits can be obtained from implementing SESAR Solutions. Assumptions were made in this V3 maturity phase towards PJ.06-01 potential options in terms of deployment scenario and candidate ACCs (with criteria) where PJ.06-01 Solution team identified OIs and ENs could potentially bring benefits. However due to the expected update of PCP Regulation in 2020, the assumptions will need to be reviewed after that.

3.5.1 Solution Scenario

The PJ.06-01 Operational Improvements are not applicable everywhere. To answer the need for a scalable Solution, a common approach to PJ.06-01 was used to define a set of deployment assumptions and to identify the ACCs and ANSPs where the solution could be applicable and having the potential to bring benefits.

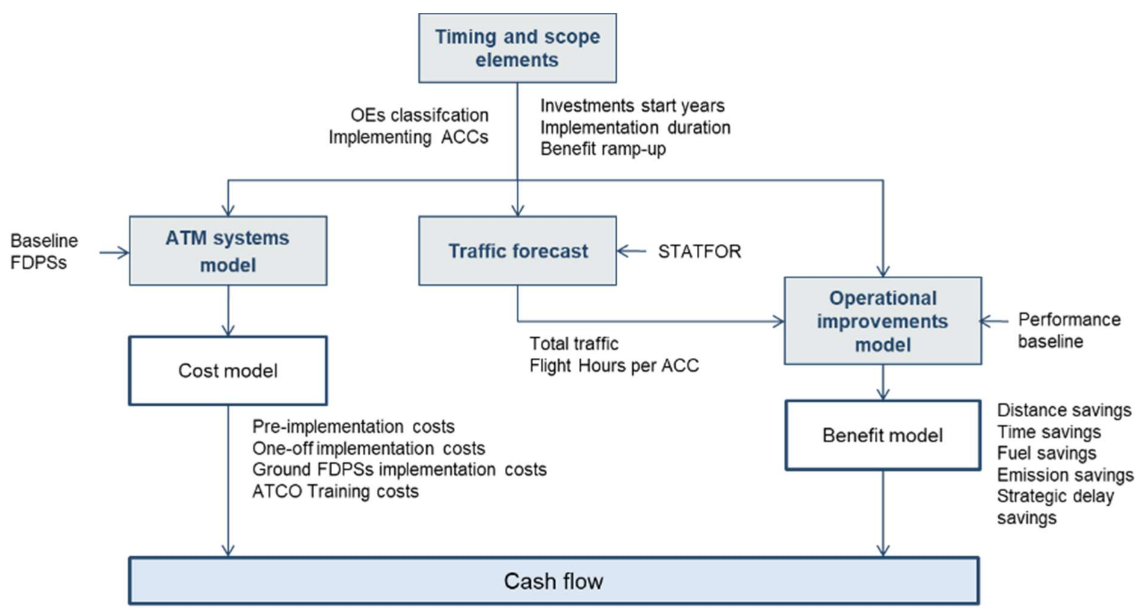


Figure 4 CBA Model workflow

Table 4 below is a high-level description aimed at illustrating the way in which the CBA model has been shaped and adapted to fit for purpose for the PJ.06-01 V3 CBA. It summarizes the different variables aligned with EMOSIA methodology and how they have been used within the model developed for this analysis.

Estimated costs and benefits have to be always considered as "Delta" values with respect to the baseline scenario. Hence, variables described in Table 4 are those for which changes are expected with respect to the baseline scenario. In particular, the investment model generates an input only for ANSPs in this analysis, since no specific investment for Airspace Users is specifically imputable to the PJ.06-01 implementation and operations.

CBA variable	Variable description for the PJ.06-01 CBA
Timing variables	
Implementation start year	31/12/2024 (2 years before IOC)
IOC/FOC dates and duration	4 years Basic Solution (31/12/2026-31/12/2030) 4 years Advanced Solution (31/12/2031-31/12/2035)
CBA Timeframe	21 years (2019-2040)
Operational Improvements model variables	
Baseline performance/efficiency	Baseline efficiency indicators in terms of distance, KEP and KEA over ECAC airspace for year 2017
Investment model variables (estimated costs)	
One-off implementation estimated costs	Project Management, Initial training, Administrative, Installation/Commissioning investments required by ANSPs
Ground FDP System estimated costs	Purchase of equipment replacements or upgrades for FDP systems investment required by ANSPs
ATCO training estimated costs	ATCO dedicated training investment required by ANSPs
Operating estimated costs	Additional operating estimated costs due to the replacements of FDP system
Traffic model variables	
Baseline traffic	Baseline IFR traffic from STATFOR and Flight Hours from ANS Performance Repository (PRU)
Growth factors	Baseline IFR growth tendencies from STATFOR
Total traffic	Targeted ACCs traffic estimated figures (IFR flights equivalent to the Flight Hours)
Benefit model variables (savings)	
Distance savings	Distance savings due to PJ.06-01 implementation in terms of NM
Time savings	Time savings due to PJ.06-01 implementation in terms of min/flight
Fuel savings	Fuel savings due to PJ.06-01 implementation in terms of kg/flight
CO_2 savings	CO_2 savings due to PJ.06-01 implementation in terms of kg/flight
Strategic delay savings	Schedule buffer reduction deriving in strategic delays savings in terms of min/flight (FINALLY NOT INCLUDED)

Table 4 CBA model variables summary and high-level description

Next sections are concerned with the detailed description, breakdown and estimation of each of these variables and explanation of elements included in the PJ.06-01 CBA model.

3.5.1.1 The benefit modelling approach

Benefits per stakeholder group have been identified based on the PJ.06-01 BIMs that were developed in the context of the OSED task and are presented in the Appendix A section A.2.2 *Airspace User benefits mechanism* of the PJ.06-01 V3 SPR-INTEROP/OSED Part I Final Version [20]. Only the BIM for the airspace users is shown to explain the benefit modelling approach since the BIM for they ANSPs shows zero improvement for Airspace Capacity, Human Performance and Safety, all of them maintained at the same level of performance with PJ.06-01.

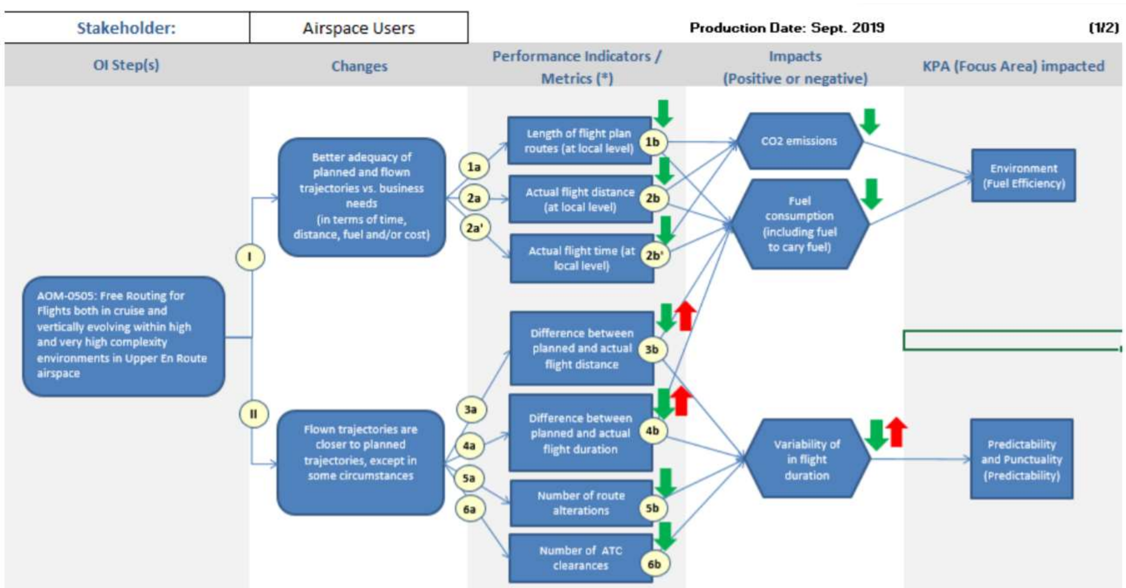


Figure 5 PJ.06-01 solution BIM for Airspace Users

As addressed in the OSED[20] and specifically stated in the PAR [21], “the expected reduction of in-flight variability in En-Route is dependent on the Free Route Airspace design itself (and its level of optimisation) as well as, the overall impact of required tactical interventions on the flights trajectory at local level”. For that reason, the benefit was declined to be monetised in the CBA.

Another particular KPA is airspace capacity, which in fact holds a close relationship with predictability. Experts from Skyguide highlighted the risk of negative impacts on predictability and capacity. It is difficult to know from validations exercises to what extent these risks are very limited or not. This is a crucial issue, in particular in light of the current difficulties of many ANSPs to provide the capacity for forecasted traffic growth. Further insights can be found in Section 4.6 of the PAR [21].

For the quantitative estimation of these benefits, the approach that has been identified as valid is:

1. Use historical data as available from EUROCONTROL PRU data sources on KEA, considering KEA as a proxy for the fuel efficiency calculation
2. Use historical data as available from EUROCONTROL PRU data sources on KEP and KEA, considering the difference [KEP-KEA] as a proxy for better planning of fuel loaded, deriving in less fuel consumption benefit (the aircraft weights less).

The CBA team decided to use a fully data-driven modelling approach. The resulting assumptions and results have been validated on the base of the results available in validations that constitute evidence of the benefits. However, to validate the amount of benefits, the PAR has been used.

Several FRA projects already implemented in Europe were monitored in terms the impact they had on KEP and KEA. In particular it was observed that national FRA project typically introduce an improvement in flight efficiency (i.e. decrease of KEA), while the cross-border FRA initiatives typically lead to a reduction of the difference [KEP-KEA].

Based on historical data it was also possible to derive some patterns that could be then extrapolated to other comparable ACCs. In particular the maximum achievable values of KEP and KEA (i.e. the KEP and KEA target values used in the CBA) were calculated based on the complexity factor of different ACCs, as well as the ramp-up function to achieve such targets. The benefit structure and ramp-up model based on data from first FRA projects is summarised in Figure below.

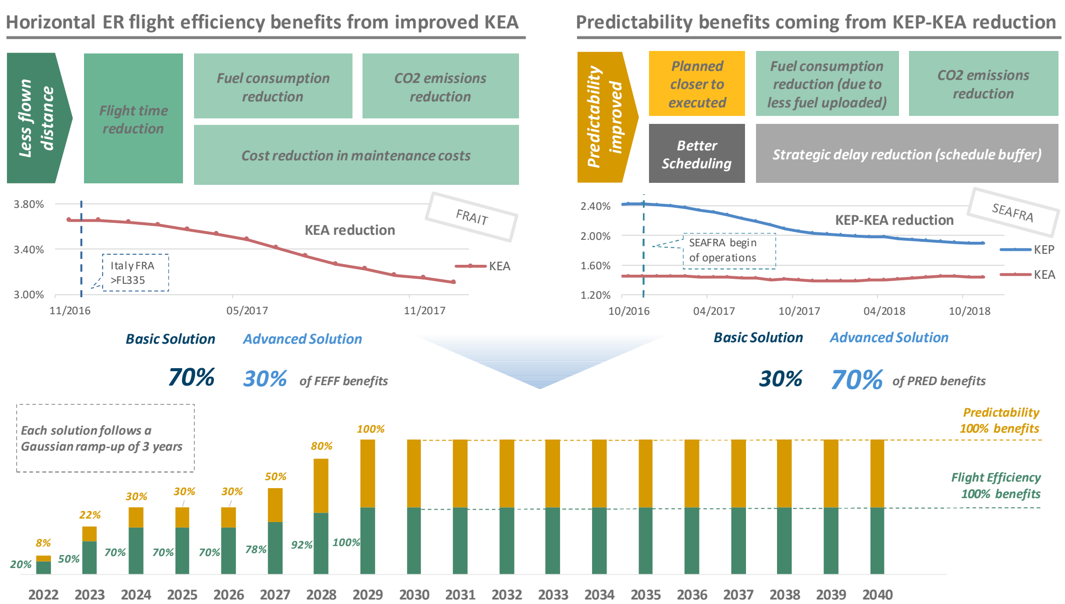


Figure 6 Benefit ramp-up modelling related to Basic and Advanced Solutions

<u>Note:</u> Strategic delay reduction has been declined as a benefit since the validations could not prove evidence of it, and experts also advised that benefits could not be significant enough to touch schedule buffer.

The calculation of the target KEP and KEA values obviously determine the final results in terms of benefits in the CBA. Therefore, particular care has been put into their calculation, based on the following methodological steps:

1. Identifying ACCs based on their aggregated traffic complexity score, following the classification of OEs from PJ20 and complexity forecast to filter only the ones within the scope of the CBA;

2. Extract **KEP and KEA** historical data for each ACC from the EUROCONTORL PRU database (2017 full year data);

3. For each of them, compute the **target KEA** after PJ.06 (both solutions 01 and 02) implementation, based on worst in class and best in class (**worst 3,00%, best 1,25%**), correlating the classes with the aggregated traffic complexity as observed in 2017;

4. For each of them, it is assumed that **[KEP-KEA]** difference will be reduce in **1.0 point percentage** according to PRR report 2016/2017.

5. Apply the yearly growth of the **STATFOR traffic forecast** expressed into # of IFR flights per year into the **flight hours per ACC** (from PRU database), to ensure benefits can be summed over different ACCs crossed by the same flight;

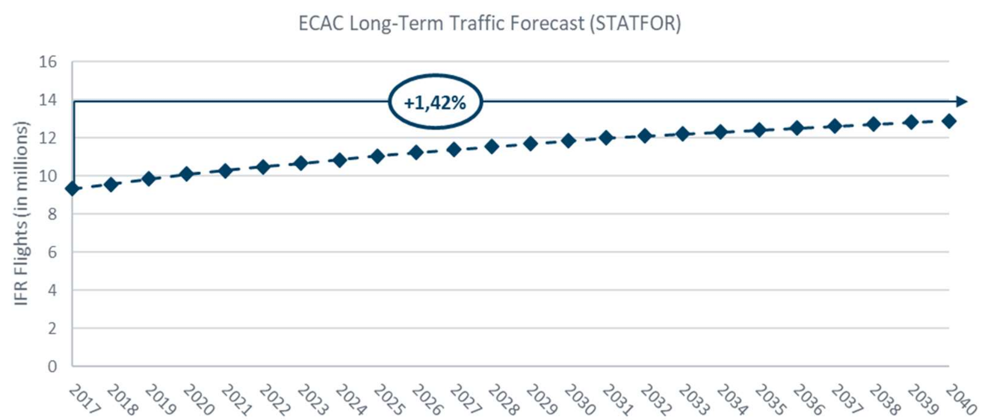


Figure 7 STATFOR long term traffic forecast (European IFR Flights)

6. Apply a **benefit apportioning factor** computed from **Network Manager Fast-Time Simulations** to account for only the flight hours applicable to the Airspace impacted by solution PJ.06-01, i.e. at or above FL305

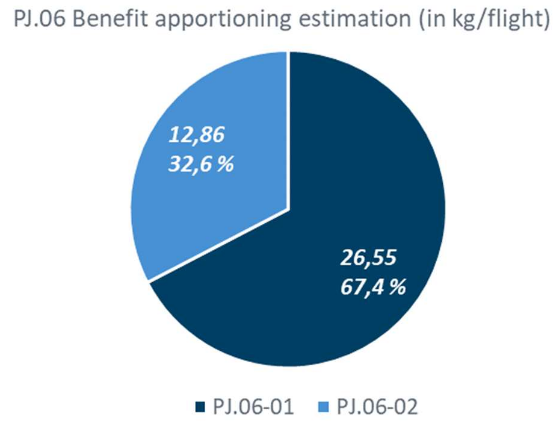


Figure 8 Benefit apportioning coming from Fast-Time Simulations for one day traffic 30/06/2017

7. Multiply the traffic by the difference between **actual (2017) and target KEA and KEP values** to obtain the **saved Nautical Miles (NM)**

8. **Monetise the NM** through fuel and time base value, in compliance with the EUROCONTROL Standard Inputs for CBAs [25]

Figure below resumes these methodological steps:

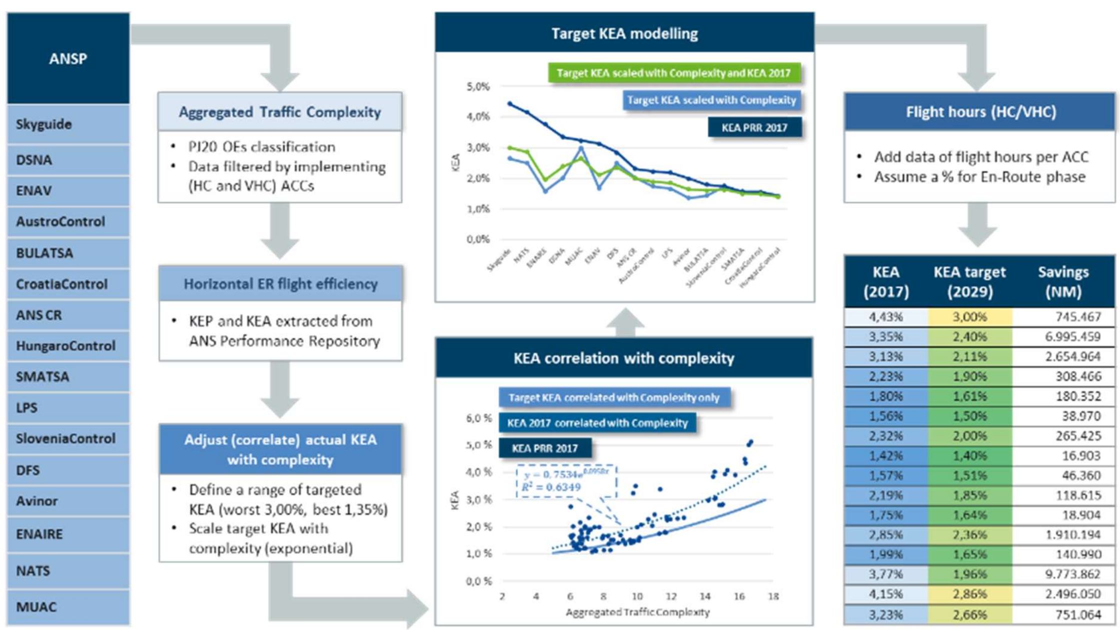


Figure 9 Benefit model KEA-driven methodology

9. **Monetise the flight efficiency (fuel to carry fuel)** improvements coming from improved KEP-KEA difference once the modelled target KEA has been computed

3.5.1.2 The cost modelling approach

For the calculation of estimated costs a data-driven approach was combined with inputs from the ANSP partners within PJ06.

1. Identifying for each ANSP within the scope of the CBA, the **current installed FDPS systems**, gathering information of manufacturer, commissioning year, planned upgrades and/or replacements, major CAPEX projects related to ATM and FDPS, and their respective scheduled dates for the investment;

2. Identifying the **earmarked investments in FDP upgrades/replacements** expected in the period 2017-2023, as published in the EUROCONTROL ACE Benchmark Report 2016 [32] by each of the retained ANSP

3. Assess with some ANSP partners within PJ06 (DSNA, ENAV and Skyguide) the specific investment they plan to face to implement Solution PJ06.01 into their ACCs, in terms of CAPEX (system upgrade) and OPEX (ATCO training) expenditure for each enabler associated with the Basic and Advanced Solutions for implementing PJ06.01.

4. Extrapolation of CAPEX: Calculate the ratio of the expected PJ.06-01 investment over the overall FDP upgrades expected in the period 2017-2023, by dividing the input in terms of CAPEX by the inputs from point 2. for each ANSP partner within PJ06

   Calculate and aggregate the cost for ATCO training, based on the number of days declared necessary and the national ATCO staff salary estimated costs as available from EUROCONTROL ACE Benchmark Report

5. Extrapolation of OPEX: Declare a % of CAPEX based on cost inputs and apply to all ANSPs

It is assumed that all ACCs have already installed pre-requisite elements that will be required before deploying the Solution (in the case of system upgrades, it is assumed they already have a current system that is new enough to be only upgraded and not replaced).

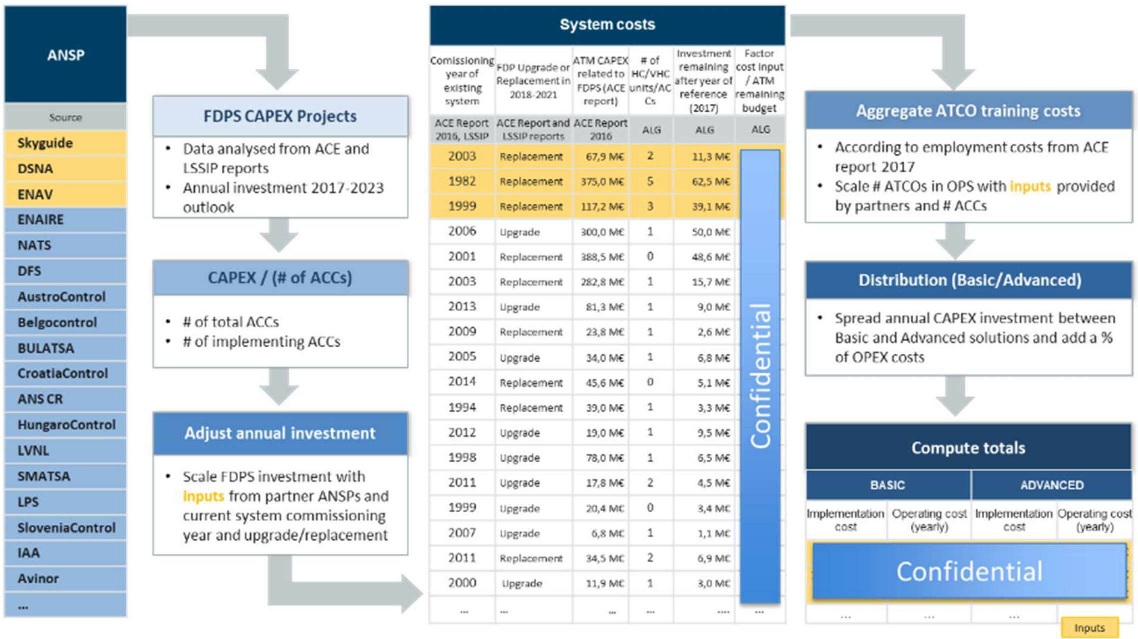


Figure 10 Cost model methodology workflow

Main drivers to assess cost and benefits for ACCs:

- The expected benefits and their relative contribution to overall performance (e.g. flight efficiency, predictability, estimated costs efficiency, etc.);
- The traffic and the complexity of the airspace and the expected traffic growth (volume of IFR flights and flight hours);
- The importance of the airspace for flight hours above FL305;
- The capacity to invest (level of resources available) related to their current planned investments and ATM infrastructure modernisation;
- The investment in the already validated elements (Implementation of current ATM systems, upgrades on existing FDPS systems, considering the capabilities offered by the different manufacturers).

3.5.1.3 Deployment scenario

The OE dataset developed by SESAR 2020 PJ20 (WP2.2 WG in April 2017) was used for the classification of ACCs. Other sources of information were added in a second step such as the latest versions of ACE Report (ATM Cost-Effectiveness), PRR (Performance Review Report), LSSIP (Local Single Sky Implementation) reports for each country and a list of targeted ACCs/ANSPs foreseen by the PCP implementation of Free Route concepts. The identification and characterization of the ACCs was done using a set of different criteria:

- Aggregated traffic complexity score (identified ACCs);

- KEA value for 2017 (from PRR);
- Flight hours in 2017, including a general assumption for flight hours above FL305;
- Expected growth of traffic based on STATFOR forecasts;

The criteria were not cumulative and of difference importance, so not always evenly taken into account in the CBA model.

Results of the characterisation

To reflect the progressive implementation of the most advanced PJ06.01 Solution in terms of functionalities, two sub-solutions (the Basic and the Advanced) were defined within the CBA.

The Basic Solution is considered an extension of the FRA solution mandated by PCP regulation, aimed at updating related systems (FDPSs) to support 4D trajectory direct segments in free routing airspace and support at ATC level the planning and execution of RBT/MBT across ACC/FIR/FAB and multiple AoRs. The Advanced Solution in turn offers further support to ATCOs for conflict detection and resolution and Demand and Capacity Balancing, including the INAP function.

The detailed list of PJ06.01 enablers were therefore associated to one and only one solution, based on the additional functionalities to be provided.

PJ.06-01 Basic Solution	
Enabler	**Description**
ER APP ATC 78	Update FDP to support 4D trajectory direct segments in free routing airspace beyond local AoR
ER ATC 91	ATC tools to support for advanced conformance monitoring (monitor downlinked aircraft parameters)

Table 5. PJ.06-01 Basic Solution Enablers list

PJ.06-01 Advanced ATC Solution	
Enabler	**Description**
ER ATC 157	Enhanced ATC System Support to the Tactical Controller for Conflict Detection and Resolution in En-Route
ER ATC 157b	Enhanced ATC System Support the Planning Activity for Conflict Detection and Resolution in En-route
PRO-046b	ATC Procedures for Using Advanced System Assistance to Medium Term CD/R

Table 6. PJ.06-01 Advanced ATC Solution Enablers list

The ACCs are clustered into groups following:

ACCs cluster	Targeted airports and expected benefits	Main operational Characteristics	Basic and Advanced ENs	Pre-requisite elements
High and Very High complexity 57,61% of traffic share 2017 **[12]**	**Targeted ACCs:** highly congested ACCs or less congested ACCs but with interacting flows and flights that face regular DCB and capacity issues and with already an important volume of traffic **Objective:** to optimise ACCs operations to be as close as possible to schedule and to optimize the routes as much as possible	• A high utilisation of the airspace (traffic density) or complex traffic structure • A high importance of interacting flows and interacting vertical flights • An important network function • A highly constrained environment	Basic *ER APP ATC 78* *ER ATC 91* Advanced *ER ATC 157* *ER ATC 157b* *PRO-046b*	There are no prerequisites for this functionality
Medium Complexity	**Targeted ACCs:** Medium complexity ACCs that are not as highly congested as the ones in the previous group but operate close to the threshold of high complexity and would change its category as from 31/12/2026 **Objective:** to consider future High and Very High complexity ACCs. In some cases they are operated by an ANSP that has already other ACCs implementing PJ.06-01 so they could implement as well.	• A medium utilisation of the airspace (medium volume of traffic) • Secondary ACCs in the Network connecting high or very high complex ACCs • No specific constraints in the environment	Basic *None* Advanced *None*	No specific pre-requisite expected
Low and Very Low complexity	**Targeted ACCs:** all other small ACCs that are not part of the previous groups	Out of the scope of the CBA analysis. No OIs implementation foreseen as no benefits expected either at local or network level.		

Table 7: SESAR PJ.06-01 Solution – Clustering of ACCs per complexity level

Each ACC could decide to deploy the most appropriate group of enablers to deal with its own traffic load and complexity. At European level, the correlation between each ACC and the chosen solution generate a matrix of possibilities but for CBA purposes and recalling that PCP mandates FRA implementation in all ACCs within ICAO EUR region, the **CBA considers the option "ACC 3" as indicated**

in table below, according to which all targeted ACCs will implement both Basic + Advanced solution in due time (benefit start year in 31/12/2026).

	ACC1 (Basic solution deployment)	ACC2 (Late Basic deployment)	ACC3 (Basic + Advanced deployment)	ACC4 (Late Basic+ Advanced deployment)
Basic Solution	IOC in 31/12/2026	IOC in 2027	IOC in 31/12/2026	IOC in 2027
Advanced Solution	N/A	N/A	IOC in 31/12/2031	IOC in 2032

Table 8: ACC solution deployment options

Remarks on the Solution deployment scenario approach:

- All the High and Very High complexity ACCs are foreseen to implement the full PJ.06-01 Solution (i.e. including the Basic and the Advanced Solutions). The EN list provided provides the key elements stemming from operational requirements for large-scale extension of Free Routing operations in high and very high complexity cross-border environments.
- Some particular medium complexity ACCs are foreseen to implement the full PJ.06-01 Solution. Either they are close to the High Complexity threshold or they suffer high seasonal traffic or peak traffic days. This is the case for example of Barcelona and Madrid ACCs.
- AOM-0505 is not envisaged to be deployed at Low Complexity ACCs. The level of investment compared to the benefits would make the Solution less attractive for them. Low complexity ACCs are less likely to face such demanding constraints that would require further support for conflict detection and resolution by ATC or Demand and Capacity Balancing, including INAP function, as provided by the Advanced Solution.

The timeframe of deployment of PJ.06-01 is expected to be as follows:

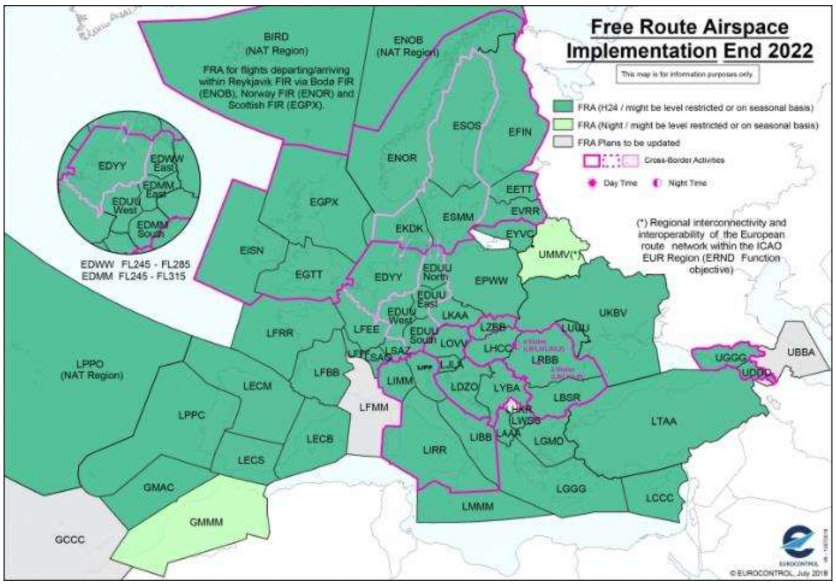
ACCs cluster	ENs	Start of deployment (investment)	End of Deployment	IOC	FOC
High and Very High + target MC	*ER APP ATC 78* *ER ATC 91*	*31/12/2024* *31/12/2024*	*31/12/2030* *31/12/2030*	*31/12/2026* *31/12/2026*	*31/12/2030* *31/12/2030*
	ER ATC 157 *ER ATC 157b* *PRO-046b*	*31/12/2029* *31/12/2029* *31/12/2029*	*31/12/2030* *31/12/2030* *31/12/2030*	*31/12/2031* *31/12/2031* *31/12/2031*	*31/12/2035* *31/12/2035* *31/12/2035*

Table 9: SESAR Solution PJ.06-01 – timeframe of deployment

The timeframe of deployment is partially based on the OIs' dates provided in the eATM Dataset DS20. The EATMA database has been refreshed the 15/09/2019 and that new changes entailed in DS20 draft have been integrated in the CBA Model. AOM-0505 has IOC in 31-12-31/12/2026 and FOC in 31-12-

31/12/2030 in line with Basic solution FOC and ER ATC 157b has FOC 31-12-2035 so that is the FOC of the Advanced solution. So everything is consistent with the "Basic + Advanced" approach.

The expected FRA implementation map for 2022 generates controversy with this IOC/FOC dates in EATMA portal DS20. IOC/FOC are late compared to **Error! Reference source not found.** map produced by EUROCONTROL. It has been already mentioned that PJ.06 project goes beyond PCP and is an enhancement of concept through performance-based management, however this identified misalignment could have an impact on the CBA assumptions related to the systems. The issue is that systems could be already there when PJ.06-01 and PJ.06-02 start implementation in 31/12/2024.



FRA implementation has to have modern air traffic management systems as a basis – and centres in in complex airspace need advanced flight data processing capability and support functions.

An example that supports the solution scenario approach is that of FAB CE Partners. They are driving forward the implementation of FRA and have become pioneers in this area. The FAB CE X-Border Free Route Airspace (FRA) study, completed in April 2017, provided a baseline evaluation of the feasibility of implementing FRA and has defined the operational and technical pre-conditions for the introduction of the procedure throughout the FAB CE area. Among its findings, the unrestricted FAB CE level cross-border FRA concept provides the desired benefits for airspace users in terms of horizontal flight efficiency and predictability.

3.5.2 Reference Scenario

The reference scenario looks at how the ACCs identified in the Solution Scenario approach would evolve if PJ.06-01 Solution was not implemented. Since PJ.06-01 is mainly impacting flight efficiency, **reference scenario for the actual data was chosen to be in 2017** because it was the most recent year from which KEP/KEA data could be obtained and the CAPEX investments were earmarked for the period 2017-2023 in ACE Report 2016 [32].

Regarding the performance baseline, it is assumed that high or very-high complex ACCs will not deliver additional En-Route performance compared to the current level, unless Solution PJ.06-01 is deployed. PJ.06-01 benefits have been considered independently of any other cross-effects with other SESAR2020 solutions (except for PJ.06-02). **Therefore, the performance baseline is the actual performance in 2017**. This list of targeted ACCs is presented in Annex 2, which might be changed or adapted to solution PJ.06-01, according to the future comments from the PJ.06 partners.

The Reference Scenario does not consider the Free Route investments that could come in 2018 and after. In fact, they are considered in the solution scenario in order to be compared to the total benefits brought by the solution. Concerning technical baseline, the delta for PJ.06-01 CBA is represented by the investment which is necessary to deploy the PJ.06-01 enablers. It is recognised that "assets in operations" are out of scope of this CBA as well as "assets under construction" which are a pre-requisite for PJ.06-01.

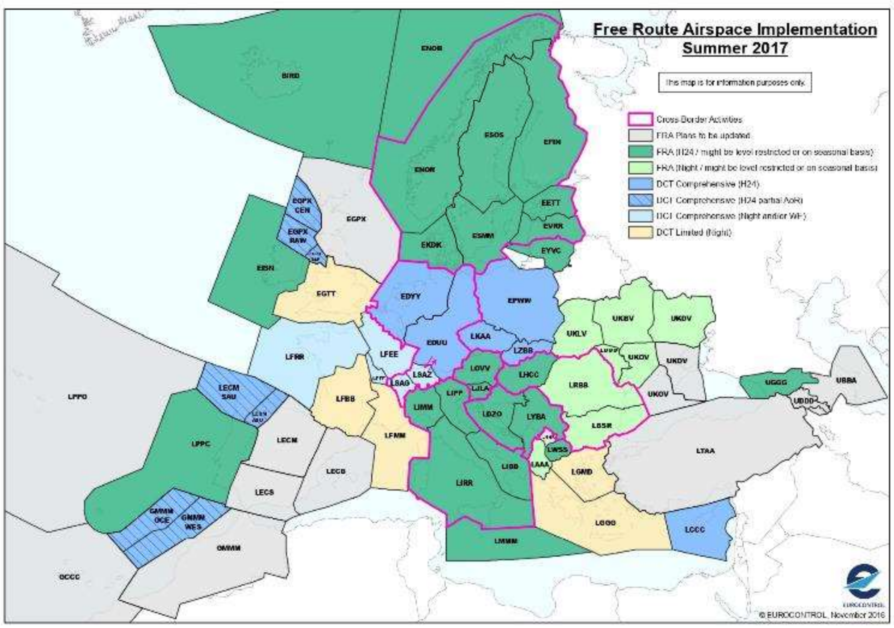


Figure 11 Free Route Airspace Implementation Summer 2017

3.5.3 Assumptions

This section aims at presenting the assumptions made to model the CBA, as well as the data upon which the economic model is based. These assumptions and data categories are structured into three basic blocks: economic and financial; operational; and technical and systems-related assumptions. The ones used to build the PJ.06-01 CBA Model:

- The estimated costs and benefits have been estimated based on the deployment scenario approach and all the Essential Operational Improvements have been considered.
- To reflect the progressive implementation of the Solution, two solutions (basic and advanced) were defined. Deployment estimated costs have been separated into those two solutions to be deployed and a 4-year Gaussian ramp up has been designed from the Initial Operational

Capability to the Full Operational Capability. The ramp up of benefits is aligned for each level of the solution.

- Estimated costs and benefits have been computed using the data inputs from ACCs or ANSPs but based on average values at ECAC Level. It is assumed that all targeted ANSP/ACCs will support the same kind of estimated costs. The order of magnitude will be adjusted according to current systems and plans available for each ACC. It is also assumed that benefits should also be equivalent although this may not be the reality for some of the benefits estimated. As it is not feasible to exactly quantify estimated costs for each ACC separately, estimated costs have been estimated per ANSP according to the deployment scenario approach and similarity with the ANSP who provided inputs, assuming that they would be of same order of magnitude.

- Regarding FDPSs, it has been assumed that all ANSPs currently operate a main FDPS at each ACC for their en-route operations. Therefore, an ANSP will have as many operational FDPS sets as active ACCs. The lifecycle of an FDPS has been assumed at 20 years (the entire CBA timeframe). This lifecycle is not expected to be altered by the implementation of PJ.06-01, whose add-ons and associated systems will abide by the same lifecycle.

Scenario feature		Year 2017	Year 2025	Year 2040	Source
ECAC traffic ('000 # flights) in line with [12]		Traffic for each country/ACC in 2017	Traffic prediction for each country/ACC in 2025	Traffic prediction for each country/ACC in 2040	STATFOR [24]
Applicability: Number of locations where Solution is deployed (# ROEs)	OI ZZ	24 ACCs (upper airspace HC and VHC)	33 ACCs (upper airspace HC and VHC)	33 ACCs (upper airspace HC and VHC)	PJ.20 OEs classification and complexity
Impacted traffic, i.e. experiencing the benefits from the Solution(s)	'000 # IFR flights per year	Traffic for each country/ACC in 2017	Traffic prediction for each country/ACC in 2025	Traffic prediction for each country/ACC in 2040	STATFOR [24]
	'000 # IFR flight hours per year	Flight hours for each upper airspace HC and VHC ACC in 2017	Flight hours projected for each upper airspace HC and VHC ACC in 2025	Flight hours projected for each upper airspace HC and VHC ACC in 2040	ANS Performance Repository

Table 10: SESAR Solution PJ.06-01 CBA Solution Scenario

Project: CBA PJ.06	Comment	Value

Project: CBA PJ.06	Comment	Value
Location:	Europe	HC/VHC and targeted MC ACCs
kind of CBA:	Maturity level	V3
Investment start	Years before IOC	2
% OPEX from CAPEX	From input partners	3.92%
PJ.06-01 IOC	Initial Operational Capability	2027
PJ-06-01 FOC	Full Operational Capability	2035
Gap year [end Basic - start Advanced] PJ.06-01	year	2
Basis:	Reference Year	2017
Implementation duration	N/A	4
Days of training	Days	4

Table 11 PJ.06-01 Project and scenario characterisation (from CBA xlsx model)

CBA inputs:			Comments
Average flight length	NM	635	STD Inputs Eurocontrol 2018 for IFR in ECAC
Average flight duration	min/flight	90	Common Assumptions 2019
cost of CO^2/ton	€/ton	4,30	Calculated with expert judgement based on reference value in STD Inputs: 5,8€
tons CO^2 / tons fuel		3,15	STD Inputs 2018: 3,15
Average fuel burn per min of flight	tons/min	0,049	DLH feedback. SDM currently uses 0,049
Flight Time airborne en-route phase per nautical Mile	(min/NM)	7,30	DLH feedback, value used by NM and SDM
fuel burnt / kg weight (mean flight)	%	6%	DLH feedback, for an A320. Tankering recommendations could counterbalance this

Table 12 PJ.06-01 Inputs, figures and sources (from CBA xlsx model)

4 Benefits

4.1 Overall contribution to performance

Benefits per stakeholder group have been identified based on the PJ.06-01 BIMs that were developed in the context of the OSED task and are presented in the Annexe A of the PJ.06-01 V3 SPR-INTEROP/OSED Final Version [20].

Qualitative descriptions and quantitative assessment description of the potential benefits per stakeholder group are provided in Section 4.2. CBA V3 successfully achieves benefit quantification and benefit monetisation mechanisms were developed and integrated in the CBA Model as well. Benefits have been estimated for HC and VHC airspace for the candidate regions over the time horizon of the CBA, from **2019 to 2040** taking into consideration a ramp up period for the OI (Basic Solution) and optional Enablers (Advanced solution) based on current implementation status (Monitoring view 2017) and PCP regulation. Project implementation timeframe is based on the Initial Operational Capability (IOC) to the Full Operational Capability (FOC), as defined in eATM Draft Dataset DS20.

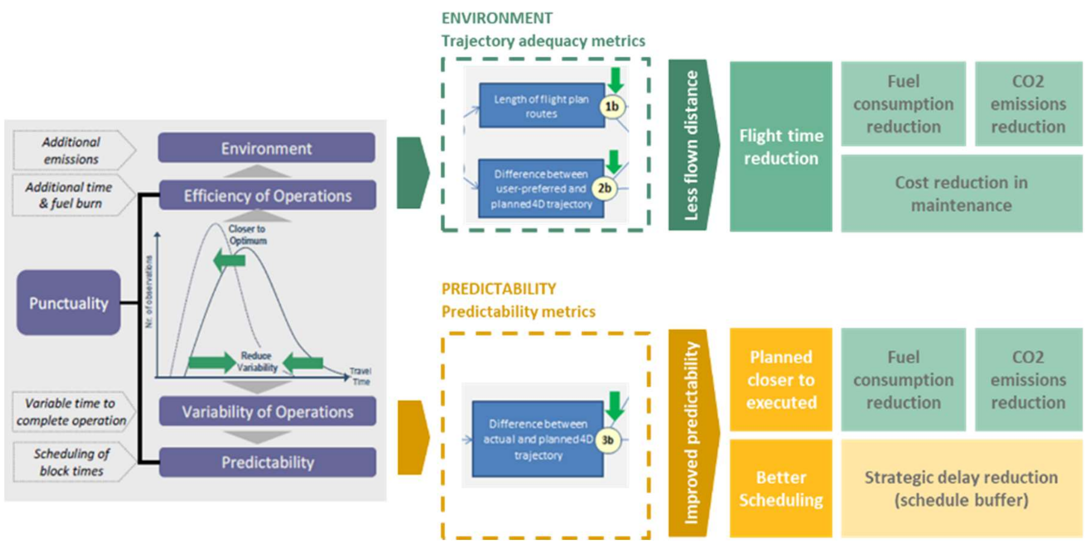


Figure 12 Benefits breakdown structure by type of metrics in order to monetise

<u>**Note:**</u> Benefits quantified as strategic delay reduction coming from reduced variance of flight variability have been finally discarded, due to lack of evidence in Validation Exercises and no other benefit mechanism to model such improvements. The CBA is also assuming no negative or positive effect on airspace capacity KPA, further details on the topic can be found in Section 4.6 of the PAR [21].

It is to note that due to lack of information and difficulty to extrapolate to different ANSPs different from the ones from the validation exercises, Airspace Users benefits quantifications are based on KEP/KEA data and on performance assessment exercises or validation targets. The objective is to check if both approaches give similar estimations of the benefits and this serves as a cross-check exercise.

Airspace Users benefits have been assessed using actual and forecasted data. The level of confidence on the calculations provided is high since they are based on actual data and modelling flight efficiency with airspace complexity seems reasonable to experts.

However, CBA lists hereby the relevant validation targets:

- PJ06.01 aims to improve flight efficiency in 27.69 kg of fuel burn/flight in High Complexity (HC) and Very High Complexity (VHC) En-Route (ER) airspace. PJ.06-01 contribution depending on the complexity of the ACC is:
    - 17.72 saving kg/flight for ER VHC
    - 9.97 saving kg/flight for ER HC
- PJ06.01 aims to improve predictability in 0,930% in variance corresponding to an improvement in the standard deviation of the schedule buffer
    - 0.595% reduced variance for ER VHC
    - 0.335% reduced variance for ER HC

The benefits in terms of predictability were not evidenced in validation exercises, hence it was decided not to quantify and monetise them in the CBA. Using VTs to assess benefits is sometimes done in V1 or V2, but not acceptable in V3.

An important input to the CBA is the extrapolation ECAC wide of the benefits in 2035. The process to calculate such benefits started from assuming a flight time reduction between 1min and 1.5min from total average flight duration. The numbers were assessed by experts, so it was decided to maintain a data-driven model for the CBA, but the values will be compared to determine how close the approaches are. The full computations in the PAR [20] are:

Fuel reduction (in %) in Very high and high complexity = (F-0005ENR 66%) x 1.1% to (SESAR2020 Common Assumption F-0005ENR 66%) x 1.7% = -0.72% to -1.11%

Fuel reduction (in kg) in Very high and high complexity = (SESAR2020 Common Assumption F-0001 ALL 4800kg) x -0.74% to (SESAR2020 Common Assumption F-0001 ALL 4800kg) x -1.11% = 34.56kg to 53.28kg

Concept apply to high and very high complexity En-Route Airspace (SESAR2020 Common Assumption ENR-VH + ENR-H) = 57.61% of the traffic (see below excerpt from the SESAR2020 Common Assumption).

Expert assumption for Year 2035 is that 80 to 100% of the Airspace will be FRA and 90% of the flights will fly FRA (Note: it only applies to upper levels, however this estimate does not consider this granularity).

NB flight impacted = 72.0% to 90.0% x (SESAR2020 Common Assumption M-0015ALL 37839) =27,244 to 34,055 flights/day

ECAC Fuel reduction in kg FEFF1 = 72% x-34.56 to 90% x-53.28kg = **- 24.88 kg to -47.88 kg** as average per ECAC flight

ECAC Fuel reduction in % FEFF1 = 72% x-0.72% to 90% x-1.11% =-0.52% to -0.99%

As for the CBA, the results in terms of SESAR2020 KPIs obtained using the model and compared to PAR are:

	PAR	CBA
% of Traffic in the implementing ACCs	57.61% (HC and VHC 2019)	64.6% (2025)
% of traffic impacted	72% to 90% (2035)	72.2% (2035)
FEFF1 yearly benefit (kg/flight)	24.88 kg to 47.88 kg (2035)	29.22 kg (2035)* 20.06 kg (2035)**

Table 13 Overall contribution to performance comparison PAR and CBA

The conclusion is that the CBA model based on actual and targeted KEA based on data-driven analysis and complexity of the airspace is aligned with the estimations based on expert judgements. In fact, the CBA value of 29.22 kg falls within the range given by the PAR, and is more conservative than optimistic, which is good because it also takes into account that PJ.06-02 is being deployed and will contribute with its own benefits. The second value which is the benefits divided by 90% of all flights in 20.06, close to the lower limit given by the PAR but also more conservative, since there is also PJ.06-02 solution to deliver benefits from FRA.

* Total benefits divided by the flights flying FRA

** Total benefits divided by 90% of ECAC flights

Performance Framework KPA	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year 2027	Year 2030	Year 2040
Predictability and punctuality	Predictability	**PRD1** Variance of Difference in actual & Flight Plan	Minutes^2	Strategic delay cost (avoided-; additional +)		0	0	0
Environment	Fuel Efficiency	**FEFF1** Average fuel burn per flight	Kg fuel per movement	Fuel Estimated costs	Kg fuel/flight (flying FRA airspace)	4.09	21.68	30.97
	Fuel Efficiency	**FEFF2** CO_2 Emissions	Kg CO_2 per movement	CO_2 Estimated costs	Kg CO_2/flight (flying FRA airspace)	12.88	68.30	97.57
	Time Efficiency	**FEFF3** Reduction in average flight duration	Minutes	Strategic delay: airborne: direct cost to an airline excl. Fuel (avoided-; additional +)	Min/flight (flying FRA airspace)	0.08	0.44	0.63

Table 14: Results of the benefits per KPA expressed in terms of KPI

4.2 Benefits per stakeholder group

The benefits of this CBA are only the ones considered for AUs. Free routing in En-Route airspace including high and very high complexity environments will allow AUs to:

- Plan flights in better adequacy with their business/mission needs;
- Execute flights closer to their planned trajectories

The ability to plan flight along user preferred routes in En-Route airspace of high complexity and across ACC/FIR borders will allow AUs to better optimise the flight plans in terms of time (more adequacy with schedule) and/or flight distance (shorter) and /or fuel and cost (more efficient) in regards with their business/mission needs.

4.2.1 Airspace Users Benefits

The benefits for the AUs in the Environmental KPA can be detailed as follows:

- **Shorter flight plan routes** in En-Route airspace means lower fuel consumption and less planned flight emissions (CO2 / NOX). This links to Environment / Fuel Efficiency (PI FEFF1.1 - Planned Average fuel burn per flight), represented by box (1b) in BIM.
- Ability to plan flight in FRA in optimised alignment with business needs will result in a **better adherence of the planned 4D trajectory to the user-preferred/optimal trajectory**. The resulting higher adherence to the user-preferred trajectory will give the opportunity to AUs to plan for routes with minimal fuel index, so fuel consumption, and consequently flight emissions (CO2 / NOX), will be reduced in En-Route, which links to Environment / Fuel Efficiency (PI FEFF1.1 - Planned Average fuel burn per flight). This benefit is depicted in box (2b) of the BIM.

The benefits for the AUs derived from the Predictability KPA can be further described as:

- The ability to plan flights along user preferred routes (close to business needs) will allow AUs to **fly much closer to planned trajectories** as the flight plan will be in optimised alignment with business needs (with for instance less tactical directs requested by pilots or given by ATCO to expedite the traffic). In other words, the **difference between planned and executed trajectories will be reduced**.

  The resulting higher adherence to the planned, optimised and possibly shorter, trajectory in En-Route airspace will improve:

  - Fuel consumption and flight emissions (CO2 / NOX), which links to Environment / Fuel Efficiency (KPI FEFF1 - Actual average fuel burn per flight; PI FEFF2 - Actual Average CO2 Emission per flight).
  - In-flight duration and its variability: there will be less trajectory revisions in En-Route, so RBT durations will be shorter and more stable, which links to Predictability (KPI PRD1 - Variance of Difference in actual & Flight Plan or RBT durations; PRD6 - En-Route variability).

4.2.1.1 Flight time, Fuel and CO^2 savings thanks to less flown distance

The following benefit quantification mechanism was used for the flight efficiency benefits thanks to less flown distance in the CBA (FEFF1, FEFF2):

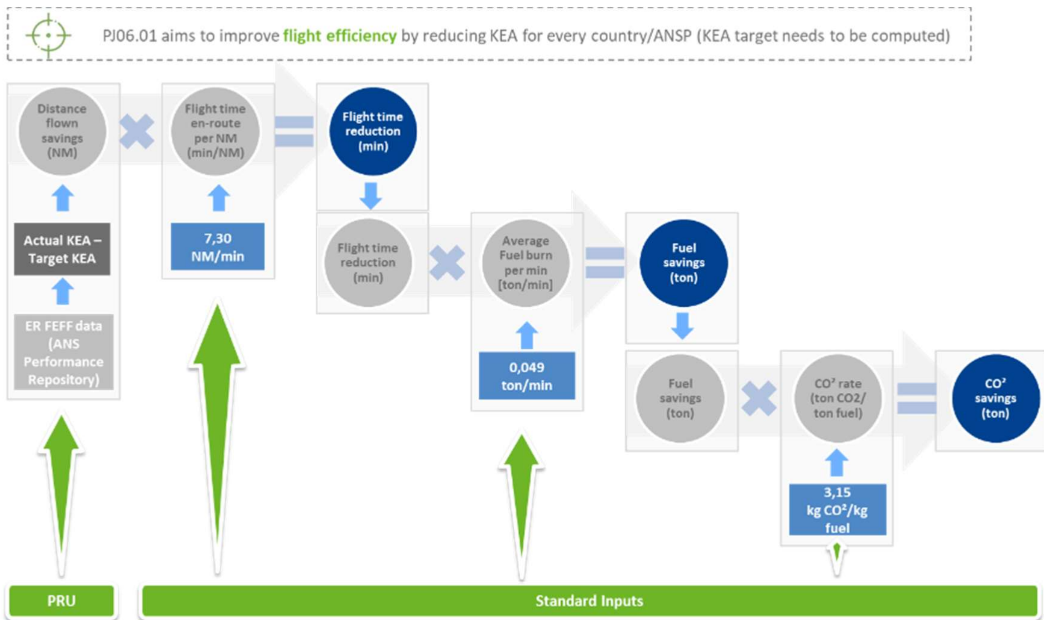


Figure 13: Fuel and CO^2 savings due to less flown distance – CBA benefit quantification mechanism

The amount of flight efficiency benefits in term of fuel efficiency was checked by comparing it to the validation targets and Free Route Airspace benefits performed by the Network Manager using one day traffic sample from 30/06/2017. The assumptions of the simulations are:

- H24 Simulation with date 30/06/2017
- 37 209 IFR flights
- No military traffic nor reserved areas taken into account
- TMAs not excluded
- Neither ATFCM regulations nor re-sectorisation applied

As a consequence, results show potential (or maximum achievable) benefits derived from FRA implementation. The CBA experts estimated some factors to take into account non-ideal conditions, mainly reduce the benefits because FRA is not applicable to TMAs, and is limited when there are airspace reservations due to military or other purposes. The corrective factors applied are summarised in the table below:

Corrective Factors	Exclude TMAs	Exclude ER hours below FL305	Take into account Military and ARES
NM FTS ACC, Regional ECAC	*0,5*	*0,5*	*0,8*

Table 15 Corrective factors to compare FRA simulation benefits with CBA benefits

Those corrective factors are also assumptions of the CBA and should be discussed and validated with operational experts. Nevertheless, the results seem to be coherent and at least comparable in order of magnitude to the benefits computed through the data-driven approach using KEA.

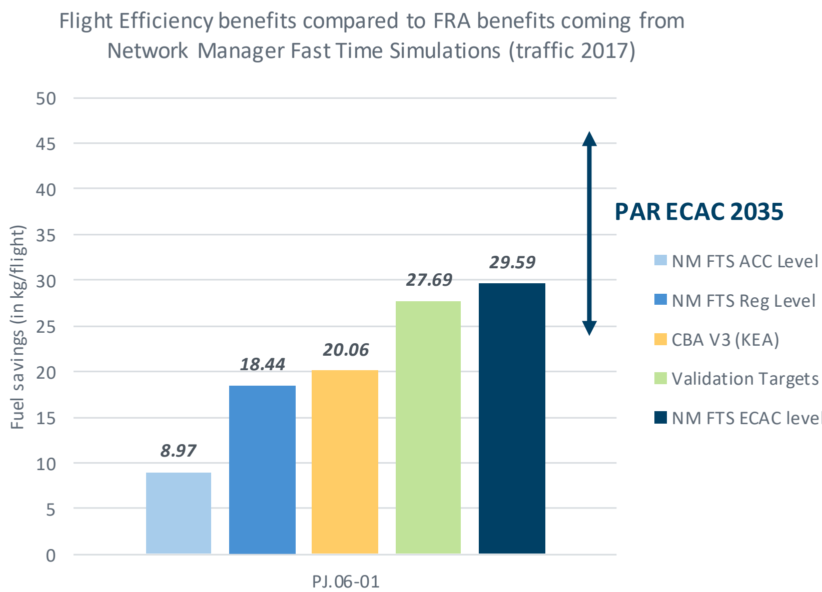


Figure 14 CBA Flight Efficiency benefits compared to FRA Fast-Time simulations performed by Network Manager after applying corrective factors (one day traffic 2017)

The outcomes of this comparative analysis is that the CBA benefit model is quite similar to the validation targets, aligned with FRA simulations at Regional Level and significantly less than full ECAC-wide FRA.

4.2.1.2 Airborne tactical maintenance estimated costs savings thanks to flight time reduction

The following benefit quantification mechanism was used for the AUs cost-efficiency benefits derived from flight time reduction (FEFF3):

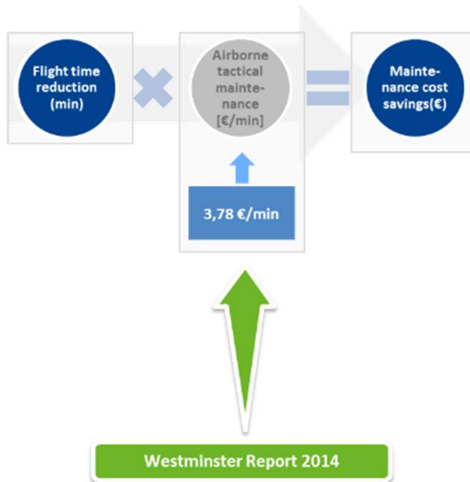


Figure 15 Maintenance estimated costs savings thanks to reduced flight time

4.2.1.3 Fuel and CO^2 savings thanks to reduced difference between executed and planned trajectories (less fuel uploaded)

The following benefit quantification mechanism was used for the AUs cost-efficiency benefits derived from better adherence of the actual flight to the flight plan (FEFF1, FEFF2):

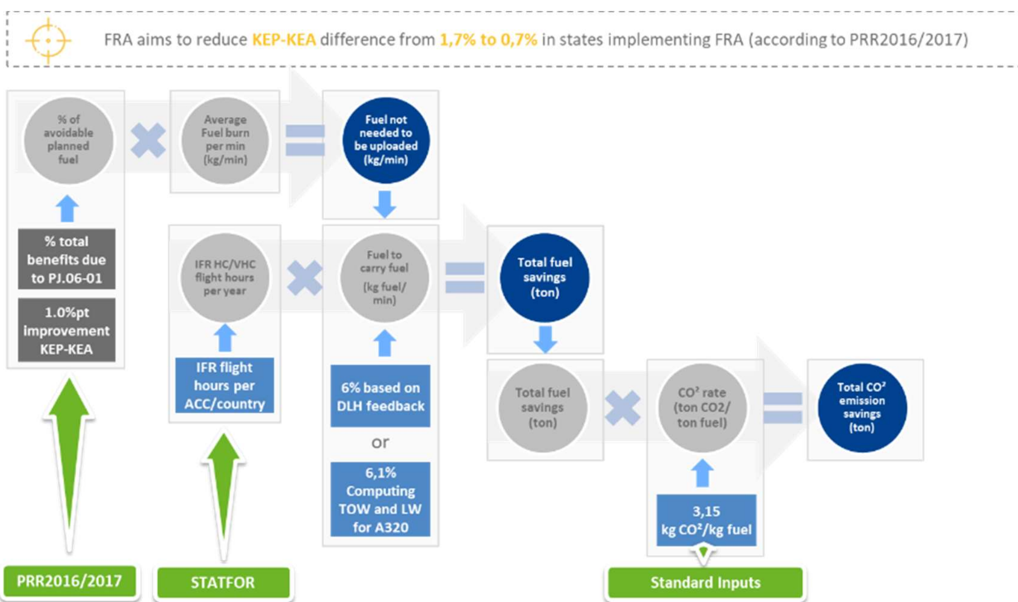


Figure 16 Fuel and CO^2 savings thanks to improved predictability leading to better planning

It is important to note that this benefit was discussed with AUs (Lufthansa); their feedback was that it could be counterbalanced by tankering recommendations due to differences in fuel price across different European countries and airports. Nevertheless, it was decided to keep the benefit because it exists. In the case airlines would rather upload more fuel than required, the benefit would just be translated into savings in fuel cost (computed by subtracting the amount of extra fuel uploaded by a fuel price difference).

4.2.1.4 Reduced strategic delay thanks to improvement in scheduling buffer (Finally not included in the CBA due to lack of evidence)

PJ.19 WP4 2019 Validation Targets document estimates a 0,335% predictability improvement for HC and 0,595% for VHC compared to the Reference Scenario. The benefit quantification mechanism depicted in the figure below could be used for the strategic buffer reduction benefit fostered by less difference between flown and planned trajectories (PRD1):

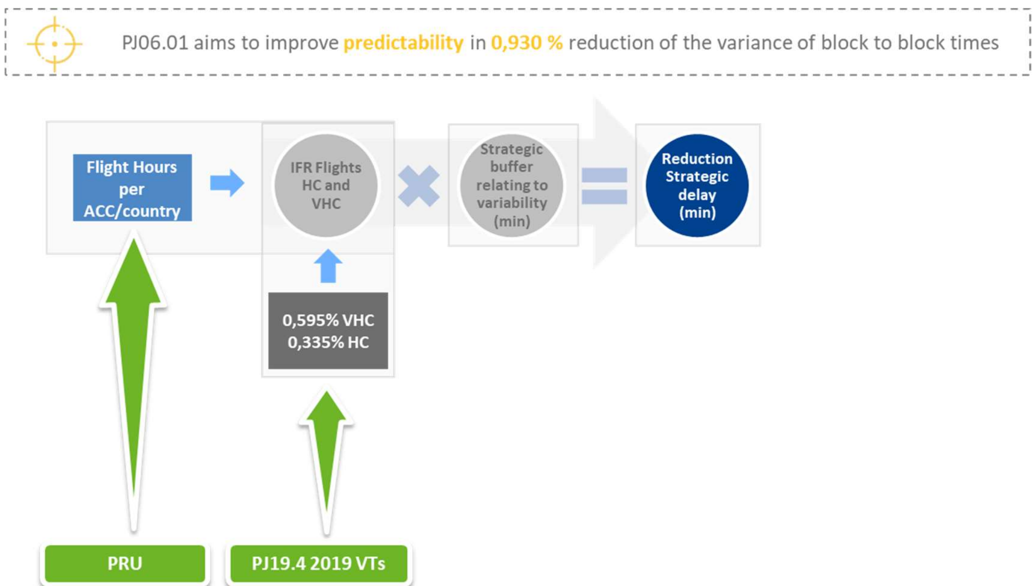


Figure 17 Strategic buffer benefit

However, advice from experts at Skyguide is that the validation targets for predictability improvements are very questionable. At least for Skyguide's airspace they believe that FRA might result in capacity reductions in highly complex airspaces that are already operated at capacity limits and minimum sector size. Therefore, the authors want to highlight the uncertainty behind the validity of predictability targets, and the risk that further validation exercises and operational trials could reveal even a negative contribution on predictability and/or a lower capacity. Further details on airspace capacity impact can be found in Section 4.6 of the PAR [21].

5 Cost assessment

The ***estimated costs*** for the ANSPs are linked to AOM-0505 — *Free Routing for Flights both in cruise and vertically evolving within high and very high complexity environments in Upper En Route airspace.*

Definition of *estimated costs*: Partner ANSPs and Manufacturers provided their view on estimated costs. Given that enablers in PJ.06 (thus PJ.06-01 as well) are not in the market yet, ANSPs and Manufacturers cannot fully commit on the final selling/buying price for ANSPs, who at the end would purchase the system. Therefore the estimation is based on past experience and cost projections based on validation exercises made in SESAR2020. The ***estimated costs*** are not ***real costs***, although may have been derived from real costs data. See for instance the methodology used by PJ06 CBA group (initiative from ECTL/ALG) to go from "real costs" (published, planned) to "estimated costs" based on available ACE data.

5.1 ANSPs estimated costs

According to the deployment scenario, the AOM-0505 is the only OI expected to be deployed, through the basic and advanced solutions approach. According to PCP Implementing rule [31], all the ACCs considered are assumed to have implemented FRA by the end of 31/12/2026, so the scope of this CBA does not make any difference among the targeted ACCs. It is assumed that every High or Very High Complexity plus some identified ACCs previously mentioned will implement:

- **Basic solution:** It requires a change in the FDP and in the OLDI module. It only provides the great circle route that ATC could assign to flights in term of magnetic or true track. The technical aspect considered under this scenario is that the transfer of flights could be done through OLDI by providing aircraft position with reference to a COP or other references (e.g. WGS-84 coordinates).

  This solution could be used in high traffic complexity environment, but where conflicting points are rather stable in 2-D dimension. Furthermore, airspace is rather static (absence or low utilisation of military training areas).

- **Advanced solution:** it is built upon the Basic Solution. It requires a change in the FDP, in the OLDI module and in MTCD configurations (one for the executive and one for the planner). It also requires a constant monitoring of the level of traffic complexity, awareness of airspace configuration (intense use of military training areas), and MET inputs (e.g. wind aloft) to determine the heading with wind correction and/or circumnavigation of thunderstorm cells.

  The solution provides for the great circle route that ATC could assign to flights in term of magnetic or true track until reaching the first STAR fix at the arrival airport. Early detection of conflicting points through MTCD. Transfer of flights could be done through OLDI by providing aircraft position with reference to a COP or other references (e.g. WGS-84 coordinates).

  This solution could be used in high or very-high traffic complexity environment, where conflicting points are variable due to changes in weather condition, military training area utilisation and spatial traffic variation (e.g. due to oceanic landmark changes).

5.1.1 ANSPs cost approach

A bottom-up approach was used to estimate the ANSPs pre-implementation, implementation and operating costs. The scope of each enabler was analysed, discussed, reviewed and challenged within the CBA team as well as with other operational and technical experts in the PJ.06 ToBeFree project.

With the support of the partners it was possible to associate a cost to each enabler. Inputs for enabler estimated costs were then aggregated at each basic or advanced solution level.

Implementation estimated costs include all type of estimated costs: hardware/software investment, integration estimated costs, initial training estimated costs and other one-off estimated costs.

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

Table 16 Cost categorisation for PJ.06-01

The cost model used keeps track of all the estimated costs associated with implementing a project from an ANSP perspective. Pre-implementation estimated costs are incurred prior to the implementation year. Implementation estimated 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. Operating estimated costs are also included in this model, computed as a percentage of capital expenditure estimated costs based on the three cost inputs gathered from partner ANSPs.

In order to crosscheck the reliability of the information provided, the inputs of the cost assessment were compared to an analysis performed with data coming from ACE Report and LSSIP report per each country in order to see if the figures could correlate with the ATM investment of each particular ANSP and the plans for the FDPS system. Figure 18 depicts the general methodology of the cost model developed in the PJ.06-01 CBA V3.

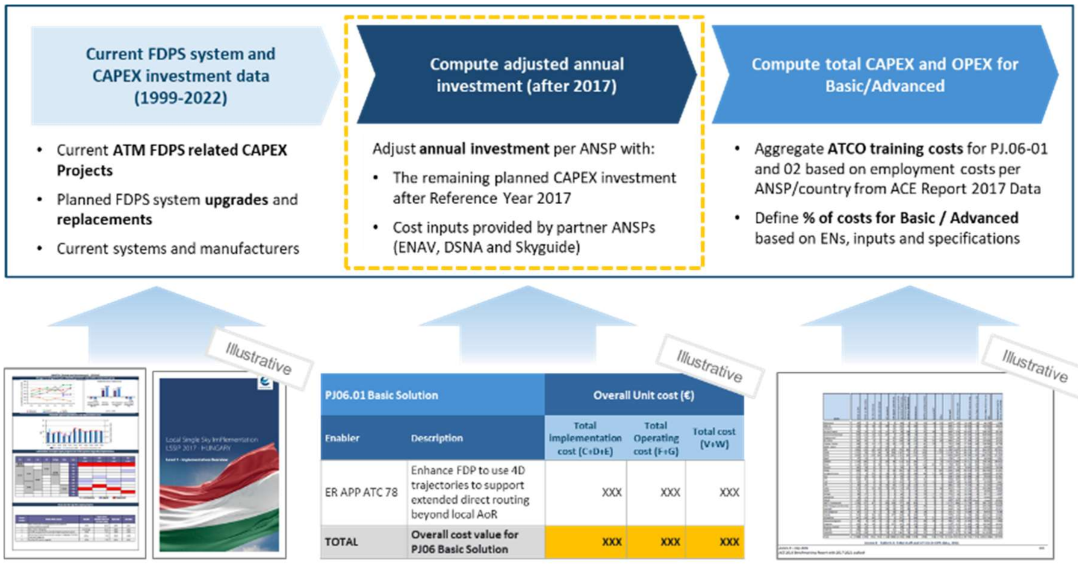


Figure 18 Cost Model general methodology and sources used

Note that the cost assessment in V3 phase is looking for a precise estimation of the deployment estimated costs, so the numbers had to be carefully analysed and a cost model had to be developed according to those inputs and real data as published by ANSPs. Several possibilities and multiple architecture options exist that could support the implementation of basic and advanced solution. The scope and the scale of services to be provided are difficult to be assessed, leading to some unavoidable uncertainty about the level of development that would be required regarding ANSP systems.

Further detail about the cost model computations and workflow is depicted in Figure 19.

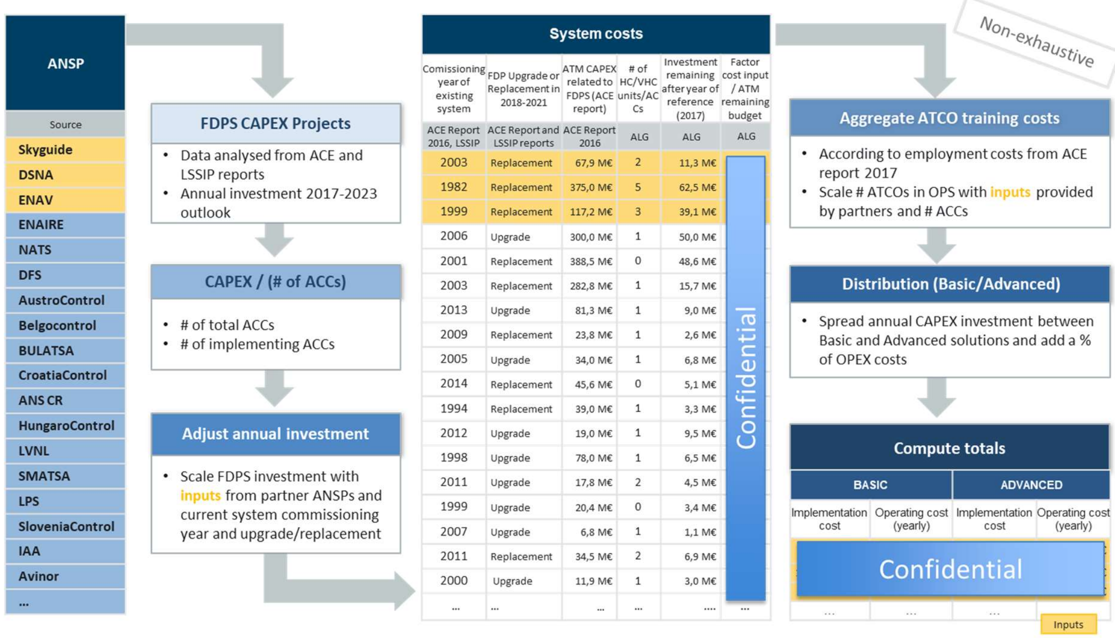


Figure 19 Cost Model structure and workflow

The level of granularity for the estimated costs is the ANSPs, for which available information about the current FDPS systems are available, mainly including commissioning year of the current system manufacturer, plans for future upgrades/replacements. That information is published in the LSSIP Reports, the most updated ones are from 2017. On the other hand, the earmarked ATM investments that could be directly related to FDP systems can be obtained from the ACE Report. The last version of the document also dates from 2017.

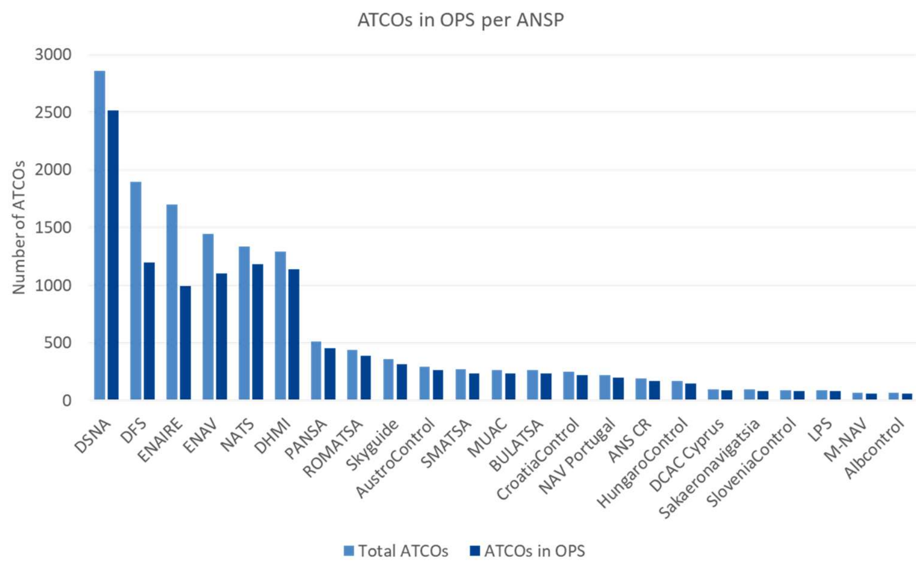


Figure 20 ATCOs in OPS eligible for training in PJ.06-01

The ATCO employment cost per day has been computed from the annual figure per ANSP, considering its total number of ATCOs in OPS and assuming 205 working days at 8 hours per day. Then the ATCO training estimated costs have been calculated by assuming that the same ratio of ATCOs per ACC as declared by contributing partners, will undergo a certain number of days of training and multiplying this number by the ATCO employment cost per day depending on the ANSP.

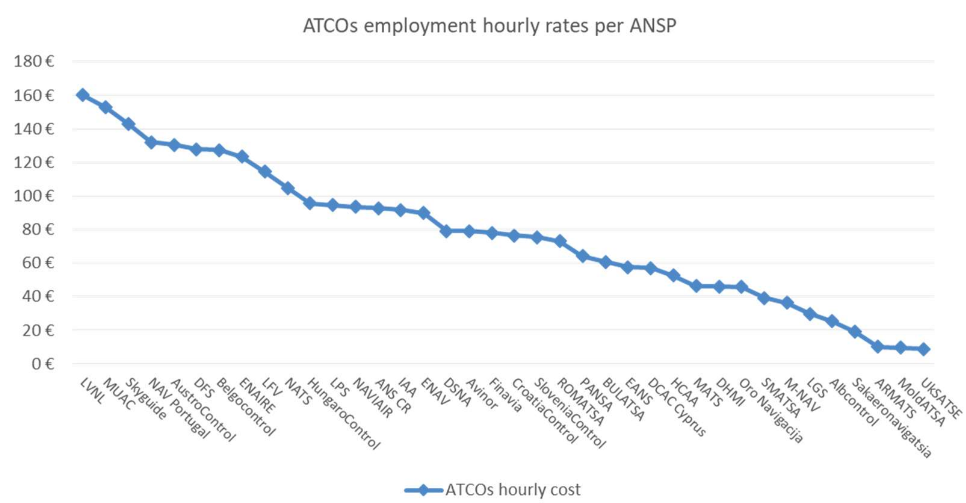


Figure 21 ATCOs employment hourly estimated costs estimation based on ACE Report 2017

5.1.2 ANSPs cost assumptions

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

- CBA assumes that the basic solution is deployed in all High and Very High complexity ACCs. The associated NM investments are also achieved but are not considered in this CBA. As PCP demonstrated, overall NM estimated costs for AF # 3 Flexible use of airspace and Free Route represented less than 0,02 bn € of a total of 0,7 bn €, that is approximately 2% of total investment.
- In line with the PCP Regulation, no pre-requisite elements for the PJ.06-01 Basic Solution are defined, thus they are considered also non-existent for this CBA.
- Implementation occurs in a 4-year transition period, where total estimated costs have been spread equally. This is also consistent with PCP cost distribution in 4 years, which considers almost the same annually percentage of cost.

The following assumptions were also made:

- Estimated costs are presented at solution (Basic or Advanced) level but estimation has been made at enabler level before being aggregated. All associated estimated costs are included (hardware/software investment, integration estimated costs, training estimated costs….).
- Declared investments in FDPSs by ANSPs, as quoted in EUROCONTROL ACE Report 2016 [32], have been understood to entail a system procurement portion, paid by the ANSP to the provider of the system, plus a portion which is incurred only when deploying a new FDPS. This has been modelled according to the upgrade/replacement plans declared in the report.
- OPEX relative to the FDPS are computed as a recurrent annual fraction over the CAPEX. To this end, the ratio of OPEX over FDPS procurement CAPEX as determined from inputs by partners has been applied to all ANSPs included in the CBA. This proportion ensures that, since FDPS CAPEX is relative to the ANSP financial data, OPEX also respects the same relationship.

5.1.3 Number of investment instances (units)

ANSP	Total number of controlled ACCs	Number of PJ.06-01 implementing ACCs
DSNA	5	5
ENAV	4	3
Skyguide	2	2
ENAIRE	5	2
NATS	2	2
DFS	4	2
AustroControl	1	1
BULATSA	1	1
CroatiaControl	1	1
ANS CR	1	1
HungaroControl	1	1
LPS	1	1

ANSP	Total number of controlled ACCs	Number of PJ.06-01 implementing ACCs
SloveniaControl	1	1
ROMATSA	1	1
MUAC	1	1
DHMI	1	1
TOTALS	**32**	**26**

Table 17: Number of investment instances - ANSPs

5.1.4 Cost per unit

The cost model results in detailed estimations at ACC level based on the published figures of total investment in ground FDP. Unit cost varies within Europe depending on the earmarked investment in ground ATC system, commissioning year of the currently installed system and plans for its upgrade or replacement.

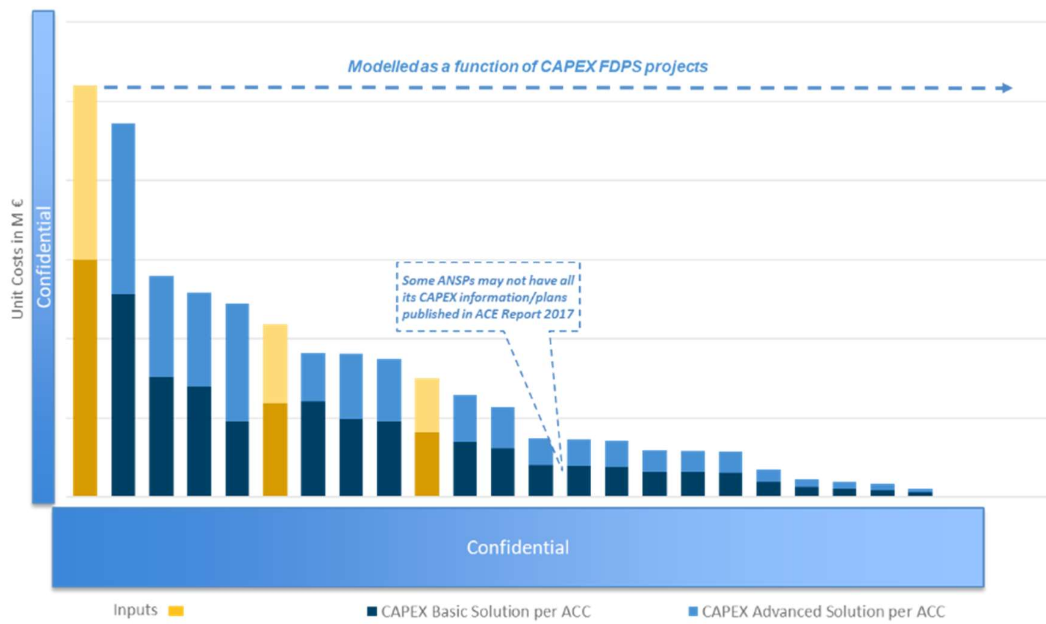
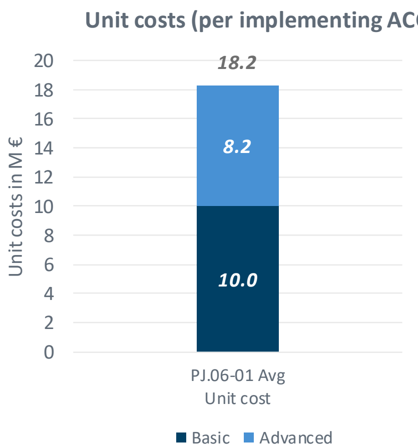


Figure 22 PJ.06-01 Unit cost (per ACC) modelled for each implementing ANSP

Average unit cost results in around 18.2 M € whilst totals amount for 309 M € and 261 M € for Basic and Advanced solutions respectively.



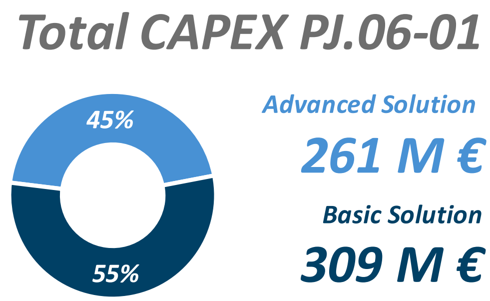


Figure 23 Average unit cost (per implementing ACC) considering all the implementing ACCs

Figure 24 Total CAPEX for PJ.06-01 implementation at ECAC level

Main conclusions is that the order of magnitude of the overall estimated costs (Basic + Advanced) is somewhat greater than the unit estimated costs computed for the PCP (around 15 M€), although many differences exist between the two systems, since PCP AF#3 Unit cost for VHC and HC ACC entails functionalities to cover Advanced Flexible Use of Airspace (AFUA) as well. It is difficult to know what amount could be attributable to Free Route functionalities in order to obtain more easy-to-compare figures. For all these reasons, one could say that Free Route system estimated costs as in PCP would be significantly less to those estimated for PJ.06-01.

6 CBA Model

The PJ.06-01 V3 CBA Model (xlsx file) is also attached as supporting document of the CBA report. This CBA Model has been developed in Excel and aims at calculating the estimated costs and benefits of the implementation of PJ.06-01 Solution based on the Deployment Scenario approach that has been defined in the context of the CBA task and in the context of SESAR2020 Wave 1 Framework.

Draft_PJ06_CBA_v1.0_
attached.xlsx

It must be pointed out that all estimated costs are analysed in the form of a "delta", this is as the difference between a current scenario where operations continue "as usual" and an implementation scenario, where PJ.06-01 is adopted by the stakeholders considered.

Such a current scenario has not been modelled as part of the analysis. Instead, estimated costs and benefits have been computed with this intrinsic delta, whereby only incremental estimated costs and benefits over the baseline scenario are computed in the model. This results in a leaner and simpler model with a clearer view of the value of PJ.06-01 solution for each stakeholder and on a global project scale. It provides an overview of the estimated costs for ANSPs and a view on the expected benefits for Airspace Users.

This model is built to support strategic decision-making and although it does not aim to achieve 100% accuracy, it aims to be a good tool to model the problem and obtain results that should be close to the real characteristics of the solution.

6.1 Data sources

The data sources used in the CBA Model are referenced in the Table 18: Data sources for Reference parameters used in the CBA Model.

Variable	Source	Comments
ECAC Traffic 2019 – 2040 (IFR flights)	EUROCONTROL - European Aviation in 2040 – Challenges of Growth [24]	
Fuel price (€/Kg)		
CO2 Tax (€/Ton)		
Emission of CO2 per ton of fuel burnt	EUROCONTROL – Standard Inputs 2018 [25]	
Discount Rate (%)	EUROCONTROL – Standard Inputs 2018 [25]	
Average flight length	EUROCONTROL – Standard Inputs 2018 [25]	
Average flight duration	EUROCONTROL – Standard Inputs 2018 [25]	

Airborne tactical maintenance estimated costs	Westminster Report 2014	Average computation for mixed fleet
cost of CO^2/ton	EUROCONTROL – Standard Inputs 2018 [25]	
Average fuel burn per min of flight	EUROCONTROL – Standard Inputs 2018 [25]	
Flight Time airborne en-route phase per nautical Mile	EUROCONTROL – Standard Inputs 2018 [25]	
fuel burnt / kg weight (mean flight)	Lufthansa input and internal calculation for A320	
PJ.06-01 Contribution to KPIs	Performance Questionnaire for PJ.06-01, Performance Assessment report (PAR V of the SESAR 2020 D2.1, PJ.06-01 V3 SPR-INTEROP/OSED [20] and Validation Targets report.	FEFF1 and PRED1 Validation Targets have also been considered in order to compare the results of the benefits calculations using KEA data.

Table 18: Data sources for Reference parameters used in the CBA Model

7 CBA Results

The following section provides the results of the PJ06-01 CBA at V3 Level. The results presented are already consolidated and can be considered as conclusive. The CBA has been built gathering the following information:

- The Investments estimated costs (pre-implementation and implementation estimated costs) and Operating Estimated costs have been identified for the main stakeholders impacted: ANSPs. Other estimated costs for other stakeholders have been considered as negligible.
- The impact of PJ.06-01 on the Capital Expenditures (CAPEX) has been analysed and only the estimated costs on top of what could be expected in the Reference Scenario have been estimated in the cost assessment and integrated in the CBA Model. Those estimated costs have been considered as negligible for NM.
- Benefits have been estimated and monetised in the CBA Model for Airspace Users in High and Very High complex ACCs (considering complexity forecast for year 2025). The inputs from the PJ.06-01 Performance Questionnaires, Performance Assessment and Validation Targets report have been used to compare the benefits, which have been quantified based on KEA actual data and its potential improvement (flight efficiency), and predicted improvement in KEP-KEA difference (predictability related benefits).
- No benefits are provided for Medium, Low and Very Low complexity ACCs where AOM-0505 Operational Improvement is expected to be proposed in the future whenever the aggregated traffic complexity score increases and reaches the level of High complexity.

A CBA can always be improved or refined, even if this is a CBA at V3 level. Further investigation could improve some areas. This is the case of the cost model which could be refined if more data was available, and also the estimation of the target KEA, which could be particularized for every ACC according to its nature. Recommendations are provided in section 9.

All the analysis in this Chapter presents the delta between the Solution Scenario (with PJ.06-01) and the Reference Scenario (without PJ.06-01).

The V3 CBA allows calculating the Payback year as the NPV of the Solution changes from negative to positive in the early years of implementation. This is due to the fact that estimated costs are higher than benefits (which are zero or partial) at the beginning.

Any small adding-up differences in the figures shown can be explained by the rounding of decimals.

7.1 PJ.06-01 overall results

7.1.1 Cumulated results 2019-2040

Figure 25 presents the PJ.06-01 cumulated estimated costs and benefits for the period 2019-2040, overall and for the viewpoint of every impacted stakeholder. Estimated costs and Benefits are estimated at ECAC level considering the targeted list of ACCs where the PJ.06-01 Solution is expected to be deployed according to the Solution Scenario.

The main figures to retain are:

- **Overall estimated costs** for the period total **846 M€** undiscounted (362 M€ discounted at 8% discount rate).
- The **investment estimated costs (CAPEX)** of deploying the PJ.06-01 Solution (Pre-Implementation and Implementation estimated costs) total an amount of **555 M€.**
- As from 2030 all OIs have been deployed and the **cumulative operating estimated costs** of running the Solution reaches **292 M€** at the end of the time horizon of the CBA.
- **Total benefits** expected reach **3,869 M€** undiscounted (**1 158 M€ discounted**). As a reminder those benefits include only AUs benefits.
- The Net Result anticipated for PJ.06-01 would be a **positive NPV of (+) 797 M€** with an 8% discount rate.

The cash flow analysis for the PJ.06-01 CBA V3 is presented in the graph below, with the main dates and milestones indicated.

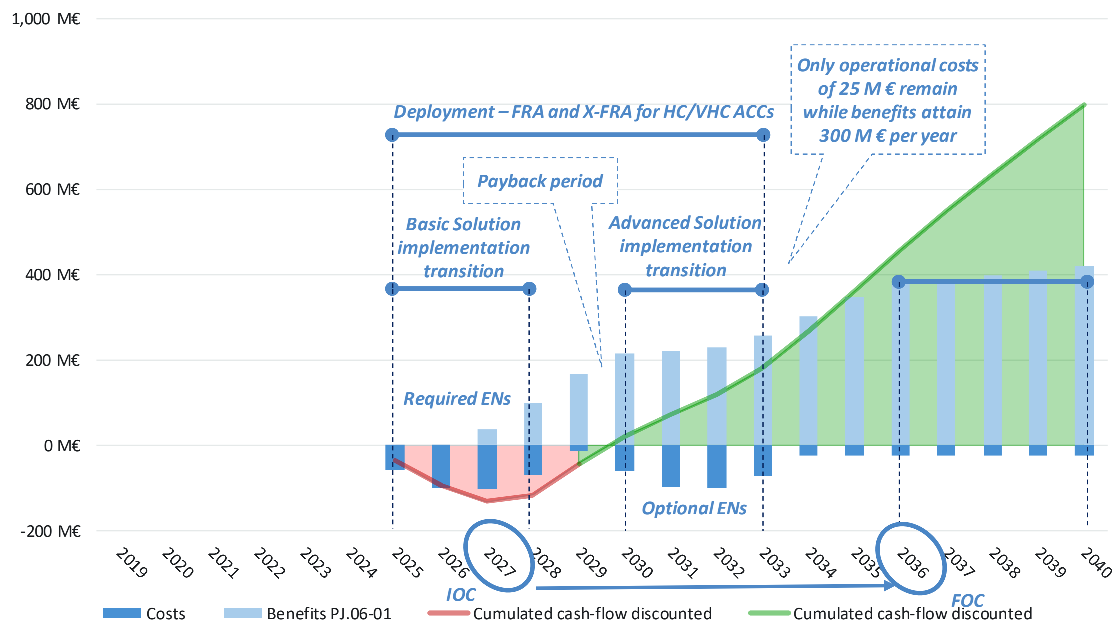


Figure 25 Cumulated results over the timeframe 2019-2040. Estimated costs start end 2024 and benefits in 31/12/2026.

7.1.2 Annual results

When Full Operational Capability (FOC) is achieved, AUs yearly benefits are sufficient to recover the incurred estimated costs from all stakeholder groups and the annual cash flow start to become positive. Table 19 presents the annual results of the CBA at FOC (i.e. in 2032) when all the OIs are deployed. The information provided is a “picture” of the situation each year. The main results are:

- The annual delta operating estimated costs once FOC is achieve raises up to 24 M€ (undiscounted), somewhat less than 1 M € per ACC in average.
- The annual benefits at FOC reach 379 M€. The benefits ramp up from 37 M€ in 2027 to 379 M€ at FOC and continue to increase afterwards in line with traffic to reach 420 M€ in 2040.
- As from 2030, the annual benefits expected would pay off the annual estimated costs that started in 2025 and would return a net annual positive return each year. Hence, payback period would result in 5 years.

Year	2019	2020	2021	2022	2023	2024	2025	2026
Sum up benefits PJ.06-01	0	0	0	0	0	0	0	0
Sum up estimated costs PJ.06-01	0	0	0	0	0	0	- 59	- 100
Discounted estimated costs	0	0	0	0	0	0	- 37	- 58
Discounted cumulated estimated costs	0	0	0	0	0	0	- 37	- 95
Discounted benefits	0	0	0	0	0	0	0	0
Discounted cumulated benefit	0	0	0	0	0	0	0	0
Cash Flow	0	0	0	0	0	0	- 59	- 100
Cash Flow discounted	0	0	0	0	0	0	- 37	- 58
Cumulated cash-flow	0	0	0	0	0	0	- 59	- 159
Cumulated cash-flow discounted	0	0	0	0	0	0	- 37	- 95

Year	2027	2028	2029	2030	2031	2032	2033
Sum up benefits PJ.06-01	36	100	168	215	222	229	257
Sum up estimated costs PJ.06-01	- 104	- 69	- 12	- 62	- 97	- 101	- 72
Discounted estimated costs	- 56	- 34	- 6	- 27	- 39	- 37	- 25
Discounted cumulated estimated costs	- 151	- 186	- 192	- 218	- 257	- 294	- 319
Discounted benefits	20	50	78	92	88	84	88
Discounted cumulated benefit	20	70	147	240	328	412	499
Cash Flow	- 67	31	156	152	124	128	185
Cash Flow discounted	- 36	15	72	65	49	47	63
Cumulated cash-flow	- 226	- 195	- 39	113	238	365	550
Cumulated cash-flow discounted	- 132	- 116	- 44	21	71	118	181

Year	2034	2035	2036	2037	2038	2039	2040
Sum up benefits PJ.06-01	301	347	379	388	399	409	420
Sum up estimated costs PJ.06-01	- 24	- 24	- 24	- 24	- 24	- 24	- 24
Discounted estimated costs	- 8	- 7	- 7	- 6	- 6	- 5	- 5
Discounted cumulated estimated costs	- 326	- 333	- 340	- 346	- 352	- 357	- 362
Discounted benefits	95	101	102	97	92	88	83
Discounted cumulated benefit	594	695	798	895	987	1 075	1 158
Cash Flow	277	323	355	364	374	385	395
Cash Flow discounted	87	94	96	91	87	82	79
Cumulated cash-flow	827	1 150	1 504	1 869	2 243	2 627	3 023
Cumulated cash-flow discounted	268	362	458	549	636	718	797

Table 19 Annual results (estimated costs, benefits, cash flow calculations) in Million €

7.1.3 Cumulated cash flow

Figure 26 shows the cumulative cash flow of the PJ.06-01. The dark blue bars below the horizontal axis represent the different yearly estimated costs incurred by ANSPs. The light blue columns over the horizontal axis show the yearly benefits (for AUs). The red area represents the first cumulative losses due to early investments, whilst the green shaded area shows the cumulative net (savings) brought by the solution.

The estimated costs of Deployment (Pre-Implementation and Implementation Estimated costs) last until the end of 2028. The cumulative net cash flow shows a negative slope only from 2020 to 31/12/2026. The model data shows that as from 31/12/2026 the solution starts delivering small benefits but it is not until the beginning of 2028 that the benefits become apparent in the graph with the first light blue column.

In 2032 when all OI are operational (FOC), the yearly benefits start to exceed the yearly estimated costs. In Figure 26 this is translated into a positive slope for the cumulative benefits until the end of the timeline. But breakeven point cannot be achieved in the time horizon due to the partial benefits estimation.

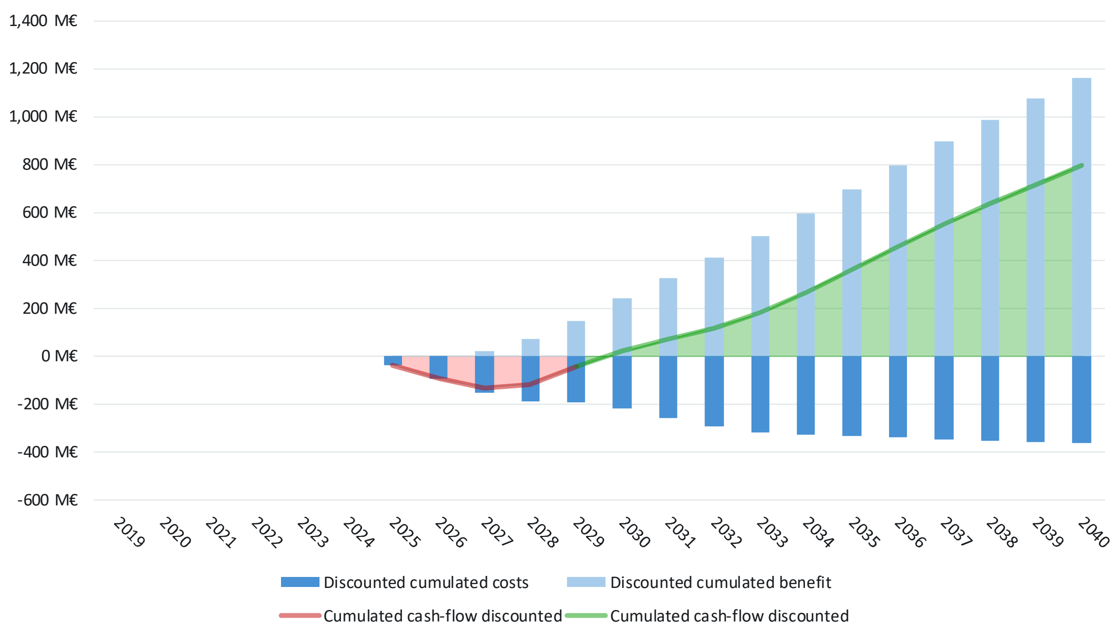


Figure 26 Discounted cumulated annual benefits, estimated costs and cash flow

7.2 Stakeholders results

This CBA report does not include separate cash-flow calculations for each of the impacted stakeholders because estimated costs are directly assumed by ANSPs whilst AUs enjoy all the benefits. Thus, their separate cash flows would give a complete negative picture for ANSPs individually and a totally positive one for the AUs, in line with the estimated costs and benefits plotted in the two respective quadrants (i.e. the positive and negative) in Figure 26.

The En-Route Air Navigation Charges will constitute the main tool to transfer the ANSP implementation estimated costs into AUs operating estimated costs. Therefore it is reasonable to compare on the same cash flow analysis the overall estimated costs and benefits as presented before, without entering in the details of any redistribution mechanism between these two stakeholder categories, which could imply the risk of double counting and introducing other uncertainties in the lag times between the outflow of cash and the corresponding inflow of charges.

8 Sensitivity and risk analysis

The following section provides an initial analysis of the impact of the main uncertainties identified when designing the PJ.06-01 CBA Model and calculating the final NPV. This analysis intends to depict the global impact in the results of the CBA. The level of confidence in the results is high due to:

- there is evidence coming from Fast Time Simulations to estimate potential benefits,
- there is evidence from Validation Exercises in the order of magnitude that PJ.06-01 brings benefits in terms of flight efficiency,
- the list of enablers is stable and so are the estimated costs estimation made for the different stakeholder groups,
- the parameters that were used in the benefits quantification and the benefit mechanisms were consolidated and allow an accurate extrapolation at ECAC level.

All the analysis presented in this section are "*ceteris paribus*" meaning changing one variable at the time and leaving the others constant.

8.1 Variables analysed and associated uncertainties

Table 20 below analyses the possible impacts under the following structure:

- **Area**: represents the nature of the variable that will be analysed.
- **Variable**: further clarifies the variable/parameter that is considered.
- **Description**: describes the nature of the uncertainty/risk identified and the reasons why CBA experts have decided to consider it in the Sensitivity Analysis.

Area	Variable	Description
Benefits Flight Efficiency	Worst KEA after PJ.06	The benefit model is a data-driven approach based on KEA indicator. The model forecasts a target KEA for each ACC after PJ.06 implementation (both solutions), that is a KEA when FOC is attained (31/12/2030). This variable represents the worst-in-class ACC, the one obtaining the higher KEA after project implementation.
Benefits Flight Efficiency	Best KEA after PJ.06	This variable represents the best-in-class KEA in the benefit model. Its value was consolidated with AUs in order to be close to a realistic maximum achievable KEA, estimated to be between 1,00% and 1,25%.
Benefits Predictability	% KEP-KEA improvement	How the planned flight will get closer to the actual. The measure is related to in-flight variability reduction, in predictability KPA. The initial estimation comes from PRR2016/2017, but it seems to be an uncertain value because it depends on many other factors for every particular ACC.

Estimated costs	Year of Reference	The cost model uses earmarked investments published in ACE Report. CAPEX comes distributed among a series of projects with an associated timeframe. This variable represents the starting year from which we account the CAPEX, removing an amount considering it as previously spent. It is important to highlight that this year is independent from the CBA reference scenario, it is just an assumption of the cost model methodology.
Estimated costs	Days of ATCOs training	PJ.06-01 partners provided cost inputs that include training activities. Training estimations were different, hence it was decided to include the days of ATCO training as a sensitivity parameter.
Estimated costs	% OPEX of CAPEX	Additional operating estimated costs are also another uncertain variable, differently estimated by our partners. OPEX has been referenced to a percentage of CAPEX based on inputs received, but will also vary to assess its impact on NPV.

Table 20 Possible variables for the sensitivity analysis

- **STK**: refers to the stakeholders group impacted by the variable
- **Range of values (Baseline, Pessimistic, Optimistic)**: minimum, maximum and average values used in the sensitivity analysis to measure the impact on the overall NPV.

Variable	Variation	Baseline	Pessimistic	Optimistic
Worst KEA after PJ.06	15%	**3.00%**	3.15%	2.85%
Year of reference for the estimated costs (based on the ACE Report)	1	**2017**	2016	2018
Target KEA (2036)	0.05%	**1.25%**	1.30%	1.20%
% KEP-KEA improvement	0.2%	**1.00%**	0.80%	1.20%
Days of ATCOs training	2	**4**	6	2
% OPEX of CAPEX	10%	**3.92%**	4.31%	3.52%
Discount rate	1%	**8.00%**	9.00%	7.00%
Year IOC	1	**2027**	2028	2026

Table 21 Analysed variables produce three scenarios: Baseline, Pessimistic and Optimistic

8.2 Most sensitive variables

Table 22 provides a view on the most sensitive variables:

- Columns on the left side order the variables considering the contribution to the variance of the NPV from highest to lowest.
- Columns on the right provide the same classification but per group of variables.

Variables	NPV +	NPV -	% Diff +	% Diff -
Discount rate	936 M €	679 M €	10.8%	-9.1%
Year IOC	902 M €	695 M €	8.1%	-7.9%
Year of reference for the estimated costs (based on the ACE Report)	823 M €	765 M €	2.0%	-2.4%
Worst KEA after PJ.06	838 M €	757 M €	3.2%	-3.1%
Best KEA after PJ.06	825 M €	769 M €	2.2%	-2.1%
% KEP-KEA improvement	805 M €	789 M €	0.6%	-0.6%
% OPEX of CAPEX	802 M €	792 M €	0.4%	-0.4%
Days of ATCOs training	801 M €	793 M €	0.3%	-0.3%

Table 22 Sensitivity variables and associated computed NPVs @ 2040

The **cost-related reference year** and the **Discount rate** are the most sensitive variables and add up to nearly **70%** of the total sensitivity of the model. This is not surprising considering the importance and how late are the IOC/FOC dates in the model, as well as the cost modelling source data. However, the model is significantly solid since all the variations are small in absolute terms.

Implementation estimated costs or **changes in Operating estimated costs for AO** are the most sensitive variables of the V3 CBA. **AUs estimated costs** have a marginal impact and the **general parameters** contribute to 21% of the total variance. The **discount rate** has a non-negligible impact contributing to 11% of the variance and the scenario of the **ECAC traffic** evolution to 8%.

Finally, Figure 27 shows the representation of the Tornado Diagram and the impact of the different variables on the overall NPV.

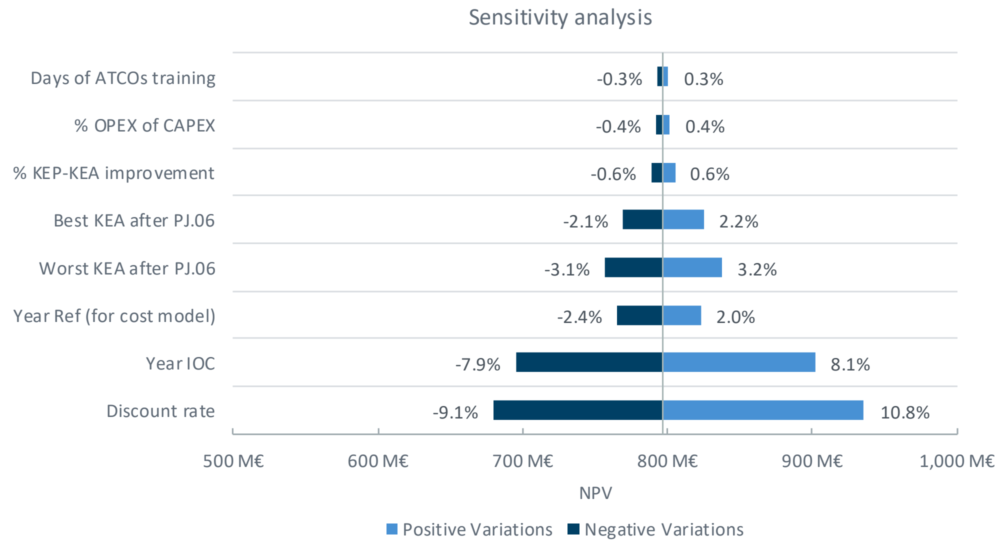


Figure 27 Tornado diagram representing the PJ.06-01 NPV @ 2040 sensitivity analysis

The Sensitivity Analysis has been useful to test the robustness of the results of the model in the presence of emulated uncertainty. It has contributed to increase the understanding of the relationships between input and output variables in the CBA.

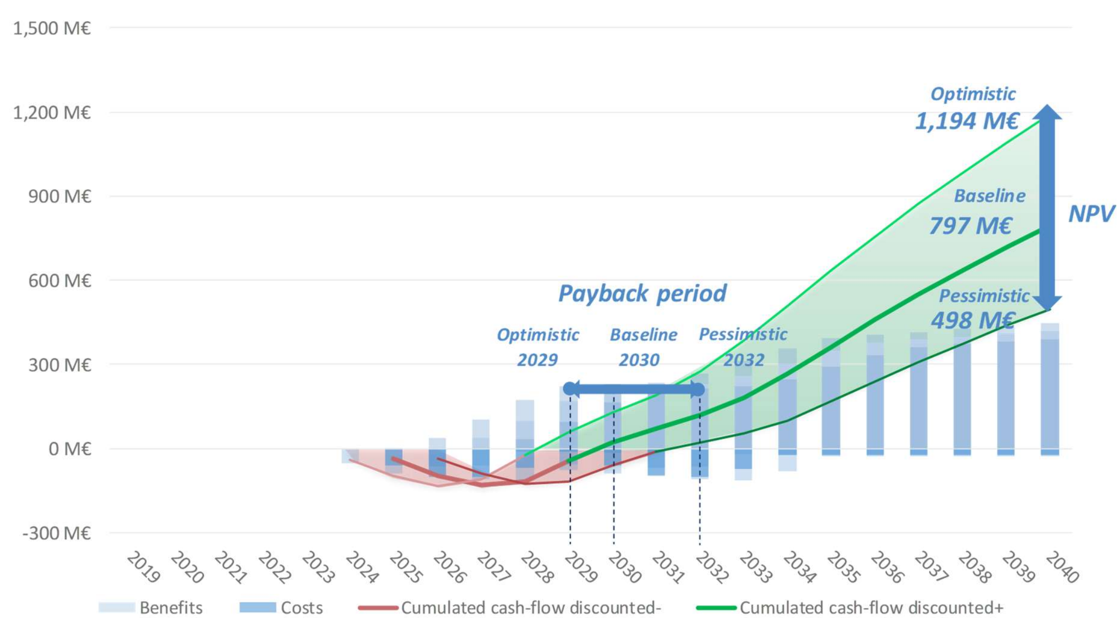


Figure 28 Cashflow for Baseline, Optimistic and Pessimistic scenarios

8.3 NPV risk profile

NPV risk modelling is an extension of the basic NPV method in which inputs to the model are allowed to vary between a maximum and minimum so as to represent the effects of risk. The model is run using Monte Carlo simulation. As the inputs vary during the simulation, the output varies in response.

Triangular probability density functions represent the risk associated with each of the selected variables and an example is illustrated in Figure 29. During each iteration of the simulation, a random value selected from the cost probability density function is used to represent the project cost and an independent random value is similarly selected for benefits.

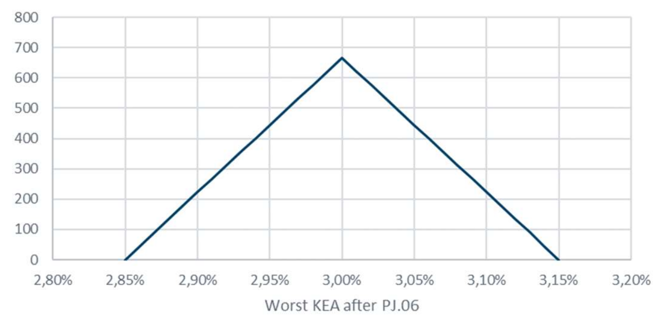


Figure 29 Triangular density function example for Worst KEA after PJ.06

After the Monte Carlo Simulations using pseudorandom values following the triangular probability density functions, the output is an NPV risk profile in the form of a cumulated probability curve that shows the nature of the oscillation of the NPV between the range values.

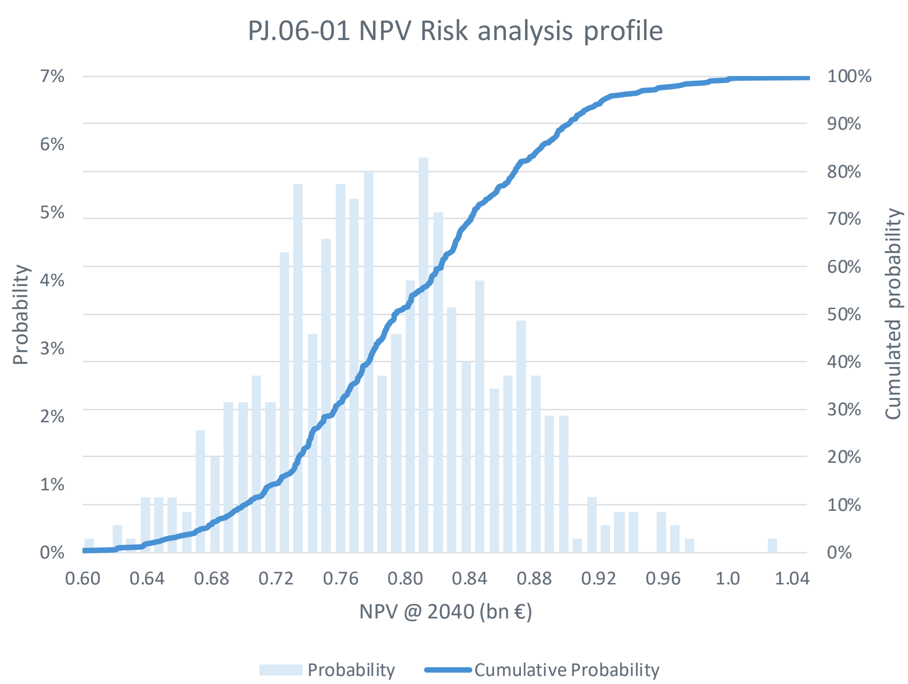


Figure 30 PJ.06-01 NPV @ 2040 risk profile using MonteCarlo Simulations of 500 samples

The reason why the NPV risk profile does not start in the minimum and maximum NPV values computed in the sensitivity analysis is precisely because triangular density functions were chosen to model uncertainty in the sensitivity parameters. This entails that values in the extremes of the range have low probabilities to occur

The NPV risk profile shows both individual and cumulated probabilities to have a certain value or range of NPV. The risk modelling exercise also produced a variety of statistical results. For the above case, these results include:

- Mean NPV = 797 M €;
- NPV standard deviation = 77.27M €;
- Skewness = 0.15;
- Probability of NPV = greater than 800 M €, approximately 51%;
- Probability of NPV between 680 M € and 920 M€, approximately 90%.

9 Recommendations and next steps

This report has identified that the effective implementation of PJ.06-01 would have a significant positive impact on Europe. It would be a broad contributor to future improved operational performance in terms of flight efficiency and predictability, as well as to support carbon-neutral growth compared to a situation without new ATM systems.

However, the benefits of PJ.06-01 are very sensitive to its implementation timeline and coordination. The full impact can only be achieved if the timely and coordinated implementation of Free Route Airspace can be ensured. For Europe to be able to enjoy the multiple benefits that FRA would bring, the required upgrades to FDPS need to be implemented / deployed on schedule and all public and private stakeholders to work in partnership to enable the orderly and efficient rollout of PJ.06-01 at ECAC level.

The risk of a de-synchronised or delayed deployment is real. As the benefits of PJ.06-01 will only materialise if a large majority of the involved stakeholders implement FRA, and since the implementation under PCP mandate has been broadly started at all ACCs in Europe, it is crucial to keep the momentum and ensure that progressive benefits can be factored-in by implementing PJ06.01.

A wide European-level implementation of PJ.06-01 solution would extend the economic benefits, as well as the operational performance, to the wider ANSP community.

- The deployment of PJ.06-01 would achieve a positive global business case with the deployment phase estimated to kick off by 2025 in all ANSPs. The net present value of such initiative could reach higher NPVs after 2040, since only OPEX remains and full benefits are accounted. Additionally, if more ACCs and ANSPs adopt such a stance the benefits will also be higher.
- The whole scenario would achieve a net present value of 797 M€ by 2040 (498 M€ in the most pessimistic scenario, and 1,194 for the most optimistic), depending mostly on the discount rate, the IOC date, the final estimated costs of the FDPS system upgrade or replacement related to PJ.06-01, and achieved KEA after project implementation (at FOC).
- Multilateral ANSP strategy remains fundamental to foster Cross-Border alliances and work towards establishing Cross-Border FRA, since flight efficiency and predictability would reach maximum potential benefits and this has a strong impact in the ECAC-wide business cases.
- It is recommended that PJ.06-01 is implemented together with PJ.06-02 to maximize benefits whilst optimising the amount of investment. Most of the estimated costs would be shared among the two solutions so that the benefits would add up without having to compensate significant extra estimated costs.
- It is recommended to present the outcome of the study and of this cost benefit analysis to other ANSPs who may be interested in pursuing a similar multilateral technological concept as a key foundation of their evolutionary roadmap, in order to foster a bottom-up drive towards adoption.

10 References and Applicable Documents

10.1 Applicable Documents

[1] SESAR 2020 Project Handbook, edition 01.00.01, 06 June 2017

[2] SESAR 16.06.06-D26_04, Guidelines for Producing Benefit and Impact Mechanisms, Edition 03.00.01

[3] SESAR 16.06.06-D26_03, Methods to Assess Estimated costs and Monetise Benefits for CBAs, Edition 00.02.02

[4] SESAR 16.06.06-D26-08 ATM CBA Quality Checklist, edition 02.00.01, 15 June 2016

[5] Method to assess cost of European ATM improvements and technologies, v1.0, 28 July 2014

[6] Cost-Benefit Analyses – Model and Methods – Part I, edition 00.01.01, 30 April 2017

[7] Cost-Benefit Analyses – Model and Methods – Part II, edition 00.01.01, 30 April 2017

[8] Cost Benefit Analyses – Standard Input, edition 01.00.00, 17 April 2018

[9] Methods to Assess Estimated costs and Monetise Benefits – Supporting Template, 30 April 2017

[10] SESAR 16.06.06-D51 SESAR 1 Business Case 2016, edition 00.01.01, 13 July 2016

[11] SESAR 16.06.06-D68-New CBA Models and Methods 2015-Part 1 of 2-00_01_01 (1_0).docx

10.2 Reference Documents

The following documents were used to provide input / guidance / further information / other:

[12] SESAR 2020 D4-0-30 PJ19 Common Assumptions 2019 (1.0)

[13] European ATM Master Plan Portal 2019 https://www.atmmasterplan.eu/working

[14] SESAR C.02-D110, Updated D02 after MP Campaign, Edition 00.01.00

[15] SESAR 2020 D108, Transition Performance Framework, Edition 00.06.00

[16] SESAR 2020 D86, Guidance on KPIs and Data Collection – Support to SESAR2020 transition

[17] SESAR 2020 D4.2, PJ19: Validation Targets (2019), Edition 01.01.00

[18] SESAR 2020 D4.8, PJ19.4.2: PAGAR 2018, Edition 00.00.05 (12/11/2018)

[19] SESAR 2020, Maturity Assessment Tool 2020, Edition 1.2

[20] SESAR 2020 D2.1.020, PJ.06-01 V3 SPR-INTEROP/OSED - Part I (Final version in V3 datapack)

[21] SESAR 2020 D2.1.030, PJ.06-01 V3 SPR-INTEROP/OSED - Part V (Final version in V3 datapack)

[22] EUROCONTROL - CODA Digest 2017 report (Edition CDA_2017_004 - 31/05/2018)

[23] SESAR 2020 D1.1, PJ.06, Project Management Plan, Edition 01.00.00 (28.04.2017)

[24] EUROCONTROL - European Aviation in 2040 – Challenges of Growth. Edition 2.

[25] EUROCONTROL – Standard Inputs for EUROCONTROL Cost-Benefit Analyses. Edition 8.0 of January 2018.

[26] ACI Europe – Airport Traffic Report. December, Q4, H2 & Full Year 2016. Edition of 17 February 2017.

[27] SESAR Deployment Manager – D.1.1 SESAR Deployment Programme 2017 - Proposal for update (Edition: 29 March 2018)

[28] EUROCONTROL – Performance Review Report 2011 (PRR 2011, Final Report - PRC, May 2012)

[29] SESAR 2020 PJ20 En-route and Terminal OEs list (April 2019 Version)

[30] STATFOR traffic forecast data (2019) – Regulation & growth scenario

[31] Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014

[32] Performance Review Unit - ATM Cost-Effectiveness (ACE) 2016 Benchmarking Report with 2017-2021 outlook

Appendix 1 - List of PJ.06-01 targeted ACCs

Table 23 below presents the list of targeted ACCs as defined by WP2.2 (PJ20). Complexity is forecasted for 31/12/2026 mainly according the traffic growth (IFR movements).

ATC Operational Unit providing ATC Services	ANSP	Lower Vertical Limit of the Controlled Airspace	Upper Vertical Limit of the Controlled Airspace	Category of OE in SESAR 2020	OEs Group/Cluster (sub-OEs) in 2017
London ACC	NATS	FL 125	FL 660	En-route OE	VHC
Karlsruhe UAC	DFS	FL 010	FL 660	En-route OE	VHC
Maastricht UAC	MUAC	FL 245	FL 660	En-route OE	VHC
Brest ACC	DSNA	FL 065	FL 660	En-route OE	HC
Reims ACC	DSNA	FL 010	FL 660	En-route OE	VHC
Bordeaux ACC	DSNA	FL 0	FL 660	En-route OE	HC
Praha ACC	ANS CR	FL 235	FL 660	En-route OE	HC
Zurich ACC	Skyguide	FL 0	FL 660	En-route OE	VHC
Padova ACC	ENAV	FL 030	FL 660	En-route OE	HC
Geneva ACC	Skyguide	FL 030	FL 660	En-route OE	VHC
Ljubljana ACC	Slovenia Control	FL 015	FL 660	En-route OE	HC
Marseille ACC	DSNA	FL 010	FL 660	En-route OE	HC
Wien ACC	Austro Control	FL 010	FL 660	En-route OE	HC
Budapest ACC	Hungarocontrol	FL 045	FL 660	En-route OE	HC
Sofia ACC	BULATSA	FL 020	FL 660	En-route OE	MC
Zagreb ACC	Croatia Control	FL 095	FL 660	En-route OE	HC
Bratislava ACC	LPS	FL 080	FL 660	En-route OE	HC
Bucuresti ACC	ROMATSA	FL 245	FL 660	En-route OE	MC
Paris ACC	DSNA	FL 010	FL 660	En-route/Terminal Airspace OE	HC
Milano ACC	ENAV	FL 010	FL 660	En-route/Terminal Airspace OE	HC
Ankara ACC	DHMI	FL 035	FL 999	En-route/Terminal Airspace OE	MC
Munchen ACC	DFS	FL 025	FL 315	En-route/Terminal Airspace OE	HC
Madrid ACC	ENAIRE	FL 025	FL 460	En-route/Terminal Airspace OE	MC
Barcelona ACC	ENAIRE	FL 095	FL 460	En-route/Terminal Airspace OE	MC
Roma ACC	ENAV	FL 010	FL 660	En-route/Terminal Airspace OE	MC
Sarajevo ACC	BHDCA	FL 095	FL 325	En-route/Terminal Airspace OE	HC
Prestwick ACC	NATS (Continental)	FL 0	FL 660	En-route/Terminal Airspace OE	HC

Table 23. List of targeted ACCs (source PJ.20 OE Classification)

Appendix 2 – Mapping between ATM Master Plan Performance ambitions and framework

Mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs, source reference *[33]*

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 estimated 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

Founding Members

EUROPEAN UNION EUROCONTROL

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> see section 3.4	Total number of fatal accidents and incidents
Security	PA10 - No increase in ATM related security incidents resulting in traffic disruptions	Security	Self- Protection of the ATM System / Collaborative Support	(SEC1)	Personnel (safety) risk after mitigation
				(SEC2)	Capacity risk after mitigation
				(SEC3)	Economic risk after mitigation

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
				(SEC4)	Military mission effectiveness risk after mitigation

[33] **Table 24: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs**

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