

SESAR Solution PJ.04-W2- 28.1 COST BENEFIT ANALYSIS (CBA) FOR V3

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PJ.04-W2 TAM

PJ.04-W2-28.1 CONNECTED REGIONAL AIRPORTS

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Abstract

This document provides the **Cost Benefit Analysis (CBA) for SESAR PJ.04-W2-28.1 Connected regional airports** solution to conclude the V3 research and development phase. The objective of Solution 28.1 is to integrate regional airports into the network by sending DPI messages to the Network Manager and implementing a quasi-automatic process for monitoring milestones during the turnaround phase, reducing the workload of airlines and ground handlers and increasing the predictability of departures.

This document was developed to:

- provide all the necessary elements, from an economic point of view, to support a V3 maturity level assessment of the solution and a go/no go decision for a V4 phase, i.e., the industrialisation phase;
- identify an initial list of targeted airports for the deployment of solution 28.1 and provide a set of recommendations for the deployment approach;
- provide an estimation of all the costs and benefits that could be expected from the solution, globally and for each stakeholder group impacted (namely Airspace Users, Airport Operators, ANSPs, and the Network Manager);
- identify critical variables that could affect the overall results of the CBA and provide risk analysis for the deployment phase.

The results of this CBA are based on the quantitative measures and the qualitative elements that were collected during the validation exercises at V1, V2 and V3 maturity levels, as well as on the expert judgment expressed by all the partners involved in the project and the CBA task.



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1 Executive Summary

This report contains the **Cost Benefit Analysis (CBA) of the SESAR Solution 28.1 – Connected regional airports** – for the V3 Phase. Solution 28.1 builds on the work performed:

- in SESAR 1 with Solution 21 - Airport Operations Plan and AOP-NOP Seamless Integration,
- in SESAR 2020 Wave 1 with Solution PJ.04-1 - Enhanced Collaborative Airport Performance Planning and Monitoring.

The solution aims to integrate regional airports into the network with a simplified and more automated solution that will provide the main advantages of the A-CDM concept but with a limited investment. The solution achieves it by (i) monitoring the turnaround processes with a reduced set of milestones, (ii) sending DPI messages to the Network Manager, and (iii) integrating the notion of automated generation of milestones in an A-CDM context.

The monitoring of the turnaround is quasi-automatic, minimising the ground handler's additional workload, and increasing the predictability of airport and network operations. The automatic determination of the aircraft-ready times is based on the aircraft event-based milestones and the status of the passenger boarding provided by the local airport system.

Solution 28.1 should be attractive for regional airports as it is less demanding in terms of effort and resources while providing greater predictability of ground operations and better integration into the network. However, the applicability of the solution strongly depends on the predictability of airport parameters, such as taxi times, turnaround times, and passenger boarding times.

Even if the solution brings local benefits to airports, the validation exercise did not quantify them. Therefore, the CBA only monetises the better departure predictability (measured in the validation exercise), which should (i) allow more accurate allocation of regulations (CTOTs) to flights, resulting in fewer lost slots; and (ii) translate into better network predictability, leading to optimised capacity buffers for the en-route ATC sectors. Both mechanisms achieve lower delays.

The CBA simulates the deployment of the solution in 156¹ airports in ECAC, resulting in an overall €48m net present value (8% discount rate) and achieving breakeven in 2036. These results showcase a positive business case for the core objective of solution 28.1, i.e., integrating the regional airports into the network and achieving better network predictability.

Besides, the CBA shows a higher benefit-to-cost ratio when considering implementation only at medium airports (2.2) than only at small airports (0.8, i.e., negative business case). This result should drive the investment prioritisation process: the network will benefit further from the integration of the medium airports, where the solution should be deployed first.

¹ The CBA solution scenario deploys the solution in the SESAR medium and small airports, which have not yet implemented A-CDM.



Each implementing airport should also explore and exploit the local benefits the solution may bring (e.g., optimisation of ground-handling resources, better allocation of gates and stands, or reduced taxi times) based on its particularities and specific constraints. This local assessment may conclude larger benefits for some small airports and encourage them to pursue the implementation of solution 28.1.

In summary, solution 28.1 would allow earlier and better planning of the airport resources (Airport Operator), which may constrain operations during traffic demand peaks and generate delays. More importantly, integrating the regional airports into the network (core objective of the solution) would enhance departure predictability and, hence, network predictability. It would allow optimising the en-route capacity buffers (ANSPs) and CTOT issuance (Network Manager), leading again to reduced delays (Airspace Users). Solution 28.1 would ultimately improve the passenger experience.

Stakeholder	ANSPs	AOs	NM	AUs	Total
Undiscounted results					
Total costs	(177)	(156)	(0)	(7)	(340)
of which CAPEX	(46)	(82)	(0)	(3)	(131)
of which OPEX	(131)	(74)	(0)	(4)	(209)
Total benefits	-	256	-	372	628
Discounted results (8% discount factor)					
Total costs	(64)	(64)	(0)	(2)	(130)
of which CAPEX	(24)	(41)	(0)	(1)	(66)
of which OPEX	(40)	(23)	(0)	(1)	(64)
Total benefits	-	72	-	106	178
Key project indicators					
NPV	(64)	8	(0)	103	48
Payback year	-	2041	---	2028	2039
BCR	-	1.1	-	41.9	1.4
IRR	-	11%	-	257%	16%

Table 1: Solution 28.1 CBA results per stakeholder (EUR million)²

² Note that the CBA results are highly driven by the traffic growth (and en-route ATFM delay) since it monetises benefits at the network level. The CBA considers the latest available traffic forecast by EUROCONTROL STATFOR [19], which includes the impact of the COVID-19 outbreak. The deployment of the solution should closely monitor the traffic evolution and validate the CBA results are still applicable.



2 Introduction

2.1 Purpose of the document

This document provides the cost-benefit analysis (CBA) for the **solution 28.1 - Connected Regional Airports** - and concludes the V3 maturity level assessment of the research and development (R&D) phase. The objective of the solution is to improve connectivity between regional airports and the Network Manager operations centre (NMOC). This will be achieved through the delivery of departure planning information (DPI) messages based on target times related to specific events and a reduced set of turnaround milestones compared to the full implementation of Airport Collaborative Decision Making (A-CDM).

The CBA is required to achieve the V3 maturity level of the solution and to complete the preliminary results, obtained at V1 and V2 levels. It should confirm the affordability of the solution before the industrialisation phase (V4).

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

2.2 Intended readership

The intended readership for this document includes:

- PJ.04 solution 28.1 members and more widely the PJ04 wave 2 partners,
- PJ.07-W2 - related solutions' partners,
- PJ.09-W2 Digital Network Management Service – related solutions' partners,
- PJ.19 – who provides inputs such as the assumptions and who will consolidate the CBA results (when required by PJ.20),
- PJ.20, in its role of master plan maintenance project,
- PJ.22 - System Engineering Data Management Framework (SE-DMF),
- SESAR programme management,
- Stakeholders (Airport Operators, Airspace Users, Ground Handlers, Air Navigation Service Providers and the Network Manager) interested in deploying this solution.

2.3 Structure of the document

This report is structured as follows:

- Section 1 provides the Executive Summary;
- Section 2 describes the purpose of the document, the audience, the structure of the report, the background, and the glossary of terms and acronyms;



- Section 3 introduces the objectives and scope of this CBA, provides a description of Solution 28.1 and the problem addressed, identifies the stakeholder group involved, and describes the different scenarios compared in this CBA;
- Section 4 describes the expected benefits for each stakeholder group, provides an overview of the Solution's overall contribution to key performance indicators (KPIs), and explains how the benefits were estimated in the CBA model;
- 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 details of the main parameters and data sources used when building the CBA Model³;
- Section 7 provides the CBA results;
- Section 8 includes a sensitivity analysis and a risk profile;
- Section 9 includes recommendations and next steps;
- Section 10 includes the references and applicable documents.

The appendices provide (a) the list of target airports for Solution 28.1, (b) the rationale and studies supporting the potential reduction of the en-route airspace capacity buffer thanks to the improved departure predictability, (c) a second solution scenarios where fewer airports implement RNI, and (d) the correspondence between the performance ambitions in the ATM Master Plan and the SESAR 2020 Performance Framework for Key Performance Areas (KPAs) and Key Performance Indicators (KPIs).

2.4 Background

Solution 28.1 – Connected Regional Airports – builds on work performed:

- **In SESAR 1 with OFA 05.01.01 – Airport Operations Management – and Solution #21 – Airport Operations Plan and AOP-NOP Seamless Integration.**

Part of solution #21 is about to be deployed within the Pilot Common Pilot implementation rule (PCP IR 716/2014). According to the PCP IR, the targeted airports will have to implement the high-level operational services of the PCP and put in place an airport operations plan (AOP) consistent with the network operations plan (NOP).

Solution #21 focused on demonstrating how the AOP improved the situational awareness of airport partners through common information sharing, and how the exchange of information between AOP and NOP improved the integration of airports in the overall ATM network.

³ The CBA Model will be provided as a supporting document.



- In SESAR 2020 wave 1, with project PJ.04-01– Enhanced Collaborative Airport Performance Planning and Monitoring. Solution #21, whose scope only extended to airport planning, steering and monitoring services, was mainly designed for large airports called upon to deploy the A-CDM concept. The rest of the concept, dealing with the ability to manage airport performance and carry out post-operational analyses, was continued by the two solutions of PJ.04 Total Airport Management project in SESAR 2020 (PJ.04-01 and PJ.04-02). In particular, PJ.04-01 through the OI AO-0824 **Regional network-integrated airports (RNI)** focused on monitoring aircraft turnaround in a more automated way, through a limited but automated generation of CDM milestones, addressing the regional airports for their integration into the network.

In SESAR 2020 wave 2, PJ.04-01 and PJ.04-02 were split into six solutions, and the AO-0824 became solution 28.1.

Previous CBA work:

- There was no cost-benefit analysis performed for OFA 05.01.01 and solution #21 in SESAR 1.
- A CBA was developed for the implementation phase of the PCP, which included part of solution #21 (i.e. the elements related to AF#2 family (A-CDM, Initial AOP) and AF#4 family (Collaborative NOP)), but the level of granularity of the data was too high to be useful for this CBA.
- Cost-benefit analyses were carried out in 2005 and 2008 by EUROCONTROL on the implementation of A-CDM. In 2016, an economic impact assessment study was carried out on around thirty airports in Europe. Nevertheless, all these studies relate only to large and very large airports.
- A CBA was performed in SESAR2020 wave 1 for the PJ.04-01 project, which included the **AO-0824 operational improvement (OI)**, basis of solution 28.1. This constitutes the baseline for the R&D work to be performed within solution 28.1 and the baseline for the CBA.

For solution 28.1 CBA, a certain number of assumptions have been taken, including the list of pre-requisite elements required before deploying the solution. Section 3.6 summarises these assumptions.

2.5 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 Costs and Monetise Benefits for CBAs (D26, Edition 00.02.02, July 2016)
Benefit and Impact Mechanism	A Benefit and Impact Mechanisms a cause-effect description of the positive and negative impacts of the Solution proposed by the project	SESAR 16.06.06 – Guidelines for Producing benefit and Impact Mechanisms (D26_04, Edition 03.00.00)
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 Costs and Monetise Benefits for CBAs (D26, Edition 00.02.02, July 2016)
Cost Benefit Analysis	A Cost Benefit Analysis is a process of quantifying in economic terms the costs and benefits of a project or a program 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. A CBA is a neutral financial tool that helps decision makers to compare an investment with other possible investments and/or to make a choice between different options / scenarios and to select the one that offers the best value for money while considering all the key criteria for the decision.	SESAR 1
Cost mechanisms	Cost mechanisms are a description of the potential 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
Net Present Value (NPV)	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.	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
Total Airport Management (TAM) project	The project develops concepts, tools and procedures that increase the predictability and resilience of airport operations, improving the punctuality of flights in a safe and environmentally sustainable manner. The aim is to improve airport/network integration for large and medium/regional airports, improve airport airside/landside integration, reduce the impact of MET aspects on airport operations, make further investigations about how environmental aspects could be monitored and managed in day-to-day airport operations.	SESAR Joint Undertaking Total airport management (Wave 2) (sesarju.eu)

Table 2: Glossary of terms



2.6 List of Acronyms

Acronym	Definition
AAT	Advanced ATC tower
A-CDM	Airport collaborative decision-making
ACGT	Actual commence of ground handling time
ANS	Air navigation services
ANSP(s)	Air navigation service provider(s)
AO(s)	Airport operator(s)
AOBT	Actual off-block time,
AOP	Airport operations plan
APT	Airport
ATC	Air traffic control
ATCO	Air traffic controller
ATM	Air traffic management
ATOT	Actual take-off time
AU(s)	Airspace user(s)
B2B	Business to business
BCR	Benefit-to-Cost Ration
BD	Big data
CAP	Capacity
CAPEX ⁴	Capital expenditure
CBA	Cost benefit analysis
CTOT	Calculated take-off time
DPI	Departure Planning Information
DS	Data set
EATM	European ATM (Portal, database, dataset)
EATMA	European ATM architecture
EC	European Commission
ECAC	European Civil Aviation Conference
E-DPI	Early – Departure planning information message
EEC	European Economic Community

⁴ Note that the term CAPEX has been used in the CBA report to indicate all the investments (pre-implementation and implementation costs).



ELDT	Estimated landing time
EN	Enabler
EOBT	Estimated off-block time
ER	En-route
EU	European Union
FEFF	Fuel efficiency
FOC	Full operational capability
FUM	Flight update message
HP	Human performance
IFR	Instrument flight rules
INTEROP	Interoperability
IOC	Initial operational capability
IRR	Internal Rate of Return
KPA(s)	Key performance area(s)
KPI(s)	Key performance indicator(s)
NM	Network Manager
NMOC	Network Manager operations centre
NOP	Network operations plan
NPV	Net present value
OE	Operating environment
OFA	Operational focus areas
OI	Operational improvement
OPEX	Operating expenditure (Considers changes in operating costs)
OSD	Operational service and environment definition
PAGAR	Performance assessment and gap analysis report
PAR	Performance assessment report
PCP	Pilot Common Project
PJ	Project
p.p.	Percentage point
PRD	Predictability
PRD#M1	Departure predictability
PRU	Performance Review Unit
R&D	Research and development
RNI	Regional Network Integrated
SAF	Safety
SDM	SESAR Deployment Manager
SE-DMF	System Engineering Data Management Framework



SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking
SOL	Solution
SPR	Safety and performance requirements
STATFOR	EUROCONTROL Statistical and Forecast service
TAM	Total airport management
TMA	Terminal Manoeuvring Area
TOBT	Target off-block time
TS	Technical specification
TSAT	Target start-up approval time
TTOT	Target take-off time
VT	Validation target
WP	Work package

Table 3: List of acronyms



3 Objectives and scope of the CBA

3.1 Scope

The scope of the Cost-Benefit Analysis (CBA) is **solution 28.1 at maturity level V3**, which is part of the PJ.04 Total Airport Management (TAM) project in SESAR 2020 Wave 2. The CBA assesses all costs and benefits generated by the operational improvement steps of the solution and the associated list of enablers (see section 3.3.3). The European ATM (EATM) dataset was used as a reference [11].

The cost-benefit analysis relates only to the deployment of solution 28.1. The solution is considered a stand-alone solution, independent of any other solution.

3.1.1 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/or will benefit from the solution. Below is the list of stakeholders taken into account in the analysis:

- Airport operators (AOs),
- Airspace users (AUs),
- Air Traffic Control (ATC) tower,
- The Network Manager (NM).

Note that the costs and benefits of the ground handling agent are part of the airspace user's view.

3.1.2 Geographical scope

The geographical scope of the CBA is the European Civil Aviation Conference (ECAC) area, as shown in Figure 1.



Figure 1: Solution 28.1 CBA - geographical scope

According to the final SPR/INTEROP OSED report that describes the operational concept of Solution 28.1 [15], the target airports where it could be interesting to deploy the solution are those classified as "medium" or "small" in the SESAR 2020 Airports' Classification Scheme developed by PJ20 (Edition March 2019 [17], and described as follows:

OEs	Sub-Operating Environments	Share of traffic (ECAC)
Airport	Medium Airport	Airports with a number of annual IFR movements greater or equal to 70.000 and less than 150,000, where a movement is either an IFR departure or an IFR arrival.
Airport	Small Airport	Airports with a number of annual IFR movements greater or equal to 10.000 and less than 70,000, where a movement is either an IFR departure or an IFR arrival.

Table 4: Solution 28.1 operational scope

More generally, solution 28.1 is intended for airports that would not wish to implement the full airport CDM concept because of a negative business case but would benefit from a reduced set of DPI messages exchanged with the NMOC. This includes standard airports not already connected to the network but also airports that have already implemented the advanced ATC tower (AAT) concept and could be interested in a better approximation of the predictability of the departure due to more accurate monitoring of the arrival flight and subsequent turnaround.

It should be noted that in SESAR 2020 Wave 1 a different classification was used in the V2 maturity level cost-benefit analysis and airports were divided into groups 1, 2, 3 and 4 in the scenario approach deployment of the solution. In addition, the targeted list of airports for solution 28.1 was limited to 42 medium-sized airports.

PJ.20 Classification for S2020 wave 2 <i>(based on 2018 traffic)</i>	Number of airports	Volume of traffic (ECAC) <i>based on 2018 Annual IFR Flight Movements (ECTRL PRU)</i>	Share of traffic (ECAC)
Very Large	14	5,244,719	28%
Large	18	3,710,192	19%
Medium	76	5,747,368	30%
A-CDM (deployed or planned)	12	1,348,584	7%
AAT (deployed or planned)	22	1,798,919	9%
Small	92	2.252.702	12%
AAT (deployed or planned)	16	449,036	2%
Others	957	2,100,827	11%
TOTAL	1,157	19,055,808	100%

Table 5: PJ.20-W2 airport classification in SESAR 2020 Wave 2

In Wave 2, the scope has been expanded and potentially medium and small airports with more than 10,000 movements per year could be interested in the solution.

For the sake of consistency between all the deliverables of the 28.1 solution in Wave 2, it was agreed to return to the PJ.20 classification rather than referring to the classification adopted in Wave1 for the PJ.04.

According to the latest classification provided by PJ.20 [17] 156 out of the 168 small and medium size airports (12 have already implemented the full A-CDM airports) could be potentially interested by implementing the 28.1 Solution, representing 35% of the ECAC traffic in 2018 (see Table 5).

3.1.3 CBA timeline

The time horizon for the analysis is 2022-2043 as recommended in the PJ19 Common assumptions for Cost Benefit Analysis in SESAR 2020 wave 2.

3.2 Problem addressed by the solution

Regional airports are an important part of the aviation system in Europe and account for around 42% of the total ECAC traffic, playing an important role in the overall performance of the network. Although they are less subject to local congestion and extended peak hours, they may have an important impact on the air traffic network, especially those subject to seasonality. Sharing accurate take-off times for flights from such airports could potentially bring network performance benefits, as a result of the enhanced traffic predictability and thereby reducing the need for sector capacity 'buffers'.

Additionally, when there is no agreement on target times for the aircraft turnaround process between local partners, it implies that available and scheduled resources, such as runway slot, parking position, door, pusher or bus service are not used optimally. The late or non-existence of TOBT updates can generate locally:

- Sub-optimal use of runway capacity at times of high demand, leading to additional delays for the entire system;
- Pushback vehicles and passenger buses standing too long and missing elsewhere;
- Parking positions remain unexpectedly occupied and arriving aircraft have to wait on the apron or have to be re-located at short notice. This causes late gate changes and delays for the respective rotation;
- Non-compliance with calculated take-off time (CTOT): a slot returned at short notice can no longer be used by other aircraft. As a consequence, it might result in a very late CTOT allocation afterwards.

Currently, the integration of airports into the ATM Network is achieved through either the A-CDM (Airport Collaborative Decision Making) concept or the AAT (Advanced ATC Tower) concept.

Implementing the full A-CDM concept requires important investment and resources that are not necessarily affordable for a regional airport. The concept is often perceived as too complex for a regional airport and may require long months of organisation and implementation to educate and train the personnel, as well as to install the systems to operate it. It requires additional human resources and relatively heavy planning management for a reduced set of peak hours compared to a hub or a large airport with a high volume of traffic. It also requires from airlines and their ground



handler's subcontractors dedicated staff, which may not be feasible for all airlines, especially if their presence in the airport is limited.

To date, the A-CDM concept is implemented in 33 airports⁵ and 8 airports have plans to implement it. Most of them belong to the large and very-large categories, and 12 of them belong to the medium category.

On the other hand, the AAT concept enables a first step towards the integration of airports into the network. However, this solution offers limited capabilities in terms of turnaround monitoring as it only provides a first DPI message to the Network Manager when the aircraft is leaving the gate, i.e., the ATC-DPI message reflecting the actual off-block event. Such a DPI message contains an accurate estimation of the taxi time, the standard instrument departure (SID) procedure and the target take-off time (TTOT).

Whilst establishing a crucial link with the network through this solution, AAT airports receive very little of the efficiency benefits they would gain from the full deployment of A-CDM. Benefits at the local level are limited⁶ and the concept does not help increase the level of efficiency of the turnaround process, including a reduction in fuel burn, optimisation of gate-allocations, and efficient use of resources. To date, the AAT concept is implemented in 26 airports⁷ and 24 airports (of which 38 are medium or small airports) have started to deploy it.

In standard airports where there is no connection with the Network Manager and no real collaborative work in place between partners, departure estimates are usually based on flight plan data and the airport sends updates through delay (DLA) or change (CHG) messages. The departure predictability is not optimal.

Furthermore, small and medium airports often suffer from the use of software solutions that work in silos, i.e., addressing a specific issue (such as requesting assistance from ground handling services), with limited connectivity and therefore generating numerous duplicate entries of information, a source of inefficiency for the operational teams.

SESAR 1 activities suggested that a wider integration of regional airports into the network would be feasible by addressing a reduced set of A-CDM milestones. This would bring network and local benefits to all impacted stakeholders: Airport Operators, Airspace Users, ANSPs and the Network Manager.

⁵ See EUROCONTROL web page: [Airport collaborative decision-making \(A-CDM\) | EUROCONTROL](#) (accessed on August 2022)

⁶Main benefits of the Advanced ATC Tower concept for airports is to freeze CTOT and flight plan at the actual off-block time event.

⁷ See EUROCONTROL web page: [Advanced Towers Map | Tableau Public](#) (accessed on August 2022)



3.3 SESAR Solution description

The 28.1 solution aims to facilitate the integration of regional airports, i.e., small and medium-sized airports, into the network through simplified monitoring of the turnaround process and including in particular the notion of automated generation of milestones in an A-CDM context.

The solution consists of setting up an information-sharing platform at the airport that allows data to be shared, sorted and correlated with all local partners. Data will be exchanged with the NMOC via B2B services. The airport will receive an accurate estimated landing time (ELDT), based primarily on the ELDT provided by the NM. This ELDT could also potentially be updated through access to local (ATC) systems should such information be available.

The solution, which requires lower investment and resources, is expected to be cost-effective for regional airports compared to the full A-CDM concept. This could provide sufficient motivation for regional airports, including those that have already implemented the AAT concept, to deploy an increased degree of connectivity with the ATM network.

Integration into the network will be achieved through the monitoring of a reduced set of milestones during the rotation phase, i.e., 7 milestones instead of the 16 identified in the A-CDM, and the provision of DPI messages to the Network Manager based on target times.

The reduced set of turnaround milestones (7 out of the original 16 full A-CDM milestones) are the following:

- M1 (ATC Flight Plan Activation : EOBT - 3h) → Time milestone needed for the E-DPI
- M3 (Take-off from outstation) → event milestone
- M8 (Ground Handling starts - ACGT) → combining M6, M7, M8 and M9 into a single event milestone
- M10 (TSAT issued) → event milestone
- M11 (Boarding starts) → event milestone
- M15 (Off-block - AOBT) → event milestone
- M16 (Take-off - ATOT) → event milestone

Additionally, DPI messages will be produced automatically, limiting the effort required by the Ground Handler to manually intervene in the process and correct relevant block time information.

The applicability to regional airports is reliant on the high degree of predictability of airport parameters including taxi-times, turnaround times and passenger boarding times.

The objectives behind the operational concept for such regional airports are:

- To implement a reduced set of Turnaround milestones to be monitored, concentrating on those which are 'event driven' rather than 'time is driven',
- To generate such milestones in a quasi-automatic manner,
- To reduce Ground Handler workload in terms of inputs to the system to become the 'exception' rather than the 'rule',
- To offer the full set of DPI messages to the Network Manager and simultaneously respect the quality criteria inherent in the full A-CDM implementation.

Compared to the A-CDM concept, ground handlers' workload is reduced as a result of the automatic determination of the aircraft target off Block time (TOBT) based on the aircraft event-based milestones and the status of the passenger boarding provided by the local airport system. This simplifies the overall departure sequencing process, which is possible due to the lower traffic volumes at regional airports.

RNI airports will therefore be positioned between full A-CDM airports and AAT airports concerning the degree of turnaround process monitoring and the level of information provided to the Network Manager.

3.3.1 Expected benefits and validation targets

As with A-CDM, the RNI concept will improve the efficiency of the rotation phase thanks to better information sharing between airport partners. The key milestones of each flight will be available for each of the airport's partners via the AOP tool. The tangible benefits attributable to the RNI will be realised through the improvement of the following⁸:

- A more accurate landing time of the inbound flight,
- An increased off-block predictability,
- An increased take-off predictability.

Note that there is a strong link between the last two mechanisms as take-off predictability improvements are barely possible without improvements to the off-block predictability.

Additionally, the provision of DPI messages to the Network Manager will meet the requested quality requirements and ensure that airports deploying the RNI concept have an affordable way to meet the Network Manager's accuracy criteria.

There are no validation targets assigned by PJ19 to Solution 28.1. Nevertheless, it is expected that Solution 28.1 will locally:

- enhance predictability when measured in terms of the accuracy of the target take-off time (as provided in the DPI messages) vs the actual take-off time, leading to a reduction in sector capacity 'buffers' and as a consequence a reduction in regulations and ATFM delay;
- improve stand and gate planning;
- improve CTOT stability;

⁸ Note that unlike, the A-CDM concept, the RNI solution will have no impact on the predictability of arrivals but the FUM messages sent by NM will make it possible to increase the estimate of the inbound landing time.



- reduce airport operations' inefficiencies and help optimise Ground Handling resource allocation when serving the airlines (ramp and passengers services) for both inbound and outbound flights.

Moreover, the integration of medium and small airports into the network should provide network benefits as it should improve traffic predictability for FMPs.

It should be noted that the solution improves the predictability of the departure thanks to the DPI messages sent to the Network Manager but no particular advantage is expected on arrival other than a better situational awareness thanks to the implementation of milestone 3.

3.3.2 Solution 28.1 - Operational Improvement steps

Table 6 describes the operational improvement (OI) steps expected with the solution 28.1. There is only one OI step in the solution: AO-0824 Connected Regional Airports (RNI).

OI step reference	OI step description	OI step coverage	Source of reference
AO-0824 Regional network-integrated airports (RNI)	The connectivity between regional airports and the NMOC is improved thanks to the provision of DPI messages based on target times and a reduced set of turnaround milestones compared to the full A-CDM implementation. The applicability to regional airports is reliant on the high degree of predictability of airport parameters including taxi-times, turnaround times and passenger boarding times. Ground handler workload is reduced as a result of automatic determination of the aircraft-ready time (TOBT) based on the status of the passenger boarding provided by the local airport system. The expected benefits relate to Predictability and capacity.	Fully	SPR-INTEROP/OSED Part I [14]

Table 6: Solution 28.1 – list of operational improvement steps

3.3.3 Solution 28.1 – Enablers

Table 7 provides an overview of the cost drivers for solution 28.1. The cost drivers are represented by so-called Operational Improvement (OI) enablers, reflecting enabling requirements by stakeholder group (staff, procedures, tools) that need to be fulfilled in order for solution 28.1 to be deployed.

Enabler ⁹ reference	Enabler description	Required /optional	Impacted stakeholders	Comment	Source of reference
AIRPORT-03c	A local management tool dedicated to regional airports allowing:	Required / Develop	Civil Airport Operator(s)	Costs associated with the development	SPR-INTEROP/O

⁹ This includes System, Procedural, Human, Standardisation and Regulation Enablers



Light Airport Operational Plan (AOP) Management Tool (for RNI airports)	- All airport partners (Airspace Users/Ground handlers, ANSP and Airport Operator) to access the set of ATV (airport transit views) forming a light version of an AOP (which provides a common and collaboratively agreed rolling plan that will form the single source of airport operations information), - The Airspace Users/Ground handlers to manually update TOBTs when it could improve the overall operations predictability, - The monitoring of 8 A-CDM milestones (out of the original set of 16 A-CDM milestones) using statistical historical analysis (to create VTTs, expected turnaround time and expected boarding duration time) - The sending of corresponding DPIs towards NM through a B2B service connection. - PDS or DMAN might be integrated with the solution, but they are not mandatory, providing the Lite AOP Management tool a pseudo pre-departure sequencer			and implementation of this lightweight AOP tool will be borne by the airport operator. It includes the interface to Network Manager B2B services. All the local partners (airlines, ground handlers, ATC control tower) will have access to the tool via a dedicated web interface	SED Part I [14]
STD-116	Update of EUROCONTROL DPI implementation guide to cover RNI (Regional Network Integrated) airports. NB: note that this enabler is not directly attached to the AO-0824 OI but to the enablers.	Required / Develop	Network Manager	This enabler covers the need to develop specific guidelines for the RNI concept as part of the standardisation process.	SPR-INTEROP/O SED Part I [14]
AERODROME-ATC-114	Update of the Aerodrome ATC system to align with RNI airport operations to enable display and management of TSAT.	Required / Develop	ANSPs	Upgrade the Tower ATC system to provide the TSAT to the flight crew	SPR-INTEROP/O SED Part I [14]
HUM-036	Ground Handling Agent role updated for RNI concept of operations. The GH mainly deals with TOBT management (check and manual update)	Required / Develop	AUs/GHs	This enabler covers the need to implement the new role and the operational	SPR-INTEROP/O SED Part I [14]

RNI concept of operations				procedure for GHs to monitor and follow the milestones of the turnaround phase and the status of the TOBT. ¹⁰	
HUM-058 Tower Ground Controller role updated for RNI concept of operations	Tower Ground Controller role updated for RNI concept of operations: management of TSAT notion.	Required / Develop	ANSPs	This enabler covers the need for new operational procedures and training for the TWR GND ATCO.	SPR-INTEROP/O SED Part I [14]
HUM-059 Flight Crew role updated for RNI concept of operations	Flight Crew role updated for RNI concept of operations: management of TSAT notion.	Required / Develop	AUs	This enabler covers the need for new operational procedures and training for the Pilots.	SPR-INTEROP/O SED Part I [14]

Table 7: Solution 28.1 – list of enablers

3.4 Objectives of the CBA

The objective of the V3 cost-benefit analysis is to provide a consolidated and a more accurate assessment of the costs and benefits of deploying solution 28.1 than that carried out in V2, extending the scope of the solution to all small and medium-sized airports in Europe, which have not yet implemented the A-CDM concept.

This CBA will assess whether the benefits of the solution are expected to exceed the costs over the CBA time horizon and if it is worthwhile to go for the deployment phase. The V3 CBA includes all the evidences gathered in terms of impacts, benefits and costs of the solution. The output is the NPV overall and per stakeholder group, sensitivity analysis, CBA model report and recommendations.

The CBA aims also to capture the breakeven year (payback time), i.e., the year when benefits will start compensating for the costs incurred.

Predictability benefits have been monetised in the CBA for Airspace Users and Airports, in full alignment with the Benefit Impact Mechanisms described in the OSED [15].

Although the views of the different stakeholders involved in the deployment are taken into account, this CBA does not provide results for local deployments, but gives an order of magnitude of the costs and benefits expected for each group of stakeholders at ECAC level.

¹⁰ Note that the notion of TOBT does not exist at the airport prior to the introduction of RNI concept.



Finally, the CBA should confirm whether the solution will bring benefits in an operating environment where capacity shortages are not an issue and what kind of benefits are expected at those airports.

3.5 Stakeholders¹¹ 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
ANSPs	Essentially: Apron/Tower Controller (ATC) of all medium and small airports The FMP (Flow Management Position) is not foreseen to be impacted by this solution.	The impact on the day-to-day work of the ATCOs in the TWR and in the TMA will be limited. Their role will consist of: - accessing the light AOP tool to see the most accurate information related to the TSAT. - monitoring the conformance of the start-up request time to the allowable TSAT window. <u>Costs:</u> Upgrade of the Aerodrome ATC system to align it with RNI airport operations (display and management of TSAT). Small training costs since ATC already monitors the conformance of the start-up request according to the flight plan. With the RNI solution the check will be with the TSAT instead of the flight plan. <u>Benefits:</u> increase the predictability of the departure measured in terms of the accuracy of the TSAT and the actual take-off time; it should help to optimise the departure sequence.	LFV ATCOs were part of the V3 validation exercise executed in Gothenburg in June 2022 and have been consulted for the ANSPs costs. Besides, Indra has provided the cost figures for the update of the Aerodrome ATC system (AERODROME-ATC-114).	Yes. System and training costs are considered.
Airport Operators	All medium and small airports that have not yet deployed the A-CDM concept	<u>Costs:</u> Airport Operators will support the vast majority of the costs associated with Solution 28.1, i.e. the development and the implementation of a light airport operational plan (AOP) and the monitoring of 7 milestones during the turnaround phase.	Reassessment of the costs estimated in V2 by the CBA team in v3; including SWEDAVIA.	Partially. Reduction in passenger waiting time derived from the better adherence to slot and departure predictability.

¹¹ Note that the terminology used to describe AU stakeholders in the CBA differs from that associated with Enablers in the dataset. This is due to costing being provided for different types of aircraft regardless of the operations they perform.



		<u>Benefits:</u> increase predictability of the turnaround process and departure. Better allocation of airport resources (stand/gate allocation, GH activities subcontracted by the AO, de-icing equipment planning, parking management...)		No benefit on the turnaround process has been monetised.
Network Manager		<u>Costs:</u> NM costs will be limited to the Update of the EUROCONTROL DPI implementation guide to cover RNI (Regional Network Integrated) airports. <u>Benefits:</u> an enhanced flow management process and a reduced number of wasted ATFCM slots resulting in better used of the capacity throughout the Network. This is due to a more accurate information provided by the airport on the TSAT and the actual take-off time;	Reassessment of the costs estimated in V2 by EUROCONTROL and discussed in the CBA team in v3.	Yes. Costs are considered, network benefits are transferred to airspace users as reduced ATFM delay.
Scheduled Airlines		<u>Costs:</u> Airlines costs will be limited and will be related to the new processes that will have to be put in place for the ground handling activities. GH will have to check the status of the TOBT during the turnaround phase and to manually update it if required. So there will be small one off costs and OPEX for GH. ¹² The access to the light AOP tool will be provided free of charge by the AO. <u>Benefits:</u> Like all the partners in the airport, Airlines will benefit from a situational awareness increase with a more accurate information about the status of the TBOT and the TSAT. It should enable to optimise their GH resources allocation during the turnaround phase.	Reassessment of the costs estimated in V2 by the CBA team was not performed. Direct participation of airlines to the CBA work was not possible. Therefore, the cost estimation refers to previous A-CDM CBAs.	Yes. GH costs are included in the SA CBA. Benefits monetise the reduction in delay, deriving from better adherence to slot and departure predictability.
Business Aviation	Not applicable	Only scheduled airlines are concerned by the TAM concept; the monitoring of the turnaround	N/A	N/A
Rotorcraft	Not applicable		N/A	N/A

¹² Note that the solution should not affect airline processes since the changes concern GH activities, but if airlines prefer to be in charge of TOBT monitoring and not rely on Ground Handlers, then this will represent a direct cost to AUs. However, the cost estimate remains valid.



General Aviation IFR	Not applicable	process does not concern Business Aviation, General Aviation or Rotorcraft. No costs & benefits are expected for those types of airlines.	N/A	N/A
General Aviation VFR	Not applicable		N/A	N/A
Military Airborne	–	Not applicable	N/A	N/A
Military Ground	–	Not applicable	N/A	N/A
Ground Handling	All services related to cabin service, catering, ramp service, passenger service, baggage handling, field operation service, refuelling...	Since the costs and benefits of GH will ultimately be borne by the airlines, it was decided, for the sake of simplicity, to integrate the costs and benefits of ground handlers into the airlines' CBA view.	A questionnaire was sent to the GH company that took part to the Gothenburg exercise to collect their inputs on the costs. No answer was received. Therefore, the cost estimation refers to previous A-CDM CBAs.	Partially. GH costs are included in the SA CBA. GH benefits are not monetised (not included in the OSED [15]).

Table 8: Solution 28.1 CBA - stakeholders and impacts

3.6 CBA Scenarios and Assumptions

The CBA compares a solution scenario (solution 28.1) with a reference scenario. The reference scenario is the scenario without implementing solution 28.1 and can be considered the “business as usual” scenario. Both scenarios encompass the same period of analysis, from 2022 to 2043. They are both looking for costs and benefits assessment at the ECAC level, as recommended in the PJ19 Common Assumptions document [9].

The CBA used a delta approach, i.e., the solution scenario identifies any additional element to implement beyond what is assumed to be deployed in the reference scenario, which includes the common pilot project (PCP) and common project 1 (CP1) implementation rules. Only the costs and benefits of these additional elements are taken into account in the CBA. Therefore, the items included in the PCP and CP1 deployment programme constitute the baseline for both the solution and reference scenarios and the costs of these items are not considered in the CBA. This also means that if an investment is planned in the baseline scenario but is abandoned or replaced by another investment in the solution scenario, it should be counted as a potential cost saving.

Costs of the enablers that are common to other SESAR 2020 solutions have been integrally considered in the CBA.

The solution scenario is built on deployment assumptions and a list of airports has been identified as a potential target for solution 28.1 implementation. However, it should be noted that the role of SESAR R&D is to demonstrate that tangible benefits can be obtained from the implementation of SESAR solutions and not to address deployment. If the solution successfully passes the V3 maturity gate, it will be up to the SESAR Deployment Manager to (i) finalise and validate the targeted environments, and (ii) synchronise and coordinate the deployment of future common projects.

3.6.1 Reference Scenario

The reference scenario looks at how the targeted airports identified in the solution scenario will evolve if solution 28.1 is not implemented.

In the cost-benefit analysis at the V2 level, the scope was limited to group 2, i.e., 42 medium-sized airports. It was assumed at that time that all group 2 airports would have a connection to the network via the A-CDM or AAT concept. However, these assumptions must be revisited due to the impact of the COVID crisis on airport investment and because the scope of the solution has been extended to all small and medium-sized airports in the ECAC area.

According to the latest SESAR 2020 Airports' Classification Scheme (Airports' Group in 2018 according to SESAR 2020 Airports' Classification Scheme – PJ.20 latest updated list – March 2019), there are 168 small and medium-sized airports. 12 have implemented or are about to implement the A-CDM concept, 38 have implemented or plan to implement the AAT concept and 118 have no connection.

For most of these airports, implementing the full A-CDM concept is far too costly compared to the benefits provided. Only medium-sized airports with a complex runway system and more than 70,000 movements per year are likely to implement the full A-CDM concept. This represents 7 additional airports on top of the 12 medium-sized airports that have already implemented A-CDM.

Regarding the AAT concept, among the 118 airports that have no connection to the Network Manager, only a few are likely to implement the concept by the end of 2040. The following assumptions were made:

- For medium-sized airports, it can be expected that they will all be looking for better network integration and those that are not candidates for A-CDM will certainly opt for the Advanced Tower concept. This represents a potential of 42 additional airports in addition to the 22 already AAT.
- For smaller airports, although they may all be interested in being connected to the network, it is assumed that only a few of them are likely to implement AAT by 2040. Those that have largely-seasonal traffic or are subject to the coordination of airport slots are likely to be prime candidates. This represents a potential of 7 additional airports in addition to the 16 already AAT.

However, there is a high risk that these investments will be delayed as long as traffic remains below 2019 levels and the losses caused by the COVID crisis are not absorbed. ACI estimated in its ninth quarterly assessment published in February 2022 that, worldwide, airports lost more than USD 83.1 billion in revenue in 2021 and a further loss of US\$60.8 billion US is scheduled for 2022¹³. The return to 2019 traffic is not expected before the end of 2023/2024.

Due to traffic uncertainties and the time it will take to recover from the COVID crisis, it has been decided, for a conservative approach, not to consider potential investment in A-CDM or AAT concepts

¹³ The impact of COVID-19 on the airport business—and the path to recovery ([ACI Press release](#) – Published February 24, 2022)

in the reference scenario. However, it is worth mentioning that the solution scenario would provide additional benefits over the reference scenario if such an investment were considered:

- Less investment is required with Solution 28.1 compared to full A-CDM implementation;
- Better network integration with Solution 28.1 compared to the advanced tower concept and more efficient allocation of resources in the airport.

3.6.2 Solution Scenario

Solution 28.1 offers a lean CDM process to monitor the aircraft rotation phase through a reduced set of milestones and more automation compared to the full A-CDM concept. For example, information about the start and end of the passenger boarding process is automatically uploaded to the system and the TOBT is adjusted accordingly. Implementing such a solution should be easier and will require less effort and investment than the A-CDM.

In addition, the solution will provide a higher degree of integration than the AAT, providing also local benefits such as a better situational awareness in the airport and an optimisation of the local resources. This is achieved through the full implementation of the set of DPIs messages (but P-DPI), which leads to a higher predictability in RNI compared with AAT Airports. Additionally, this higher degree of integration will enable a more precise DCB process by the NMOC in advance and will increase the situational awareness of the airport Stakeholders, supporting resource allocation processes.

It should be noted that, despite the fact that the RNI solution only monitors 7 of the 16 milestones contained in the A-CDM manual of operations¹⁴, it should be sufficient to guarantee the integrity of the target-off-block time calculation. This solution, which is less complex to deploy, should offer the same advantages as A-CDM but to a lesser extent since these airports have a reduced volume of traffic compared to large and very large airports and are therefore less subject to congestion and delays at departure.

The RNI concept is designed for standard small and medium-sized airports that do not benefit from a connection with the Network Manager. Besides, airports that have already deployed the Advanced Tower concept could also be interested to increase their level of integration and improving the visibility over the Milestones increasing situational awareness over the Target Off Block Times.

There are 168 small and medium-sized airports in the ECAC region. If we remove those that are already A-CDM, Solution 28.1 could potentially be deployed in 156 airports in ECAC (see section 3.1.2). This objective will serve as the basis for estimating the costs and benefits of the solution.

Table 9 shows the deployment schedule for Solution 28.1. Deployment should start beginning of 2025 with the implementation in the first airport and end in 2035 with the last of the 156 airports to be equipped, i.e., an average of 14 airports to be equipped per year over 11 years.

¹⁴ Note that the RNI solution provides all the DPIs messages envisaged in the A-CDM concept.



Note that the Appendix B shows the results for an alternative solution scenario where the current AAT airports do not transition to RNI, reducing the number of candidate airports to those non-ACDM and non-AAT.

Airport OE	OIs	Start of deployment (first airport to be equipped)	End of Deployment (last airport to be equipped)	Initial Operational Capability (IOC) ¹⁵	Full Operational Capability (FOC) ¹⁶
Small & medium sized airports	AO-0824	01/01/2025	31/12/2035	01/01/2027	31/12/2035

Table 9: SESAR Solution 28.1 – deployment schedule

Figure 2 shows that:

- Investment costs are spread following a bell curve between the Start and End of Deployment dates (assuming that the airports adopt the solution following an S curve).
- Benefits ramp-up following an S curve between IOC and FOC and then continue up to the end of the CBA period.
- Operating cost impacts would also start at IOC and ramp up following an S curve to FOC before continuing for the rest of the CBA duration.

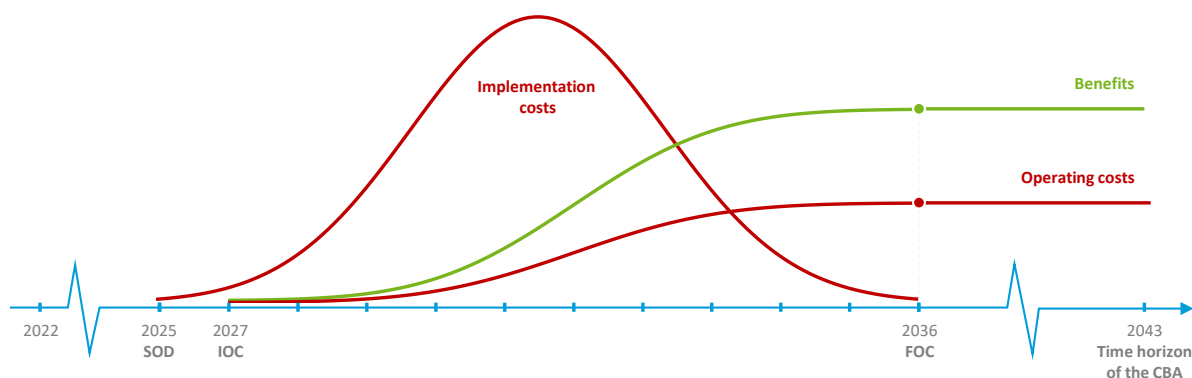


Figure 2: Overview of CBA Dates

¹⁵ This is the year when the first benefits are expected with the completion of the deployment of the first airport.

¹⁶ This is the year when the annual benefits culminate with the completion of deployment to all ECAC target airports.



In line with PJ19 guidance, the CBA model calculates the cash flows up to 2043 and then discounts the values back to 2022¹⁷ to calculate the Net Present Value. The discount rate of 8% is used for all stakeholders.

3.6.3 Assumptions

The following set of assumptions is used to build the CBA model of Solution 28.1:

- The costs and benefits were estimated based on a delta approach between the solution scenario and the reference scenario. For more information, see sections 3.6.1 and 3.6.2;
- The solution is expected to be deployed in 156 small and medium-sized airports (see section 3.1.2); it is assumed that the implementing airports in the solution scenario are standard airports with no connection with the network and no AAT concept already deployed¹⁸.
- The deployment schedule for Solution 28.1 is shown in Table 9 and the cost estimate will be consistent with this schedule. To reflect the progressive implementation of the solution in the 156 target airports, a deployment phase has been defined. The investment costs were distributed on a bell curve over this period and the operating expenses follow an S curve ramp-up phase between the date of initial operational capability (IOC) and the date of full operational capability (FOC);
- The only pre-requisite elements required are for the airport to have an Airport Operational Database (AODB) or equivalent, and to be able to reliably link (ideally automatically) inbound flights to outbound flights as in the Airport Transit View (ATV) concept. Such a database is assumed to be in place before deploying the solution.
- The expected benefits follow the same logic as the operating expenses; they will grow progressively as the implementation progresses in the 156 target airports and will reach their maximum annual value from the FOC date.
- Costs and benefits have been estimated based on average values at the ECAC level. It is assumed that all airports in the same category will bear the same costs in the same order of magnitude. It is also assumed that benefits should be equivalent although this may not be the reality for some of the benefits estimated. As it is not feasible to quantify costs and benefits for each airport separately, they have been estimated globally for all target airports, assuming that costs and benefits would be of the same order of magnitude.
- The input parameters used in the CBA model comply with the SESAR2020 CBA guidelines and Common Assumptions provided by PJ19. All reference sources used in the model are provided in section 6.1 and the mechanisms for quantifying benefits are documented in section 4.
- The benefits have been estimated taking into account the traffic share of the airport groupings in 2018. It is assumed that this share of traffic will stay constant all over the time horizon.

¹⁷ as specified in the PJ19 Common Assumptions [9]

¹⁸ AAT airports should have lower implementation costs, however, the difference should be negligible. Therefore, the cost assessment does not differentiate between airports that have already implemented AAT and airports that have not.

- There is no interdependence nor is there a common enabler with the other SESAR solutions.

The assumptions used in the cost assessment are detailed in the subsections of Chapter 5.

3.6.4 Traffic evolution

The analysis considers the latest available STATFOR long-term traffic forecast provided by EUROCONTROL [20]. The outlook considers three (3) growth scenarios: low, base and high, as depicted in Figure 3.

The CBA model includes further detail, segmenting the data into overflights, non-ECAC arrivals and departures, and internal (from ECAC to ECAC) flights.

The CBA model takes the base forecast as reference value for the calculation of the solution net present value (section 7), but it presents also the NPV results for the low and high traffic scenarios.

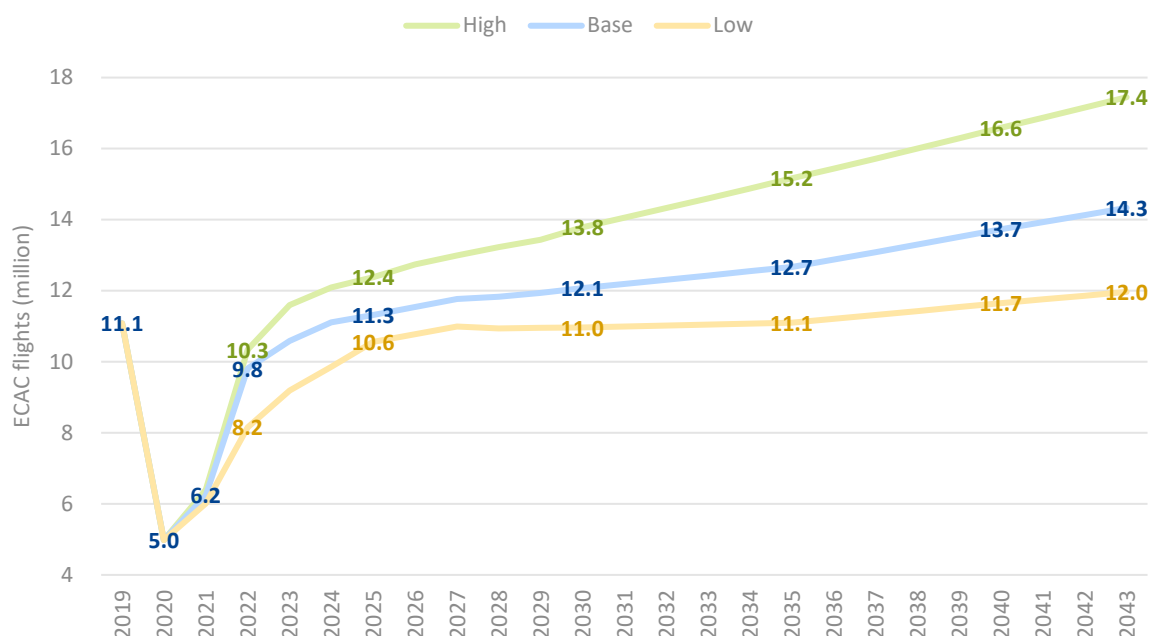


Figure 3: Traffic forecast (EUROCONTROL STATFOR long-term outlook) [20]



4 Benefits

Solution 28.1 should bring local benefits to medium and small airports even if they are less constrained and congested than large and very large airports. The solution is also expected to help increase slot adherence, reduce ATFM delays and en-route capacity buffers at the network level.

Benefits were identified based on the Benefit and Impact Mechanisms¹⁹ (BIMs) developed in the OSED (see final version of the SPR/OSED report [15]). Previous studies on A-CDM²⁰ were also consulted to complete the list of potential qualitative benefits.

Table 10 presents the list of all potential benefits of solution 28.1 and their beneficiaries. It should be noted that not all these benefits will be achieved in all the targeted airports and the amplitude of such benefits will also depend on the characteristics of the airport and the extent to which RNI procedures are adopted.

Benefit type	OE	Local (L) Network (N) benefit	Beneficiary(ies)				
			AO	AUs	GH	ANSP	NM
Increase adherence to schedule (in average) / Turnaround time closer to SLA		L			X		
Increase departure punctuality for passengers		L	X	X			
Reduction of taxi-out time	medium sized airports only during peak hours	L	X	X			
Reduction of taxi-in time		L	X	X			
Reduce ground emission and noise		L	X	X			
Improve ground handling resources and asset utilisation		L			X		
Improve stand and gate planning (i.e., Reduction in the number of late stand and gate changes)	Only for airports that are capacity-constrained	L	X	X			

¹⁹ Benefit mechanisms are causality diagrams that document the changes a given application introduces in the ATM environment and how those changes lead to benefits for the various partners.

²⁰ Cost-benefit analysis performed by EUROCONTROL in 2005 and 2008, as well as the A-CDM economic impact study carried out in 2016.



Reduce delays at local level:							
a) Push-back delay after start-up approval		L			X	X	
b) Phantom start up delay		L		X		X	
c) Off-block delays (green delays)		L	X	X		X	
Increase peak departure rates at the runway	Only for airports that are capacity-constrained	L+N	X	X			X
Reduce in flight activation monitoring (FAM) suspensions		N					X
Reduce ATCO workload		L				X	
Increase resilience in case of adverse conditions		L	X	X		X	
Safety benefits (lower accident repair costs)		L	X	X			
Improve customer service		L	X	X			
Improve fleet utilisation		L+N		X			
Increase ATFM slot adherence and CTOT stability, reduce ATFM delays		L+N		X		X	X
Fewer lost slots and over delivery/, reduced En-route sector buffers		L+N		X		X	X
Reduce reactionary delays due to late inbound		L+N	X	X		X	X

Table 10: Solution 28.1 - Summary of benefits per stakeholder group (in light blue, monetised benefits)

A short description of all those potential benefits is provided in sections 4.1 Local benefits and 4.2 Network benefits.

When quantification and monetisation of benefits were possible, benefit monetisation mechanisms were developed and integrated in the CBA Model. Section 4.3 presents the results of the validation exercises carried out at V3 level and how quantitative results have been used in the CBA Model to estimate the benefits of Solution 28.1.

Note that not all benefits could be quantified and monetised in the CBA due to the lack of quantitative results from the validation exercises.

4.1 Local benefits

Increase adherence to schedule / turnaround time closer to SLA

The target off-block time is set in relation to the estimated off-block time; which is also set to respect the estimated take-off time or calculated take-off time (CTOT) for regulated flights. By meeting the TOBT, airspace users are more likely to be within the take-off window, which improves slot compliance. Over time, this will allow for gradual improvement in schedule adherence, reducing the gap between planning and execution of plans and the need for various buffers included in airport processes.

In addition, this improved adherence should also help constrain turnarounds towards the agreed service levels. This is a qualitative benefit to ground handlers, but also to airlines and airports depending on who is the contracting party of the service.

Increase punctuality at the departure for passengers

Although the RNI concept does not have a direct influence on many causes of delays, it should increase the punctuality of departures through better predictability and efficiency of ground operations and adherence to schedules via the TSAT procedure. This is a perceived benefit for passengers²¹, which should result in greater visibility and a better brand image for the airport.

Reduction of taxi out time

Data sharing between local partners and the continuous monitoring of the turnaround phase through milestones will contribute to more reliable and stable TOBTs, avoiding last minute updates. This will support a more reliable and optimised departure sequence represented by TSATs.

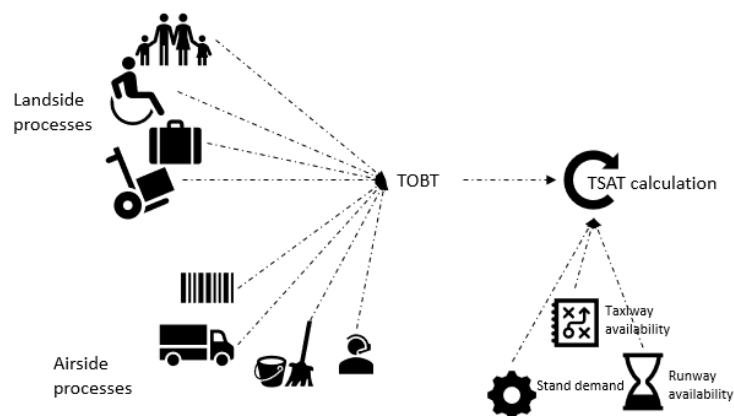


Figure 4: Inputs to TSAT calculations

²¹ Note that the overall benefit to passengers depends on the net delay of the flight when it arrives at its destination. Part of a departure delay can be absorbed in the progression in En-route or through the normal schedule buffer. It is assumed that there is a relation between departure and arrival punctuality.

A TSAT is given by the ATC based on knowledge about all possible queues or obstacles that might occur during the turnaround (see Figure 4). If there is no specific bottleneck in all the airside and landside processes from stand, through taxi to take-off, the taxi time is as short as it can be (unimpeded taxi-time). Therefore, a more stable off block predictability can lead to optimise taxi-out time.

In addition, the TSAT procedure will help ground handlers to better schedule push back to match the departure sequence, enabling more efficient and predictable apron control.

Reduce taxi in time

Reduced inbound flight taxi time stems from better tactical planning of stand and gate assignment. Through the exchange of information with the network, the airport operator will receive a more accurate landing time of incoming flights; by comparing with the target off-block time of the aircraft currently occupying its stand, it will facilitate the decision to allocate a different stand in the event of a longer occupation time. The benefit comes from the reduced operating time of the inbound aircraft, which does not waste time waiting for a stand.

Reduction of ground emission and noise

A reduction in taxiing time means for the airlines a reduction in fuel consumption and less CO₂ emissions.

Coupled with better management of ground vehicles serving aircraft, which should make it possible to reduce engine noise, it is also a direct benefit for airports given the environmental constraints in force.

Improved ground handling resource and asset utilisation

Providing a more accurate ELDT and EIBT information for inbound flights will help ground handlers to plan their operation based on evolving tactical information rather than largely inaccurate schedules. Resource idle time is reduced, airport asset utilisation (contact stands, towing vehicles, buses, push vehicle, de-icing equipment...) increased and staff planning optimised. Should an inbound flight be delayed then that presents an opportunity for the GH to reallocate resources.

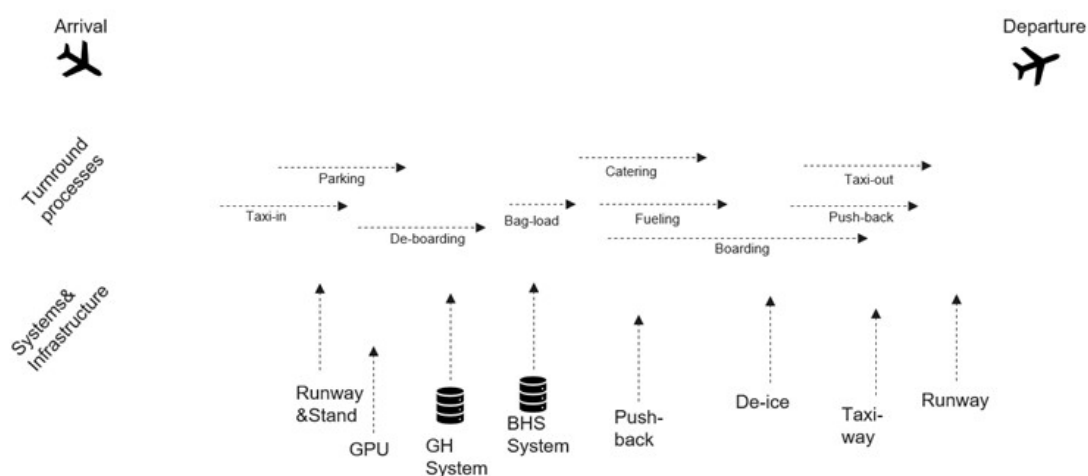


Figure 5: GH landside & airside processes



In addition, the improved off-block predictability and transparency of the TSAT timestamp provides ground handling agents with better information (compared to schedules) to plan the location of push vehicles.

Improve stand and gate planning

The NM provides an accurate ELDT, possibly enriched with the latest information from ATC, and the EIBT is automatically generated from the ELDT and the estimated taxi-in (EXIT) time. This should make better use of stand occupancy time by reducing the number of stands congestion and late changes. In addition, outbound delays due to passengers arriving late at the gate should be reduced. This benefit should apply particularly to airports where stand capacity is a constraint, where the traffic and fleet mix restricts full use of all stand assets during operational peaks.

Reduce delay at local level

Reduction in push-back delays after start-up approval

Delays after start-up approval are usually due to a lack of resources (push-back truck, personnel) or the need to wait for the availability of the taxi-way, the de-icing equipment and/or the access to the runway. In some cases, the aircraft on stand must push-back to release the stand to the next aircraft. The optimal scenario is when the aircraft is given a TSAT that has also considered the availability of all relevant resources and infrastructure and combines this with information about if the stand is needed by a new aircraft instantly. The aircraft would then go through all airside processes based on just-in-time principles.

As for the A-CDM concept, the RNI concept requires strict adherence to CDM procedures. This means that start-up is only granted within TSAT +/- 5 minutes and it implies that the resources planned for departure are available at the right place and the right time.

Phantom start-up delay

The TSAT procedure should help to reduce phantom start-up delay, i.e. delay caused by flights that are 'in the departure sequence' but are unable to consume the slot they have been allocated. With the TSAT procedure, it will no longer be possible to call in advance to secure an earlier slot and flights that are unable to push within 5 minutes of receiving start-up clearance will be automatically re-sequenced with more delay than initially provided.

Reduction of green delay

The TSAT procedure supports a reduction in ground movement congestion and runway queue reductions by retaining flights on stand until capacity in the ATM system is available to accept the flight. In this case, delay is simply transferred from the taxi-phase to the stand and contribute to reduce environmental impact.

Increase peak departure rates at runway

As for the A-CDM, the RNI process should make it possible to optimize the runway departure sequence thanks to the adoption of the TOBT and TSAT procedures. This is the result of the off-block predictability increase (less phantom start up delay and less push back delay) and the reduction in controller task load (Radio Transmission activity is more distributed with the TSAT procedure) providing spare capacity to facilitate an optimal departure sequence on the runway. However, this will be the case only for airports with capacity constraints during peak hours.



Reduce in flight activation monitoring (FAM) suspensions

If a flight is not reported as airborne 30 minutes after the ETOT (Estimated Take Off Time) or TTOT (Target Take Off Time), NMOC will automatically suspend the flight and release the ATFM slot occupied by the flight. TTOTs sent in the payload of DPI message will help eliminate FAM suspensions from RNI airports.

Reduce ATCO workload

For the ground tower controller, the RNI solution should help to reduce the task loading of the clearance delivery position. This is driven mainly by improved off-block predictability from the TSAT, resulting in less radio transmissions (RT) and planning workload – particularly in periods of high traffic demand.

For regulated flights, if the airport has a DMAN or pre-departure sequencer, a TSAT is generated which considers both runway capacity (runway slot availability) and ground congestion levels (in the EXOT). As a result, the slot tolerance window (STW) is much easier to facilitate – with less disruption caused for other flights in the process.

Increase resilience in case of adverse conditions

The RNI solution is expected to minimize the impact of disruptions in adverse conditions by speeding up recovery to normal operation through improved predictability of ground operations. This is especially true during winter periods, when the demand for snow and ice removal equipment exceeds the supply. In such conditions, poor predictability can quickly lead to operational chaos.

These specific situations require common situational awareness, increased data exchange and faster communication between all actors involved in airport operations.

Safety benefit (lower accident repair cost)

Although it is difficult to prove and quantify the safety benefit, with fewer aircraft on the apron and on the taxiways at the same time, there is some potential for accident reduction in RNI airports.

Improve customer service

Ground inefficiencies will be reduced and passenger experience increased: less time spent at the gate and less last-minute gate changes, less time waiting for buses to reach the remote area in the tarmac, less time waiting for luggage on the carousel, less time spent at customs and controls, etc. All sort of things that will have a positive impact on the image of the airport and airlines.

4.2 Network benefits

Improve fleet utilisation / flexibility of departure

Airlines will benefit from an improved arrival time predictability and the possibility to proactively re-planned (or cancelled) an aircraft that is planned to fly several sectors over the course of the day in case of delay notifications received during earlier legs.

At the network level, better adherence to schedules should enable aircraft operators to make greater use of their aircraft. The progressive implementation of the RNI concept in small and medium-sized



airports should increase the predictability of the overall system due to the number of rotations of an aircraft per day.

Increase ATFM slot adherence and CTOT stability

The ATFM slots generated for flights departing from RNI airports are better suited to the operational constraints faced by the airport in real time. As a result, ATC are better able to ensure take-off clearance within the slot tolerance window (STW), whilst minimising disruption to other flights in the departure flow.

A more achievable CTOT is made possible through the improved accuracy of the TTOT (and the EXOT) that is published within DPI messages. This results in improved slot utilisation, increased CTOT stability and a reduction in overall ATFM delay issued as part of each flow restriction.

In a previous study conducted in 2016, CDM airports have been shown to generate better ATFM slots with less average ATFM delay per regulation than prior to full A-CDM operations.

Fewer lost slots and over delivery, reduced En-route capacity buffer

Airspace Users will benefit from gradual improvements in ATM network management due to progressive adherence to schedule in the RNI airports and the knock on effect it should have in increasing the En-route ATC sector productivity.

Today, the Network Manager works with a non-optimal traffic demand picture based on EOBT and default taxi time. To function optimally, it needs a stable and predictable demand picture in order to avoid traffic overload and congestion, applying unnecessary restrictions and wasting ATFM slots. Improving take-off predictability will reduce the potential for sector over-delivery, which in turn, could result in the reduction of en-route sector buffers without compromising levels of safety.

Reduce reactionary delays

With sufficient notice, RNI Airport should be able to change the initial stand or gate assignment to accommodate a late arrival. As a result, the rotation of the aircraft can be optimised, the transit of connecting passengers facilitated, and the propagation of reactionary delays avoided.

The advantage applies to all cases where the stand for the arrival flight has been negotiated to reduce reactionary delays.

4.3 Benefit quantification in the CBA model

The Validation exercise has quantified the predictability PRD#M1 performance metric, which is an indicator of the departure predictability not listed in the SESAR Performance Framework [12], but described in the Benefit Impact Mechanism (BIM) in Appendix A of the SPR-INTEROP/OSED [15].

This CBA monetises two network benefits that can be derived from the PRD#M1 numerical results:

- Fewer lost slots due to better departure (take-off time) predictability; and
- Capacity buffer reduction resulting from better departure (take-off time) predictability, which, consequently, improves the predictability of the en-route sector entry time at the network level (see Appendix B for more detail).

Table 11 captures the departure predictability (PRD#M1) results achieved by the solution during the validation exercise and registered in the Validation Report [19].

Metric	Solution scenario ATOT-TTOT		Reference scenario ATOT-ETOT	
Results (minutes)	Mean (μ)	Std. Deviation (σ)	Mean (μ)	Std. Deviation (σ)
9h to ATOT	27.2	34.6	33.0	35.8
7h to ATOT	23.0	29.1	28.7	30.9
5h to ATOT	19.8	23.5	26.4	28.6
3h to ATOT	13.8	19.5	22.3	22.7
2h to ATOT	11.9	14.3	19.3	18.5
1h to ATOT	9.8	9.4	17.8	16.5

Table 11: Validation results – PRDM#1 Departure predictability [19]

4.3.1 Fewer lost slots

The Network Manager (NM) will issue better and more stable regulations (CTOTs) based on more accurate departure data (TTOT). This benefit will translate into fewer lost slots by airspace users. Once an aircraft loses its slot, it has to wait until a new one and accumulates further delay. Therefore, the CBA transfers the predictability benefit to airspace users, monetising the avoided tactical and strategic delay, as well as to airport operators, considering the time saved by passengers through the passenger value of time.

Figure 6 shows the calculation followed in the CBA to monetise the improved adherence to CTOT.

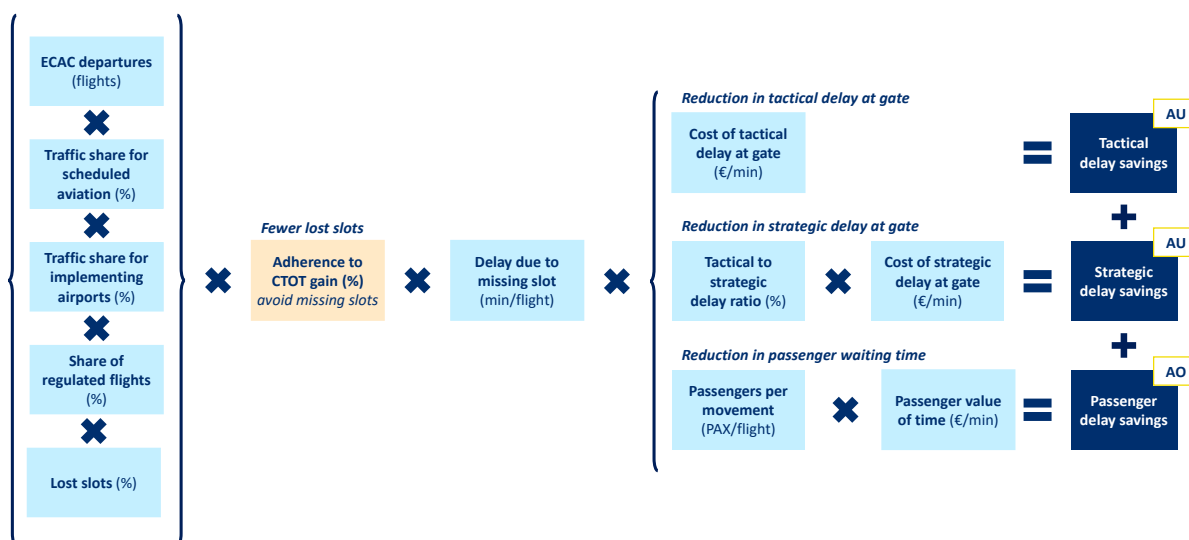


Figure 6: Monetisation of network predictability (1/2) – Slot adherence
(in orange, results from validation exercise)

Improved adherence to CTOT

The connected airports will send the predicted TTOT (coming out of the TOBT prediction and sequencing processes) to the NM, feeding the calculation of the flight regulations (CTOTs). The TTOT

and the CTOT shall be therefore compatible. Meeting the TTOT should ensure compliance with the CTOT. Therefore, the CBA estimates the gain in slot adherence (CTOT) based on the reduced probability of infringing the TTOT. To do so, it considers a ± 5 minutes²² TTOT compliance window.

The NM issues the flight regulations, at least, 2 hours before the estimated off-block time (EOBT). Subsequently, the analysis considers the *ATOT-TTOT* results for *2h to ATOT*, as the best approximation for *2h to EOBT*. Assuming that Table 11 metrics follow normal (Gaussian) distributions, the reduced probability (P) of $|ATOT-TTOT| > 5 \text{ minutes}$ can be calculated as follows:

$$\Delta \text{Slot Adherence} = \frac{\text{REF} - \text{SOL}}{\text{REF}} \begin{cases} \text{SOL} = P(|ATOT - ETOT|)_{\text{REF}}, > 5 \text{ min} \\ \text{REF} = P(|ATOT - TTOT|)_{\text{SOL}}, > 5 \text{ min} \end{cases}$$

The solution would **avoid 12.0% of the currently missed slots at the implementing airports.**

4.3.2 Reduced en-route capacity buffer

The declared capacity, determined by the ANSP and declared to the NM, is the number of aircraft per hour that a sector can normally accommodate [26] being protected from overload. This value is typically below the sector maximum safe capacity, i.e., the maximum aircraft per hour that sector controllers can handle without exceeding the overload threshold [27]. The difference between both is the capacity buffer, which covers unexpected traffic, i.e., over-deliveries.

The uncertainty of the aircraft entry time to the en-route sector is one of the factors contributing to the need for a capacity buffer. The better departure (and network) predictability should allow for reducing the en-route capacity buffer and therefore increasing the declared capacity up to a closer value to the maximum safe capacity. This implies an increase in the declared en-route capacity, which should reduce the ATFM delay. The CBA monetises this benefit as route throughput (CAP2), as depicted in Figure 7.

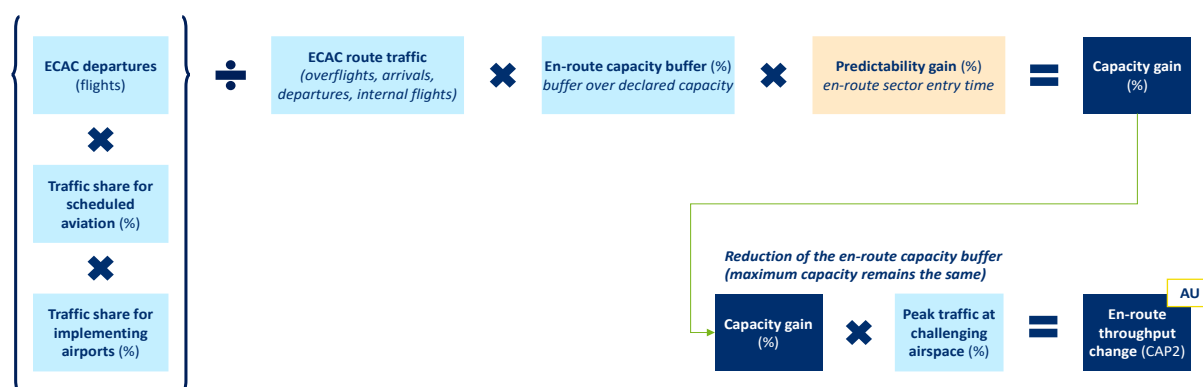


Figure 7: Monetisation of departure predictability (2/2) – Network predictability
(in orange, results from validation exercise)

²² The NM considers a ± 5 minutes tolerance in the TTOT value (Milestone 3, [23]). Dublin Airport: “Take-off clearance will be given at TTOT ± 5 minutes” [24].

Improved network predictability

The underlying assumption for this calculation is that the departure predictability (take-off time) measured in the validation exercise [19] is equal to the network predictability (entry-time to the en-route sector).

Therefore, the predictability gain is calculated as the change in the standard deviation of the departure predictability $PRD\#M1 = |ATOT - TTOT|$ with and without the solution, as per the following equation:

$$\Delta PRD = \frac{\sigma_{SOL} - \sigma_{REF}}{\sigma_{REF}}$$

Again, the *2h to ATOT* values from Table 8 are selected for the calculation, resulting in a **+22.8% departure predictability gain** for at the implementing airports. This result translates in a **+5.9% network predictability gain** and **+0.15% CAP2**, as per the calculation depicted in Figure 7 and the inputs listed in section 6.

Monetisation of en-route throughput (CAP2)

The CBA models the increased en-route throughput as a reduction in ATFM delay. The CBA monetises this benefit in three (3) ways:

- **Reduction in tactical delay at gate:** The CBA considers the time savings a benefit for airspace users and monetises them with the cost of tactical delay at gate.
- **Reduction in strategic delay at gate:** A reduction in the tactical delay should also bring a decrease in the strategic delay at gate. The CBA captures this effect as an additional benefit for airspace users, monetising it with the cost of strategic delay at gate.
- **Reduction in passenger waiting time:** The reduction in tactical delay brings also a reduced waiting time for the passengers of the flight. The CBA considers this benefit for the airport operator (i.e., in terms of improving the airport's brand image) and monetises it via the passenger value of time.

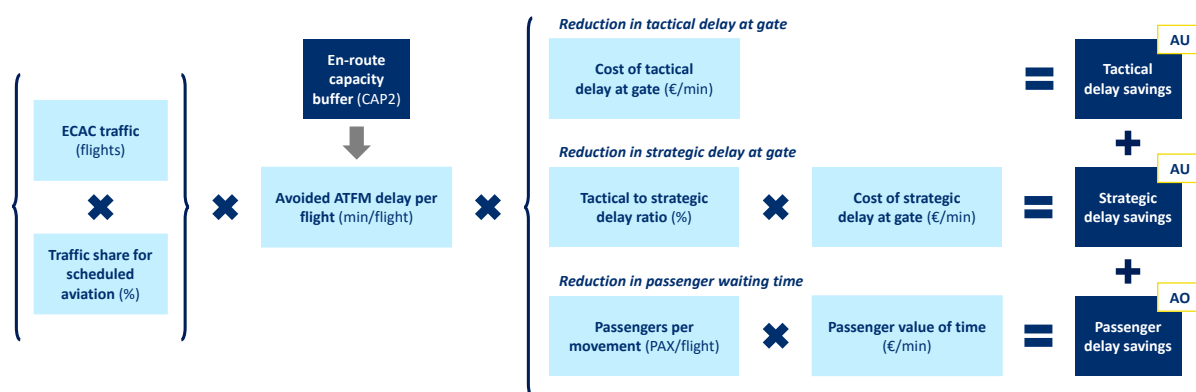


Figure 8: Monetisation of en-route capacity buffer reduction (CAP2)

Figure 8 shows the calculation sequence followed in the CBA to monetise the en-route capacity buffer reduction resulting from departure predictability increase. The translation of CAP2 into avoided delay per flight is done as per the methodology in section 6.1.1.



4.3.3 Summary of quantified benefits

Table 10 summarises the solution 28.1 benefits and beneficiaries monetised in the CBA model. It links the (a) BIM described in the solution SPR-INTEROP/OSED [15] with the (b) mechanisms used in the CBA to monetise the solution benefits. Besides, it connects these mechanisms with the (Key) Performance Indicators listed in the SESAR 2020 Performance Framework [12].

Solution PJ.04-W2-28.1		SESAR performance framework [12]	
Quantified benefit	Impact on CBA	KPA & FA	KPI/PI
Fewer lost slots (-12%) <i>at implementing airports</i>	Reduce delay <u>AUs</u> : Reduce tactical delay at gate (and subsequent strategic delay) <u>AOs</u> : Reduce passenger waiting time	Predictability & punctuality Predictability	N/A
Improved departure predictability (+22.8%) <i>at implementing airports</i>	Reduce airspace capacity buffer: increase declared airspace capacity <u>AUs</u> : Reduce tactical delay at gate (and subsequent strategic delay) <u>AOs</u> : Reduce passenger waiting time	Cost efficiency Airspace User Cost efficiency	CAP2 (+0.15%) En-route throughput, in challenging airspace, per unit time

Table 12: Solution 28.1 benefits monetised in the CBA



4.4 Overall contribution to performance

The calculations to fill Table 13 follow the relationships established in Table 12 between the CBA benefits and the SESAR KPIs/PIs. Note that the table does not include the benefits derived from the avoided missed slots since no equivalent KPI in SESAR framework has been identified.

Performance Framework KPA ²³	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year 2027	Year 2036	Year 2043
Cost Efficiency	ANS Cost efficiency	CEF2 Flights per ATCO-Hour on duty	Nb	ATCO employment Cost change	€/year	N/A	N/A	N/A
				Support Staff Employment Cost Change	€/year	N/A	N/A	N/A
				Non-staff Operating Costs Change	€/year	N/A	N/A	N/A
	Airspace User Cost efficiency	CEF3 Technology cost per flight	EUR / flight	G2G ANS cost changes related to technology and equipment	€/year	N/A	N/A	N/A
		AUC3 Direct operating costs for an airspace user	EUR / flight	Impact on direct costs related to the aeroplane and passengers. Examples: fuel, staff expenses, passenger service costs, maintenance and repairs, navigation charges, strategic delay, landing fees, catering	€/year	N/A	N/A	N/A

²³ For information, the mapping to the Performance Ambition KPAs (used in the ATM Master Plan) is available in the Appendix D.



Performance Framework KPA ²³	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year 2027	Year 2036	Year 2043
		AUC4 Indirect operating costs for an airspace user	EUR / flight	Impact on operating costs that don't relate to a specific flight. Examples: parking charges, crew and cabin salary, handling prices at Base Stations	€/year	N/A	N/A	N/A
		AUC5 Overhead costs for an airspace user	EUR / flight	Impact on overhead costs. Examples: dispatchers, training, IT infrastructure, sales.	€/year	N/A	N/A	N/A
Capacity	Airspace capacity	CAP1 TMA throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
		CAP2 En-route throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	-0.1m	-17.0m	-30.1m
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	0.0m	-1.0m	-1.8m
			% and # movements	Passenger delay cost (avoided-; additional +)	€/year	-0.1m	-12.4m	-22.0m
	Airport capacity	CAP3 Peak Runway Throughput (Mixed mode)	% and # movements	Value of additional flights	€/year	N/A	N/A	N/A
	Resilience	RES4a Minutes of delays	Minutes	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
		RES4b Cancellations	% and # movements	Cost of cancellations	€/year	N/A	N/A	N/A



Performance Framework KPA ²³	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year 2027	Year 2036	Year 2043
		Diversions	% and # movements	Cost of diversions	€/year	N/A	N/A	N/A
Predictability and punctuality	Predictability	PRD1 Variance of Difference in actual & Flight Plan or RBT durations	Minutes^2	Strategic delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
	Punctuality	PUN1 % Departures < +/- 3 mins vs. schedule due to ATM causes	% (and # movements)	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
Flexibility	ATM System & Airport ability to respond to changes in planned flights and mission	FLX1 Average delay for scheduled civil/military flights with change request and non-scheduled / late flight plan request	Minutes	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
Environment	Time Efficiency	FEFF3 Reduction in average flight duration	% and minutes	Strategic delay: airborne: direct cost to an airline <u>excl. Fuel</u> (avoided-; additional +)	€/year	N/A	N/A	N/A
	Fuel Efficiency	FEFF1 Average fuel burn per flight	Kg fuel per movement	Fuel Costs	€/year	N/A	N/A	N/A
	Fuel Efficiency	FEFF2 CO2 Emissions	Kg CO2 per movement	CO2 Costs	€/year	N/A	N/A	N/A
Civil-Military Cooperation & Coordination	Civil-Military Cooperation & Coordination	CMC2.1a Fuel saving (for GAT operations)	Kg fuel per movement	Fuel Costs	€/year	N/A	N/A	N/A



Performance Framework KPA ²³	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year 2027	Year 2036	Year 2043
		CMC2.1b Distance saving (for GAT operations)	NM per movement	Time Costs	€/year	N/A	N/A	N/A

Table 13: Results of the benefits monetisation per KPA



5 Costs

This section describes and analyses all the costs stemming from implementing the solution 28.1. The analysis considers 28.1 as a stand-alone Solution, i.e., deployed independently from any other SESAR 2020 Solution.

A first cost estimate was provided in V2 based on the list of enablers contained in the EATMA DS18a dataset [30]. The list of enablers having been slightly modified, the costs were reassessed in V3 taking into account the new list of enablers (see Table 7) and the latest developments in the operational concept and the architecture of the solution (see the final version of the OSED and the TS/IRS). Detailed costs by stakeholder group are provided in the sections below and are based on the delta approach between the solution scenario and the baseline scenario.

5.1 ANSPs costs

5.1.1 ANSPs cost approach

ANSPs will access the AOP tool through a dedicated web interface that will be provided free of charge by the Airport Operator. However, this CBA considers an appropriation to update the ATC system to align it with RNI airport operations and enable the display and management of TSAT.

The solution should have minor impact on the way the ANSPs (i.e., the ATC Tower) are operating in the airport. The solution will only increase situational awareness by providing more accurate information about when the aircraft is ready to leave the gate. Again, the CBA considers an appropriation for the initial and recurrent training of the Tower Ground controllers, who will manage the TSAT.

5.1.2 ANSPs cost assumptions

The upgrade of the ATC system (AERODROME-ATC-114) will highly depend on the current capabilities and level of equipment of the Tower. Three (3) scenarios are foreseen (from lower to higher cost):

- Installation of a workstation and a screen in the Tower to share the AOP data.
- Development and testing of an interface with an available e-strips system for the Tower.
- Installation of a new e-strips system for the Tower, as well as its integration with the AOP.

Besides, the CBA considers the costs of training the Tower Ground controllers (HUM-058). The EUROCONTROL Airport CDM CBA [28] considers the following effort (person-days) to develop the new procedures and train the staff, when implementing a full A-CDM project:

Cost item	One-off effort	Recurrent effort
Procedure development	29 person-days	-
Training	67 person-days	10 person-days

Table 14: Staff effort to implement full A-CDM [28]

This estimation covers all the staff involved (Tower ground controllers, but also airport operations and ground handling). Therefore, this CBA assumes that 50% of the effort is associated to the Tower ATCOs



(i.e., cost for ANSPs) and 50% to the Ground Handler (see section 5.4). To translate the staff effort into monetary costs for the ANSPs, the CBA considers €119 per ATCO hour [29].

Note that the estimation should be conservative since solution 28.1 implements a “light” A-CDM concept in small and medium airports, whereas the reference [28] considers the full A-CDM concept in large and very-large airports.

5.1.3 Number of investment instances (units)

Solution 28.1 is expected to be deployed in the 156 small and medium airports in ECAC that have not yet implemented the A-CDM concept. Therefore, the CBA considers 156 Aerodrome ATC Towers.

Aerodrome ATC Towers (i.e., airports)				
Extra Large	Large	Medium	Small	Others
--	--	64 (76-12 already A-CDM)	92	--

Table 15: Number of investment instances – ANSPs

5.1.4 Cost per unit

Table 18 presents the ANSP costs for one Aerodrome ATC Tower.

Cost category	Unit cost per ATC Tower (k€)		
	MIN	BASE	MAX
Implementation costs	71	296	746
Change in operating costs vs the reference scenario	10	65	125

Table 16: ANSP - Unit cost per aerodrome ATC tower

5.2 Airport operators costs

5.2.1 Airport operators cost approach

A bottom-up approach was used in V2 to estimate the CAPEX and OPEX of a medium-sized airport. The costs were then aggregated at the ECAC level, by multiplying the unit cost by the number of medium-sized target airports.

In V3, the costs have been re-evaluated taking into account the changes in the list of enablers²⁴. It has been agreed between the project partners that the range of values provided in V2 will still be valid in V3 although the list of target airports has been expanded to include smaller airports. In the CBA model, costs are aggregated at the ECAC level by multiplying the unit cost by the number of all small and medium-sized target airports.

²⁴ Note that airport-38 and airport-50 enablers have been merged into a single enabler, airport-03c.

The values are based on experience from other similar projects and inputs from IT (Information Technology) experts in the aviation domain. Both costs from CDM and PCP implementations were used to compare values from earlier procurements and implementations of AODB (Airport Operational Data Base). In addition, the value of the information sharing platform (AOP tool), provided by the experts, was compared to the actual cost of the prototypes used in the validation exercises in Alicante in V2 and Gothenburg in V3 to refine the cost assessment.

The airport operator will bear the vast majority of the costs of solution 28.1 through the Airport-03c enabler. The solution will not affect airport procedures or the current way of operating, it should only increase overall situational awareness through more accurate indicators (TOBT, TSAT...). The cost assessment includes:

CAPEX and other one-off costs

- The development and implementation of the “light” AOP (Airport Operation Plan) management tool (AIRPORT-03c enabler). The tool should be able to :
 - check consistency between ATC flight plan, airport slot and airport flight data and confirm the flight to the Network Manager (via the e-DPI²⁵ message sent to NMOC), allowing further local processing of the flight;
 - compute the required parameters (TOBT, TTOT, ACGT, TSAT...) and update the status of these parameters when required;
 - send the DPI message required by the RNI concept;
 - share information with local partners through a dedicated web interface.

This AOP tool will mainly consist of evolving the airport operator's AODB system to fulfil the required functions. The range of costs provided in the estimate takes into account the complexity of the AODB system in place and the importance of the modifications to be made to the hardware part. In some cases, the airport will prefer to replace the AODB system rather than upgrade it and will directly implement a “lite” AOP tool, but it was agreed in the CBA team that the replacement cost cannot be entirely attributed to solution 28.1. Consequently, the maximum value has been significantly reduced compared to V2.

In addition, we found that the fact that an airport has already implemented a DMAN will not have an impact on the cost of the solution since the cost of the prototypes used in Alicante for the V2 exercise (where there is a DMAN) and in Gothenburg for the V3 exercise (where there is no DMAN) were similar. The only difference is that:

- If DMAN exists, then the Lite AOP tool will consider the value proposed by the DMAN for the TSAT value.
- If DMAN does not exist, then the TSAT value will be:
 - TOBT if there is no CTOT
 - CTOT – EXOT if there is a CTOT

²⁵ E-DPI = early DPI message. The transmission of an E-DPI shall confirm to NMOC that an airport slot and flight plan for a particular flight have been correlated in accordance with local rules at the airport (A-CDM Milestone 1)



- The connection to the NM B2B service for automatic transmission of appropriate DPI messages to the NMOC, when required.
- The development and production of the parameters necessary to compute the key indicators (TOBT, TTOT, ACTG, TSAT...): taxi-in and taxi-out times per stand and runway combination, expected turnaround time for a flight, expected boarding duration time for a flight.... This will be achieved through statistical historical analysis and based on the airport's business model.

The airport operator will provide each local partner (airlines, ground handling and control tower) with access to the Lite AOP tool via a dedicated web interface, where the most recent information regarding all key indicators, including TOBT (Target off-block time) and TSAT (Target Start-up Approval Time), will be displayed and shared with all local partners.

OPEX:

- The maintenance of the Lite AOP tool,
- The renewal of the certificate for the connection to the NM B2B service (which is currently negligible),
- The recurrent training for the staff in charge of the RNI concept and the AOP tool.

5.2.2 Airport operators cost assumptions

Pre-requisite elements:

Connected Regional Airports (RNI Airports) solution is a cost-efficient way of achieving the connection with the Network Manager, reducing the effort of the stakeholders in the airport compared to a full A-CDM solution. Therefore, the list of pre-requisite elements required before deploying solution 28.1 is limited to:

- the availability of an Airport Operational Database (AODB);
- the ability to reliably link (ideally automatically) inbound flights to outbound flights in a manner consistent with the SESAR concept of the Airport Transit View (ATV)²⁶.

Cost assumptions:

- Costs are provided per airport in kilo Euros and encompass all the elements described above and associated with the AIRPORT-03c enabler;
- In the CBA, costs are calculated as follows:
 - For the CAPEX and other investments, costs are allocated linearly between the start and end dates of the deployment phase;
 - For the OPEX, there is a progressive increase in the costs between the IOC and FOC dates which reflects the implementation ramp-up of solution 28.1 in all of the 156 targeted airports. From the date of full operational capacity, operating expenses are at their maximum level each year.

²⁶ Note that the information to link an inbound flight to an outbound flight can also be provided manually.



- The costs are provided at the enabler level and include all the elements described in section 5.2.1 (hardware and software investment, development, integration, statistical analysis of historical data, key parameters set-up, interface, procedure and documentation, etc.);
- Looking at the OPEX, only delta costs are captured, i.e., assessing how much the operating costs will increase (per year) when comparing the solution scenario to the reference scenario.²⁷ In V2, OPEX represented 7% of total investment, the same ratio was used in V3 to re-evaluate OPEX costs.
- It should be noted that cost savings are not treated as a reduction of the costs in the CBA model but as a potential benefit of the solution and accounted for on the benefit side.

5.2.3 Number of investment instances (units)

Solution 28.1 is expected to be deployed in the 156 small and medium airports in ECAC that have not yet implemented the A-CDM concept, as shown in Table 17.

Airport				
Extra Large	Large	Medium	Small	Others
--	--	64 (76-12 already A-CDM)	92	--

Table 17: Number of investment instances – Airports

5.2.4 Cost per unit

Table 18 presents the Airport Operator costs for one airport.

Cost category	Unit cost per airport (k€)		
	MIN	BASE	MAX
Implementation costs	420	525	630
Change in operating costs	29	37	44

Table 18: Airport Operator - Unit cost per airport

5.3 Network Manager costs

5.3.1 Network Manager cost approach

The investment from the Network Manager in the RNI solution will be limited. A rough and initial estimate was provided by EUROCONTROL in V2 based on the DS18 list of enablers and the deployment assumption that the solution would be implemented in 42 medium-sized airports.

²⁷ It should be noted that potential cost savings resulting from better use of airport resources through solution 28.1 will be treated as a benefit.



Since some enablers have been removed from the original list, NM costs have been re-evaluated in V3. The main change concerns the initial training to be given by EUROCONTROL to airports applying for integration. The objective of this training session was to train local airport staff on A-CDM processes and new modes of operation, namely tracking milestones, producing DPI messages and using the ATV view. As the RNI concept will be much simpler than the A-CDM, and the production of DPI messages quasi-automatic without the need for local intervention, the need for the training session will be limited and could be considered negligible. The presentation of the new HMI set up by the airport to follow the progress of the turnaround phase should serve as initial training and no additional training should be required. Therefore, training costs have been eliminated from the previous cost assessment.

Therefore, the only cost item that the Network Manager will support for solution 28.1 is the need to develop guidelines for the RNI concept (STD-116), ensuring that the same data quality requirements (data format, data quality etc.) will be applied to the light AOP than those required in the current A-CDM standards.

5.3.2 Network Manager cost assumptions

The cost assessment carried out by EUROCONTROL in phase V2 was reviewed in V3 and discussed within the CBA team. It has been confirmed that:

- It is not necessary to organize training sessions on the RNI concept and the applicable CDM standards for airport staff, as they are not involved in the monitoring of milestones and the production of DPI messages since everything is almost automatic.
- The value provided in v2 for the development and production of the RNI guidelines is still valid. The cost was carried over to the STD-116 enabler instead of the Airport-38 which was removed from the original list.

5.3.3 Network Manager cost figures

Table 19 presents the Network Manager costs for solution 28.1

Cost category	Unit cost (k€)		
	MIN	BASE	MAX
Implementation costs	50	50	50
Change in operating costs	--	--	--

Table 19: Network Manager – Unit cost

5.4 Airspace User costs

5.4.1 Airspace User cost approach

The only costs that Airlines will support are related to the GH support in the CDM processes. There is only one enabler, which relates to airline costs (HUM-36). This enabler deals with the updated role of ground handling in the RNI concept, i.e., related to the lightweight CDM process. The tasks of the Ground Handlers will change, as maintenance of block time in A-CDM will now be done by the system, i.e. by the new AOP tool. This will result in a task change from a manual entry to a monitoring task. GH companies operating at the airport will need to identify one or more focal points that will have to:



- Access the Lite AOP tool and cross-check the information and the status of the TOBT;
- Manually modify the TOBT in the event of a discrepancy or anomaly. This should always be done in close coordination with the aircraft operator and through internal agreements;
- Deliver Milestone11 on time and with integrity;
- Participate in the activities and functions of the RNI Airport program in a collaborative manner.

5.4.2 Airspace User cost assumptions

The CBA considers the costs of training the Ground Handling Agent (HUM-036). The EUROCONTROL Airport CDM CBA [28] considers the following effort (person-days) to develop the new procedures and train the staff, when implementing a full A-CDM project:

Cost item	One-off effort	Recurrent effort
Procedure development	29 person-days	-
Training	67 person-days	10 person-days

Table 20: Staff effort to implement full A-CDM [28]

This estimation covers all the staff involved (airport operations and ground handling, but also Tower ground controllers). Therefore, this CBA assumes that 50% of the effort is associated to the Ground Handler (i.e., cost for AU-GH) and 50% to the Tower ATCOs (see section 5.1). To translate the staff effort into monetary costs for the AU-GH, the CBA considers €46 per GH Agent hour²⁸.

Note that the estimation should be conservative since solution 28.1 implements a “light” A-CDM concept in small and medium airports, whereas the reference [28] considers the full A-CDM concept in large and very-large airports.

5.4.3 Number of investment instances (units)

Solution 28.1 is expected to be deployed in the 156 small and medium airports in ECAC that have not yet implemented the A-CDM concept.

Airspace users – Ground handlers				
Extra Large	Large	Medium	Small	Others
--	--	64 (76-12 already A-CDM)	92	--

Table 21: Number of investment instances – AU-GH (number of airports)

²⁸ Average labour cost for Airport operations and handling personnel is €43 per hour (2013 value, [31]). The value has been adjusted for inflation to 2019 prices [10].



5.4.4 Cost per unit

Table 22 presents the Airspace User costs for solution 28.1.

Cost category	Unit cost (k€) per airport		
	MIN	BASE	MAX
Implementation costs	18	18	18
Change in operating costs	2	2	2

Table 22: Cost per unit – AU-GH

5.5 Military costs

Not applicable to Solution 28.1

5.6 Other stakeholders

Ground handling costs are included in airspace user costs.

5.7 Summary of costs

Table 23 summarises the number of investment instances and unit costs that feed the CBA model.

Item		Stakeholder			
		ANSPs	AOs	NM	AUs (GHs)
Investment instances		156	156	1	156
Unit implementation cost (EUR'000)	Low	71	420	50	18
	Base	296	525	50	18
	High	746	630	50	18
Unit operating cost (EUR'000 per year)	Low	10	29	-	2
	Base	65	37	-	2
	High	125	44	-	2

Table 23: Summary of solution 28.3 unit costs and investment instances



6 CBA Model

The CBA model allows calculating the project yearly cash flows as well as the cumulative values for each concerned stakeholder. The CBA model is attached below (Microsoft Excel file).



PJ.04-W2-28.1_CBA_
20221111_v1.4.xlsm

6.1 Data sources

The following table summarises the inputs required for the monetisation of solution 28.1 benefits (as described in section 4.3).

Topic	CBA input	Value	Source
Traffic characterisation	Traffic forecast (non-ECAC departures & arrivals, ECAC internal flights, overflights)	See section 3.6.4	EUROCONTROL Aviation Outlook 2050 (April 2022) [20]. Additional detail (yearly forecast) provided by EUROCONTROL STATFOR
	Traffic share for scheduled aviation	87.1%	2019 value. EUROCONTROL Standard Inputs for Economic Analyses [10]
	Traffic share for Medium & Small airports	35%	See section 3.1.2
Delay cost	Cost of tactical delay at gate	€67.9 per min	Calculated, as per section 6.1.2
	Strategic to tactical delay ratio	25%	SESAR Cost-Benefit Analysis Model [4]. Calculated from EUROCONTROL CODA Digest 2010 report
	Cost of strategic delay at gate	16.0 € per min	EUROCONTROL Standard Inputs for Economic Analyses [10]
Passenger value of time	Passengers per movement	129 passengers per flight	2019 value. EUROCONTROL Standard Inputs for Economic Analyses [10]
	Passenger value of time	€23.0 per hour	Calculated, as per section 6.1.3
Lost slots	Adherence to slot gain	12%	Calculated as per section 4.3.1, based on VALR [19]
	Regulated departures	25.2% of total departures	2019 value. EUROCONTROL CODA calculation
	Missed slots	3.1% of regulated departures	2019 value. EUROCONTROL AIU – ATFM slot adherence dataset . Late (regulated) departures at Medium and Small airports
	Average additional delay if lost slot	36.4 min per lost slot	EUROCONTROL Airport CDM CBA [28]

En-route capacity	Departure predictability gain (at implementing airports)	22.8%	Calculated as per section 4.3.2, based on VALR [19].
	En-route capacity buffer	5.5%	2019 value. EUROCONTROL AIU – ATFM slot adherence dataset . Regulated departures out of the slot tolerance window (STW)
	Peak traffic at challenging airspace	44.49%	SESAR2020 Common Assumptions [9]: Aggregation Assumptions 2035. Challenging airspace is defined as very-high, high and medium complexity en-route airspace, as suggested by the SESAR Performance Framework [12]: footnote 9.
	Off-peak traffic at challenging airspace	52.71%	

Table 24: Inputs for the monetisation of the solution benefits

6.1.1 En-route ATFM delay

The CBA model projects the en-route ATFM delay per flight as per the following formula, extracted from the SESAR integrated CBA model [4]:

$$\frac{dD}{D} = \kappa \cdot \frac{dT}{T} \rightarrow \text{Delay per flight} = \left(\frac{\text{Flights}}{\text{Capacity Index}} \right)^7$$

The starting point for the capacity index²⁹ is defined in 2019, where both the traffic [20] and the en-route ATFM delay per flight [18] are known.

The capacity index has been assumed to increase at a constant annual growth rate of +0.59% (half of traffic CAGR for 2019-2043, base traffic forecast scenario), which drives into more conservative results in delay savings than the SESAR integrated CBA model assumption (+0.5% annual increase [4]). This assumption avoids excessive benefits in the high traffic growth scenario (+0.92% annual capacity index increase, instead of a constant +0.5%) since it could be expected that the Member States will invest more in capacity if the traffic demands it.

Table 26 summarises this calculation. To estimate the delay reduction thanks to the solution, the CBA model repeats the calculation adding the calculated route capacity gain (CAP1, Table 24) to the baseline annual capacity increase (+0.59%).

Metric	2019	2022	2025	2030	2035	2040	2043
En-route ATFM delay (min/flight)	1.55	0.58	1.40	1.79	2.04	2.91	3.48
ECAC flights	11.1m	9.8m	11.3m	12.1m	12.7m	13.7m	14.3m

²⁹ The capacity index is a constant value resulting from the boundary condition (delay per flight and number of flights for a given year) required to solve the delay-traffic differential equation presented above. The SESAR integrated model uses $\kappa = 7$, calculated based on 2001 traffic and delay figures (Benefits of Improved Predictability Final report, v1.0, 14-12-2012).



Capacity Index	10.4m	10.6m	10.8m	11.1m	11.4m	11.8m	12.0m
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Table 25: En-route ATFM delay

6.1.2 Cost of tactical delay at gate

ECTRL Standard Inputs [10] provide two values for the cost of tactical delay at gate, depending on the duration of the delay. This CBA uses the weighted average value for the cost of tactical delay at gate, as per the following calculation and Table 26.

$$\text{Cost of tactical delay at gate} = \frac{34.1\% \cdot 40\text{€/min} + 12.0\% \cdot 147\text{€/min}}{34.1\% + 12.0\%} = \text{€67.9 per minute}$$

CBA input	Value	Source
Cost of tactical delay at gate (less than 30 min)	€40 per minute	EUROCONTROL Standard Inputs for Economic Analyses [10]
Cost of tactical delay at gate (more than 30 min)	€147 per minute	
Departures delayed less than 30 min	34.1%	EUROCONTROL CODA Digest 2020 [17]. All causes departure punctuality for commercial flights. Values for 2019
Departures delayed more than 30 min	12.0%	

Table 26: Cost of tactical delay at gate

6.1.3 Passenger value of time

ECTRL Standard Inputs [10] provide two values for the passenger value of time, depending on the trip purpose (i.e., personal or business). This CBA uses a weighted average value for the passenger value of time, as per the following calculation and Table 27.

$$\text{Passenger value of time} = 81.6\% \cdot \frac{14.4\text{€/hour} + 22.0\text{€/hour}}{2} + 18.4\% \cdot 44.4\text{€/hour} = \text{€23.0 per hour}$$

CBA input	Value	Source
Passenger value of time (personal)	€14.4-22.0 per hour	EUROCONTROL Standard Inputs for Economic Analyses [10]. Value 1 – European Commission
Passenger value of time (business)	€44.4 per hour	
Other (holidays, visiting friends and relatives, miscellaneous) passengers	81.6%	EUROCONTROL Standard Inputs for Economic Analyses [10]. Value 1 – UK Department for Transport (2018)
Business passengers	18.4%	

Table 27: Passenger value of time



7 CBA Results

The following sections present the main CBA results. Note that monetary values are presented undiscounted and (discounted) at an 8% discount rate when written between brackets.

7.1 Overall results

Figure 9 shows the overall cash flow analysis for solution 28.1 during the 2022-2043 time horizon:

- Solution 28.1 achieves **€628m benefits (€178m)** and incurs **€340m overall costs (€131m)**, which are split between:
 - €130m (€66m) investment costs faced during 2025-2035, and
 - €210m (€64m) operating costs, starting in 2027 (IOC).
- Once the solution reaches the full operating capabilities in 2036, the operating costs are stabilised at €16m per year while the benefits reach €44m per year (continuously growing with traffic up to €69m in 2043). Therefore, from the FOC onwards the solution achieves a **>€28m (>€9m) annual surplus**.
- The project reached the **payback year in 2039**, once the discounted cumulative cash flow becomes positive. The payback period is fourteen (14) years from the initial investment (2025).
- The project develops the following indicators:
 - **Net present value (NPV): €48m**
 - **Benefit to cost ratio (BCR): 1.4**
 - **Internal rate of return (IRR): 16%**

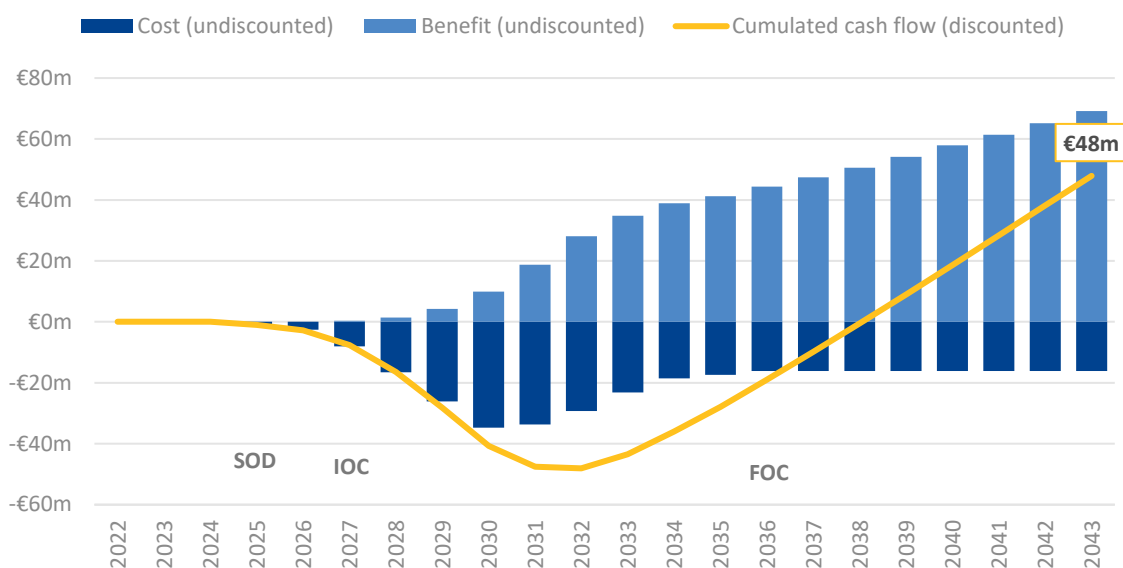


Figure 9: Cash flow analysis for solution 28.1 (8% discount rate)



The following table completes the graphical information and shows the yearly numerical results (undiscounted and discounted) for solution 28.1 CBA:

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Undiscounted results																						
Costs	-	-	-	(1.3)	(2.6)	(8.0)	(16.5)	(26.1)	(34.8)	(33.7)	(29.2)	(23.2)	(18.6)	(17.4)	(16.1)	(16.1)	(16.1)	(16.1)	(16.1)	(16.1)	(16.1)	(16.1)
Benefits	-	-	-	-	-	0.3	1.4	4.2	9.9	18.8	28.1	34.8	38.9	41.2	44.4	47.4	50.6	54.1	58.0	61.4	65.1	69.1
Cash flow	-	-	-	(1.3)	(2.6)	(7.7)	(15.1)	(21.9)	(24.9)	(14.9)	(1.1)	11.6	20.4	23.8	28.3	31.3	34.5	38.0	41.8	45.3	49.0	53.0
Cumulative cash flow	-	-	-	(1.3)	(3.9)	(11.6)	(26.7)	(48.6)	(73.5)	(88.4)	(89.6)	(77.9)	(57.6)	(33.8)	(5.5)	25.7	60.2	98.2	140.1	185.4	234.4	287.4
Discounted results (8% discount factor)																						
Costs	-	-	-	(1.0)	(1.8)	(5.0)	(9.6)	(14.1)	(17.4)	(15.6)	(12.5)	(9.2)	(6.8)	(5.9)	(5.1)	(4.7)	(4.4)	(4.0)	(3.7)	(3.5)	(3.2)	(3.0)
Benefits	-	-	-	-	-	0.2	0.8	2.3	4.9	8.7	12.1	13.8	14.3	14.0	14.0	13.8	13.7	13.5	13.4	13.2	12.9	12.7
Cash flow	-	-	-	(1.0)	(1.8)	(4.8)	(8.8)	(11.8)	(12.4)	(6.9)	(0.5)	4.6	7.5	8.1	8.9	9.1	9.3	9.5	9.7	9.7	9.7	9.8
Cumulative cash flow	-	-	-	(1.0)	(2.7)	(7.6)	(16.4)	(28.2)	(40.7)	(47.6)	(48.1)	(43.5)	(36.0)	(27.9)	(19.0)	(9.8)	(0.5)	9.0	18.7	28.4	38.1	47.9

Table 28: Cash flow analysis for solution 28.1 (EUR million)

7.1.1 Detail view on benefits

Figure 10 presents the solution benefits grouped by benefit mechanism, showing that en-route capacity buffer reduction brings around 70% of the solution's total benefits.

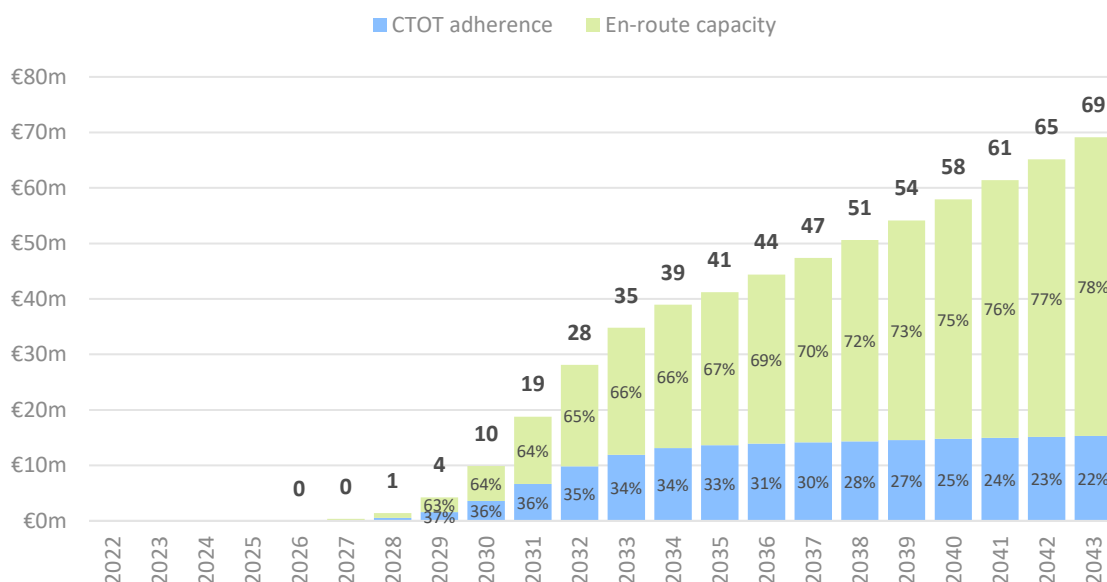


Figure 10: Benefit breakdown for solution 28.1 (undiscounted)

7.1.2 Detail view on costs

Figure 11 presents the solution capital (CAPEX) and operating (OPEX) annual expenses. CAPEX (€130m, undiscounted) spreads from 2025 (SOD) to 2035. OPEX grows up to €16m per year in 2036 (FOC).

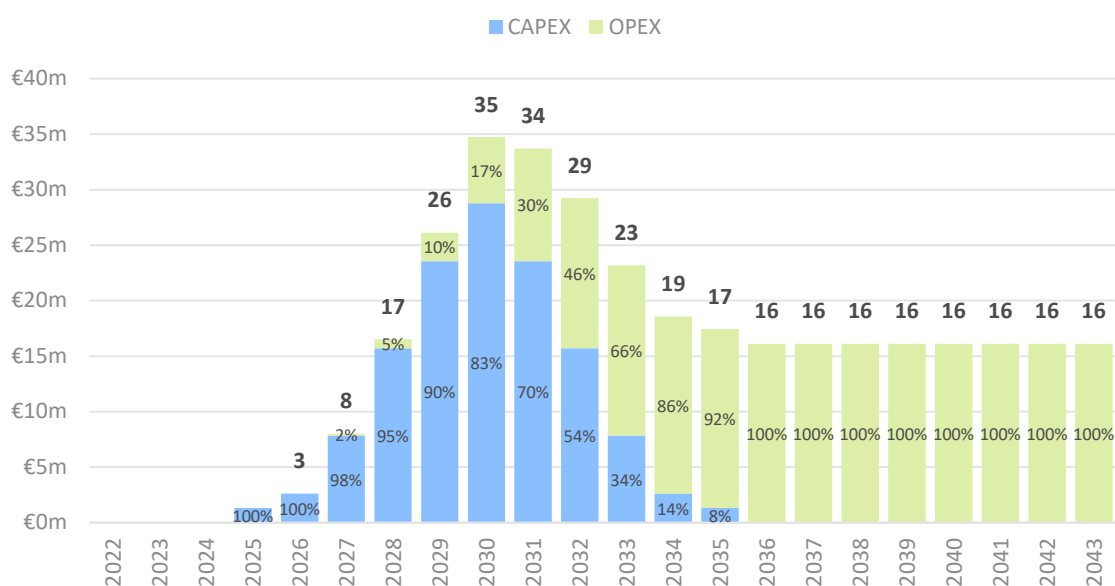


Figure 11: Cost breakdown for solution 28.1 (undiscounted)



7.2 Results per stakeholder

Table 31 summarises the CBA results per stakeholder. Note that the Network predictability benefit has been monetised as delay savings for airspace users, therefore the NM's benefits are null.

Stakeholder	ANSPs	AOs	NM	AUs	Total
Undiscounted results					
Total costs	(177)	(156)	(0)	(7)	(340)
of which CAPEX	(46)	(82)	(0)	(3)	(131)
of which OPEX	(131)	(74)	(0)	(4)	(209)
Total benefits	-	256	-	372	628
Discounted results (8% discount factor)					
Total costs	(64)	(64)	(0)	(2)	(130)
of which CAPEX	(24)	(41)	(0)	(1)	(66)
of which OPEX	(40)	(23)	(0)	(1)	(64)
Total benefits	-	72	-	106	178
Key project indicators					
NPV	(64)	8	(0)	103	48
Payback year	-	2041	---	2028	2039
BCR	-	1.1	-	41.9	1.4
IRR	-	11%	-	257%	16%

Table 29: Solution 28.1 CBA results per stakeholder (EUR million)

7.3 Results per airport grouping

Table 30 summarises the CBA results per airport grouping (medium or small). This view may support the decision on which airports to prioritise for investment.

Implementing airports	Only medium	Only small	Small & Med.
Undiscounted results			
Total costs	(140)	(200)	(340)
of which CAPEX	(54)	(77)	(131)
of which OPEX	(86)	(123)	(209)
Total benefits	412	216	628
Discounted results (8% discount factor)			
Total costs	(54)	(77)	(130)
of which CAPEX	(27)	(39)	(66)
of which OPEX	(26)	(38)	(64)
Total benefits	117	61	178
Key project indicators			
NPV	64	(16)	48
Payback year	2035	-	2039
BCR	2.2	0.8	1.4
IRR	31%	2%	16%

Table 30: Solution 28.1 CBA results per airport grouping (EUR million)

7.4 Results per traffic forecast scenario

The CBA traffic figures come from the EUROCONTROL Aviation Outlook 2050 [20] (see section 3.6.4). This CBA calculates the net present value of the project for the three defined scenarios: low, base and high growth (see section 3.6.4).

The **traffic growth** has a significant impact on the net present value of the project, ranging between €-25m and €+276m. This is due to two effects embedded in the CAP2 monetisation mechanism: (i) more traffic means more ATFM delay per flight (see section 6.1.1) and therefore CAP2 gain saves more delay per flight, and (ii) more traffic means a large multiplier for the saved delay minutes per flight.

For the low growth scenario, the NPV is negative. Indeed, the internal rate of return is estimated at 2%, below the 8% discount factor used in SESAR CBAs and the financial (and social) discount rates used for EU co-financed transport projects: 4% (3-5%)³⁰. Therefore, traffic development implies a significant risk for the deployment of the solution.

Deployment planning should monitor the traffic growth and the evolution of the ATFM delay to ensure that these CBA results are still applicable.

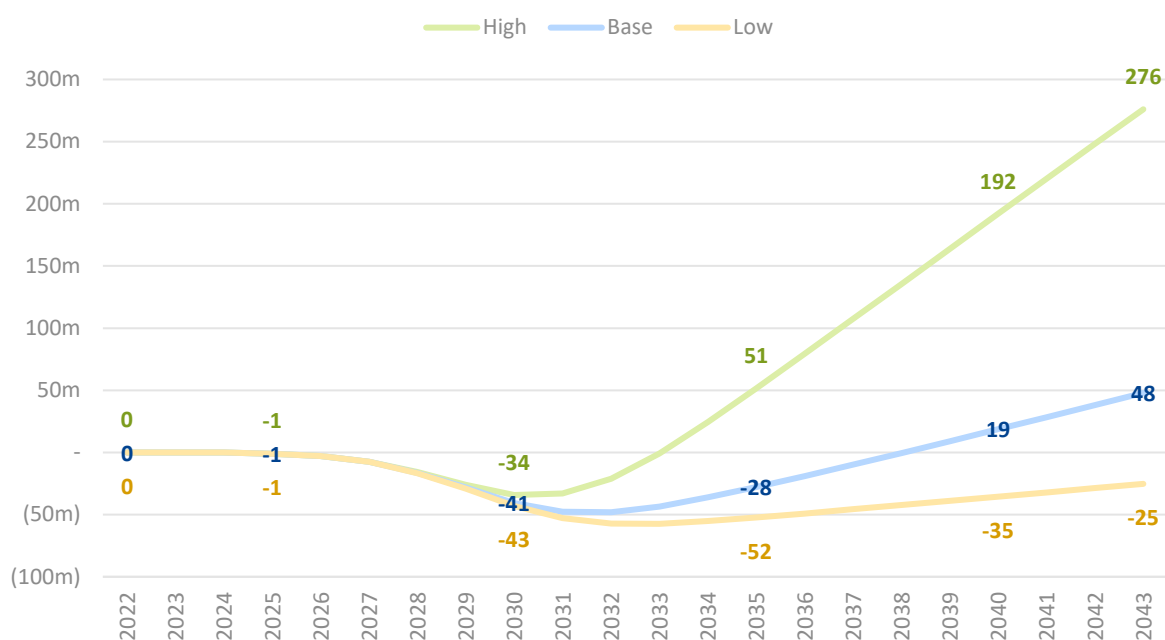


Figure 12: Discounted cumulative cash flow (CCF) for the three traffic growth scenarios (million EUR)

³⁰ European Commission, Economic Appraisal Vademecum 2021-2027, General Principles and Sector Applications.



8 Sensitivity and risk analysis

The sensitivity and risk analyses identify the main uncertainties of the CBA model for solution 28.1 and evaluate how they impact the project's net present value (NPV).

8.1 Sensitivity analysis

The CBA model allows identifying the following parameters as the main uncertainties for solution 28.1:

- **Solution (capital and operating) costs:** The solution partners have provided the cost figures following a bottom-up approach: for each enabler and stakeholder they have estimated a cost range (i.e., minimum, baseline and maximum value). Section 7 considers the baseline cost figures, while this section analyses (i) the worst-case scenario (all cost figures are maximum) and (ii) the best-case scenario (all cost figures are minimum).
- **Discount rate:** The 8% baseline value comes from SESAR [9] recommendations for an R&D project. As the technology-readiness level (TRL) of the solution increases, the risk of the project decreases, and so does the discount rate. The sensitivity analysis considers ± 1 percentage points (p.p.).
- **Adherence to slot gain:** The baseline value (12.0%) is a result of the validation activities (see section 4.3.1). The analysis considers a variation of $\pm 15\%$ to cover for potential future deviations (future development of the solution).
- **Network predictability gain:** The baseline value (22.8%) is a result of the validation activities (see section 4.3.2). The analysis considers a variation of $\pm 15\%$ to cover for potential future deviations (future development of the solution).
- **En-route capacity buffer:** No data on the en-route capacity buffer has been found available. The CBA estimates it as the percentage of regulated flights that do not comply with their slot tolerance window (Table 24), which may end up causing over-deliveries and that ANSPs should consider when protecting their sectors from overload. The analysis considers a variation of $\pm 15\%$.

Table 31 presents the range of variation explored for each of these parameters. The CBA model performs the sensitivity analysis “ceteris paribus”, i.e., it modifies only one variable while keeping the rest constant (baseline value). This addresses the individual effect of each parameter on the solution net present value (NPV).

Variable	Variation	Pessimistic	Baseline	Optimistic
Capital & operating costs	Cost scenarios as per section 5	Maximum	Baseline	Minimum
Discount rate	1 pp	9%	8%	7%
Adherence to slot gain	$\pm 15\%$	10.2%	12.0%	13.8%
Network predictability gain	$\pm 15\%$	19.4%	22.8%	26.2%
En-route capacity buffer	$\pm 15\%$	4.7%	5.5%	6.3%

Table 31: Definition of scenarios for the sensitivity analysis

Figure 13 builds a tornado diagram to identify the most impacting variables.

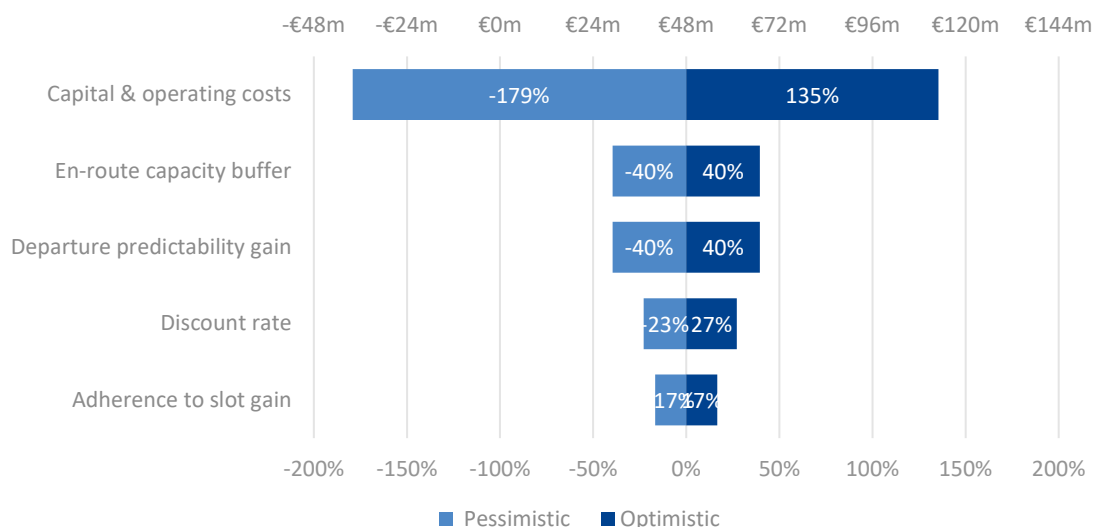


Figure 13: Results of the sensitivity analysis (tornado diagram)

The results of the sensitivity analysis show that:

- Varying the **discount rate** has more than a linear effect on discounting the future cash flows. However, the SESAR baseline value (8%) is already high and conservative, in comparison with EUROCONTROL common practice (4%) for ATM projects (mature technologies).
- The **cost survey** provides a range of around $\pm 60\%$ for the CAPEX and OPEX. This variation has a more than linear impact on the NPV of the project. The solution should monitor and update the cost figures before deployment, customising them to each specific airport (mainly based on the current on their current ATC Tower systems).
- The main operational benefit of the solution will be the **departure predictability (PRD#M1)**. Two recommendations arise from this point:
 - The CBA assumes that departure predictability (PRD#M1) can calculate the **network predictability increase** to assess the impact on the **en-route capacity (CAP2)**. Future developments should revisit this hypothesis and-or simulate the solution benefits at the network level (instead of the local PRD#M1 metric).
 - The CBA assumes that the **en-route capacity buffer** is equal to the share (5.5%) of regulated flights that do not comply with the CTOT window. Note that en-route capacity buffer and departure predictability affect equally the solution NPV.
- **The reduction in lost slots** has a minor (less than linear) effect on the project NPV. Unexpected variations in its value should not affect the decision of whether to invest in the solution.

In summary, the NPV remains positive for all the analysed parameters. Therefore, the solution shows to be robust to deviations from the baseline values.

8.2 NPV risk profile

A Monte Carlo simulation calculates the NPV risk profile based on the uncertainties of the project. The selection of parameters is equal to that in the previous section. The main difference is that the analysis

is no longer “ceteris paribus”. Each parameter takes now a pseudorandom value between the pessimistic and the optimistic limits included in Table 31.

The assessment considers a selection of Discrete, Triangular and Beta-PERT distributions for the variables, which allocate low probabilities to the limit values and high probabilities to the central ones. The outcome is random combinations of the selected parameters. The combinations are fed to the CBA model to calculate the subsequent NPV.

For more detail, refer to Table 32.

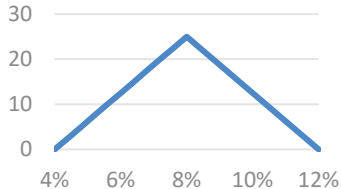
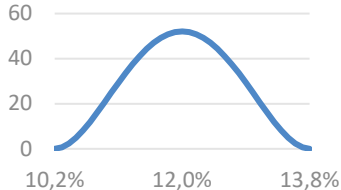
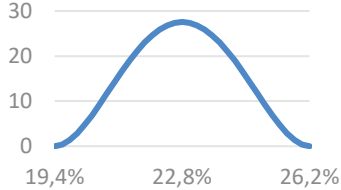
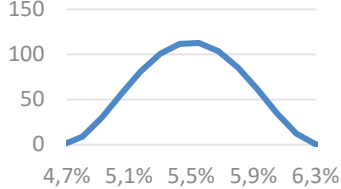
Variable	Probability distribution	Probability mass function
Capital & operating costs	Constant Baseline, since minimum and maximum costs depend on the level of equipment of the ATC Towers	N/A
Discount rate	Triangular - Minimum: 7% - Mode: 8% - Maximum: 9%	
Adherence to slot gain	Beta-PERT - Minimum: 10.2% - Mode: 12.0% - Maximum: 13.8%	
Network predictability gain	Beta-PERT - Minimum: 19.4% - Mode: 22.8% - Maximum: 26.2%	
En-route capacity buffer	Beta-PERT - Minimum: 4.7% - Mode: 5.5% - Maximum: 6.3%	

Table 32: Probability distributions for Monte Carlo analysis

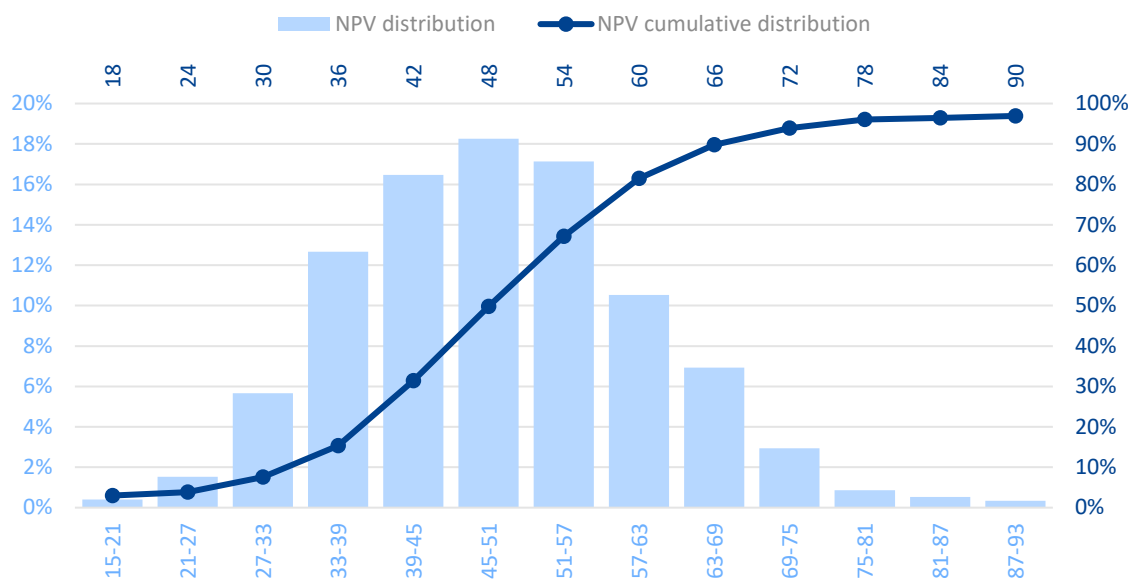


Figure 14: NPV risk profile for solution 28.1 (1500 simulations)

The Monte Carlo analysis runs 1500 simulations of the CBA model, building a comprehensive dataset of NPV values. Figure 14 illustrates the NPV risk profile with two curves:

- **NPV distribution (light blue bars):** Probability (left vertical axis) of obtaining an NPV value within a specific range (bottom horizontal axis).
- **NPV cumulative distribution (dark blue line):** Probability (right vertical axis) of obtaining an NPV equal or lower to a specific value (top horizontal axis).
 - The resulting NPVs are in the range of €15-93m, drawing a Gauss bell around the NPV baseline value (€48m).
 - No negative of the NPV samples result negative, and thus the probability of not developing a positive business case is low (for the Base traffic scenario).
 - The probability of the solution achieving the baseline NPV $\pm 20\%$ is estimated at 52%. The probability for lower NPVs is estimated at 23%, whereas for larger NPVs is 25%. The Monte Carlo simulation shows highly symmetric results.

Table 33 presents the main statistical properties of the NPV risk profile analysis (Monte Carlo simulation). The Monte Carlo analysis and results are embedded in the CBA model (section 6).

NPV risk profile	Value	NPV risk profile	Value
Mean	€49m	Standard deviation	€12m
Mode	€51m	Skewness	0.21
Median	€49m	Kurtosis	0.33

Table 33: NPV risk profile results

Note that the deployment costs are kept constant since their high variability between scenarios would disrupt the Monte Carlo results.



9 Recommendations and next steps

The CBA shows that the deployment of solution 28.1 at 156 airports would positively impact the European aviation industry. It would develop a €48m net present value (8% discount rate) and achieve breakeven in 2035 (the payback period would be ten years).

The following recommendations arise from the CBA results:

- The benefits of solution 28.1 are very sensitive to the en-route capacity buffer and its subsequent reduction once the network predictability increases.
- Besides, the costs of deployment highly depend on the current level of equipment of the aerodrome ATC towers, which adds uncertainty when performing an ECAC-wide CBA. Customising the cost figures for each specific airport level (with a local CBA) is essential to improve the accuracy of the economic model.
- Indeed, the sensitivity and risk analyses show that the solution CBA is very dependent on the input parameters and the business case may shift from positive to negative if the actual figures differ from the baseline inputs (i.e., solution performance, discount rate, implementation and operating costs, en-route capacity buffer, traffic growth).
- The V3 CBA results show better economic performance for medium airports (2.2 BCR) than for small airports (0.8 BCR, i.e., negative business case). Therefore, the solution deployment should prioritise the medium airports to achieve earlier breakeven.
- Nevertheless, future work should provide a quantitative assessment of the benefits at the airport level. This would support the decision-making process to prioritise the deployment of the solution at a specific grouping of airports, depending on their operational characteristics (e.g., resource limitation, airside layout, weather conditions, demand peak) instead of their annual traffic volume (i.e., SESAR airports' classification scheme).
- Airports willing to implement the complete A-CDM concept should benchmark it against solution 28.1 since it could satisfy their requirements for higher predictability at a lower cost and reduced workload for the ground handler.

In summary, solution 28.1 would allow earlier and better planning of the airport resources (AO). The solution would bring local benefits at airports where the allocation of gates, stands, de-icing equipment, ground handling services, taxiways... constrains operations during traffic demand peaks.³¹

More importantly, integrating the regional airports into the network (core objective of the solution) would enhance departure predictability and, hence, network predictability. It would allow optimising the en-route capacity buffers (ANSPs) and the CTOT issuance (NM), leading to reduced ATFM delays (airspace users). The delay reduction would ultimately improve the passenger experience.

³¹ Note that this CBA evaluates solution 28.1 at the ECAC level and therefore does not consider this potential saving.



10 References and Applicable Documents

10.1 Applicable Documents

This CBA complies with the requirements set out in the following documents:

- [1] SESAR Project Handbook
- [2] Guidelines for Producing Benefit and Impact Mechanisms
- [3] Methods to Assess Costs and Monetise Benefits
- [4] SESAR Cost-Benefit Analysis Model³², s7.3.5
- [5] Cost Benefit Analyses – Standard Input
- [6] Cost Benefit Analyses – Method to assess costs
- [7] ATM CBA Quality checklist
- [8] Methods to Assess Costs and Benefits for CBAs

10.2 Reference Documents

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

- [9] S2020 Common assumptions, ed. 01.00.00, 16 September 2019
- [10] EUROCONTROL Standard Inputs for Economic Analyses, ed. 9.0, December 2020
- [11] European ATM Master Plan Portal. Dataset 24 Draft | EATMA V17.0 Draft | MP L3 Plan 2022
<https://www.atmmasterplan.eu/>
- [12] PJ19.04: Performance Framework, ed. 01.00.01, 30 November 2019
- [13] SESAR Solution PJ.04-01: Cost Benefit Analysis (CBA) for V2, ed. 00.01.00, 11 September 2018
- [14] D2.1.050 - SESAR Solution PJ04-W2-28.1 SPR-INTEROP/OSED for V3 - Part I, ed. 00.00.07, 9 Jan 2023
- [15] D2.1.050 - SESAR Solution PJ04-W2-28.1 SPR-INTEROP/OSED for V3 - Part V, ed. 00.00.02, 9 Jan 2023
- [16] Local Single Sky implementation monitoring (LSSIP), 2021 documents,
<https://www.eurocontrol.int/service/local-single-sky-implementation-monitoring>

³² This reference is no more accessible from Programme library but it is now available in ATM Performance Assessment Community of Practice.



- [17] Airport OE dataset, October 2019
- [18] EUROCONTROL, CODA Digest 2020, All-causes delay and cancellations to air transport in Europe, Annual report for 2020
- [19] D2.1.040 - SESAR 2020 Solution PJ.04-W2-28.1 VALR V3 – Part I, ed. 00.00.03, 27 July 2022
- [20] EUROCONTROL (STATFOR), Aviation Outlook 2050, April 2022
- [21] EUROCONTROL, A-CDM Impact Assessment, March 2016
- [22] EUROCONTROL, Airport CDM Network Impact Assessment, EEC Note No. 10-009, March 2010
- [23] EUROCONTROL, Benefits of Improved Predictability Final report (D4), version 1.0, 14 December 2012
- [24] EUROCONTROL, Airport CDM Implementation, The Manual, 31 March 2017
- [25] IAA, Dublin Airport, A Pilots Guide to A-CDM
- [26] EUROCONTROL, Technical note on en-route capacity, A perspective on all aspects of en-route capacity, December 2020
- [27] EUROCONTROL, EEC Note No 21/03, Pessimistic Sector Capacity Estimation
- [28] EUROCONTROL, Airport CDM Cost-Benefit Analysis (CBA), Report 2005, EEC Note No 18/05
- [29] EUROCONTROL, ATM Cost-Effectiveness (ACE) 2019 Benchmarking Report, May 2021
- [30] D2.1.091 - SESAR 2020 Solution PJ.04-01 CBA V2, ed. 00.01.00, 11 September 2018
- [31] DG MOVE, European Commission, Study on employment and working conditions in air transport and airports, 2015





Appendix A List of PJ.04-W2-28.1 targeted airports

Table 34 shows the list of targeted airports by solution 28.1. It includes the medium and small airports as per the SESAR2020 airport classification scheme (considering PRU 2018 traffic statistics). Note that twelve (12) medium airports have already implemented A-CDM and thus are not candidates for the deployment of solution 28.1.

ICAO Code	Airport	State	SESAR 2020 Airports' Classification Scheme
Medium A-CDM airports (12) – Not considered in the CBA:			
EDDH	Hamburg	Germany	Medium
LFMN	Nice-Cote D'azur	France	Medium
LEMG	Malaga/Costa Del Sol	Spain	Medium
EDDS	Stuttgart	Germany	Medium
LHBP	Budapest Liszt Ferenc International Airport	Hungary	Medium
LIML	Milano/Linate	Italy	Medium
LFLL	Lyon Saint-Exupery	France	Medium
EDDB	Berlin-Schoenefeld	Germany	Medium
LIPZ	Venezia/Tessera	Italy	Medium
LIME	Bergamo/Orio Al Serio	Italy	Medium
EVRA	Riga	Latvia	Medium
LIRN	Napoli/Capodichino	Italy	Medium
Medium (64) and small (92) airports – Considered in the CBA:			
EDDK	Koeln/Bonn	Germany	Medium
EGGW	London Luton	United Kingdom	Medium
EGPH	Edinburgh	United Kingdom	Medium
GCLP	Gran Canaria	Canary Islands (Spain)	Medium
LROP	Bucuresti/Henri Coanda	Romania	Medium
LTAC	Ankara/Esenboga	Turkey	Medium
EGBB	Birmingham	United Kingdom	Medium
LFML	Marseille-Provence	France	Medium
UKBB	Kyiv/Boryspil	Ukraine	Medium
LFBO	Toulouse-Blagnac	France	Medium
LEAL	Alicante-Elche	Spain	Medium



LPPR	Porto	Portugal (Madeira and Azores)	Medium
EGPF	Glasgow	United Kingdom	Medium
ENBR	Bergen/Flesland	Norway	Medium
LTBJ	Izmir/Adnan Menderes	Turkey	Medium
LFSB	Bale-Mulhouse	France	Medium
EGLC	London/City	United Kingdom	Medium
LEIB	Ibiza	Spain	Medium
ELLX	Luxembourg/Luxembourg	Luxembourg	Medium
EDDP	Leipzig/Halle	Germany	Medium
LICC	Catania/Fontanarossa	Italy	Medium
ESGG	Goteborg/Landvetter	Sweden	Medium
LIPE	Bologna/Borgo Panigale	Italy	Medium
EGGD	Bristol	United Kingdom	Medium
GCXO	Tenerife Norte	Canary Islands (Spain)	Medium
LFBD	Bordeaux-Merignac	France	Medium
EGNX	East Midlands	United Kingdom	Medium
LEVC	Valencia	Spain	Medium
GCTS	Tenerife Sur/Reina Sofia	Canary Islands (Spain)	Medium
LYBE	Beograd/Nikola Tesla	Serbia	Medium
EDDV	Hannover	Germany	Medium
LCLK	Larnaka/Intl	Cyprus	Medium
ENZV	Stavanger/Sola	Norway	Medium
LFRS	Nantes Atlantique	France	Medium
LBSF	Sofia	Bulgaria	Medium
GCRR	Lanzarote	Canary Islands (Spain)	Medium
LGIR	Iraklion/Nikos Kazantzakis	Greece	Medium
LPFR	Faro	Portugal (Madeira and Azores)	Medium
LMML	Luqa Airport	Malta	Medium
LFPB	Paris-Le Bourget	France	Medium



EGPD	Aberdeen/Dyce	United Kingdom	Medium
LGTS	Thessaloniki/Makedonia	Greece	Medium
EPKK	Krakow/Balice	Poland	Medium
ENVA	Trondheim/Vaernes	Norway	Medium
ESSB	Stockholm/Bromma	Sweden	Medium
EDDN	Nuernberg	Germany	Medium
EBCI	Charleroi/Brussels South	Belgium	Medium
LIRA	Roma/Ciampino	Italy	Medium
LICJ	Palermo/Punta Raisi	Italy	Medium
EGAA	Belfast/Aldergrove	United Kingdom	Medium
GCFV	Fuerteventura	Canary Islands (Spain)	Medium
LEZL	Sevilla	Spain	Medium
LEBB	Bilbao	Spain	Medium
EYVI	Vilnius/International	Lithuania	Medium
EGNT	Newcastle	United Kingdom	Medium
EETN	Lennart Meri Tallinn	Estonia	Medium
LIRP	Pisa/S. Giusto (Mil)	Italy	Medium
EKBI	Billund	Denmark	Medium
LDZA	Zagreb/Pleso	Croatia	Medium
EPGD	Gdansk Im Lecha Walesy	Poland	Medium
LIMF	Torino/Caselle	Italy	Medium
ENTC	Tromso/Langnes	Norway	Medium
BIKF	Keflavik	Iceland	Medium
UBBB	Heydar Aliyev International Airport	Azerbaijan	Medium
EHEH	Eindhoven/Eindhoven	Netherlands	Small
ENBO	Bodo	Norway	Small
LGRP	Rodos/Diagoras	Greece	Small
EGGP	Liverpool	United Kingdom	Small
EGHI	Southampton	United Kingdom	Small
LIBD	Bari/Palese	Italy	Small



UGTB	Tbilisi/Tbilisi	Georgia	Small
EPKT	Katowice/Pyrzowice	Poland	Small
EGAC	Belfast/City	United Kingdom	Small
LTAF	Adana	Turkey	Small
EGNM	Leeds Bradford	United Kingdom	Small
EBLG	Liege/Liege	Belgium	Small
LIEE	Cagliari/Elmas	Italy	Small
EGJJ	Jersey	United Kingdom	Small
LIEO	Olbia/Costa Smeralda	Italy	Small
LIPX	Verona/Villafranca	Italy	Small
LIRQ	Firenze/Peretola	Italy	Small
LJLJ	Ljubljana/Brnik	Slovenia	Small
LTFE	Mugla/Milas-Bodrum	Turkey	Small
LEMH	Menorca	Spain	Small
EDDW	Bremen	Germany	Small
EPWR	Wroclaw/Strachowice	Poland	Small
LTBS	Mugla/Dalaman (Mil.Civ.)	Turkey	Small
ESMS	Malmo	Sweden	Small
EGLF	Farnborough	United Kingdom	Small
LFMT	Montpellier Mediterranee	France	Small
UKKK	Kyiv/Zhuliany	Ukraine	Small
LOWS	Salzburg	Austria	Small
EGJB	Guernsey	United Kingdom	Small
LUKK	Chisinau/International	Moldova	Small
LDSP	Split/Kastela	Croatia	Small
LTCG	Trabzon	Turkey	Small
LGKR	Kerkira/Ioannis Kapodistrias	Greece	Small
LATI	Tirana	Albania	Small
LGSA	Chania/Ioannis Daskalogiannis	Greece	Small
LFQQ	Lille-Lesquin	France	Small



EHRD	Rotterdam/Rotterdam	Netherlands	Small
EICK	Cork	Ireland	Small
EPPO	Poznan/Lawica	Poland	Small
LPMA	Madeira	Portugal (Madeira and Azores)	Small
LZIB	Bratislava/M.R.Stefanik	Slovakia	Small
LRCL	Cluj Napoca/Avram Iancu	Romania	Small
LFOB	Beauvais-Tille	France	Small
LBBG	Burgas	Bulgaria	Small
ENTO	Sandefjord/Torp	Norway	Small
EDLW	Dortmund	Germany	Small
UDYZ	Yerevan	Armenia	Small
LDDU	Dubrovnik/Cilipi	Croatia	Small
EINN	Shannon	Ireland	Small
EDDC	Dresden	Germany	Small
LFST	Strasbourg-Entzheim	France	Small
LIPH	Treviso/S.Angelo	Italy	Small
GCLA	La Palma	Canary Islands (Spain)	Small
EKYT	Aalborg (Civ/Mil)	Denmark	Small
LEST	Santiago	Spain	Small
LGKO	Kos/Ippokratis	Greece	Small
EGMC	Southend	United Kingdom	Small
LGSR	Santorini	Greece	Small
LICA	Lamezia Terme	Italy	Small
LPPD	Ponta Delgada	Portugal (Madeira and Azores)	Small
EPMO	Warszawa/Modlin	Poland	Small
EDDG	Muenster/Osnabrueck	Germany	Small
EDFH	Frankfurt-Hahn	Germany	Small
EGFF	Cardiff	United Kingdom	Small
LOWI	Innsbruck	Austria	Small



LOWG	Graz	Austria	Small
LCPH	Pafos/Intl	Cyprus	Small
LIBR	Brindisi/Casale	Italy	Small
LIMJ	Genova/Sestri	Italy	Small
LFRN	Rennes Saint Jacques	France	Small
LFKJ	Ajaccio-Napoleon-Bonaparte	France	Small
LWSK	Skopje	The Former Yugoslav Republic of Macedonia	Small
ESNU	Umea	Sweden	Small
EDSB	Karlsruhe/Baden-Baden	Germany	Small
LBWN	Varna	Bulgaria	Small
EGNS	Isle Of Man	United Kingdom	Small
EGKB	Biggin Hill	United Kingdom	Small
EGPE	Inverness	United Kingdom	Small
LFKB	Bastia-Poretta	France	Small
LTAJ	Gaziantep	Turkey	Small
LRTR	Timisoara/Traian Vuia	Romania	Small
LGMK	Mikonos	Greece	Small
ESKN	Stockholm/Skavsta	Sweden	Small
LFRB	Brest-Bretagne	France	Small
LEGE	Girona	Spain	Small
ENCN	Kristiansand/Kjevik	Norway	Small
EGTE	Exeter	United Kingdom	Small
LTAU	Kayseri (Mil-Civ)	Turkey	Small
EBAW	Antwerpen/Deurne	Belgium	Small
UKLL	L'viv	Ukraine	Small
EHKD	Den Helder/De Kooy	Netherlands	Small
LEJR	Jerez	Spain	Small

Table 34: List of targeted airports by solution 28.1 [17]



Appendix B Take-off predictability and en-route capacity buffer

The solution PJ.04-W2-28.1 has validated an increase in the take-off predictability (PRD#M1) at the implementing airports by comparing (i) |ATOT-TTOT| (solution scenario) with (ii) |ATOT-ETOT| (reference scenario).

This CBA translates the take-off predictability increase in a reduction of the en-route capacity buffer, based on the conclusions of several A-CDM impact assessment studies, which are summarised below.

EUROCONTROL A-CDM Impact Assessment (2016) [21]³³

Section	Description	Relevance for PJ.04-W2-28.1
A.3.1 Declared capacity buffers	In order to manage the variability in the time that flights arrive in the sector, ATC introduce ' buffer ' capacities which ensures that any peak in either complexity or entry rate can be safely managed by controllers. These buffer capacities [...] result in a significant under-utilisation of a piece of airspace. If every flight departed at the ETOT, there would be little need for such buffer capacities [...]	Solution 28.1 CBA (and PAR) translates the take-off predictability increase into a reduction of the en-route airspace capacity buffer. Solution 28.1 CBA does not claim an increase in the maximum airspace capacity, but an increase in the 'declared' capacity.
2.5 Take-Off Predictability Benefits	Take-off predictability is defined by both the mean take-off accuracy and the standard deviation of that accuracy. Improved take-off predictability is the key enabler of network benefits, which includes improved levels of safety and potential en-route capacity buffer reductions.	Solution 28.1 CBA monetises the en-route capacity buffer reduction as its implementation is required to increase the take-off predictability and enable the buffer reduction.
2.5.1 Take-Off Accuracy	Take off accuracy is defined as the difference between the actual take-off time (ATOT) and the time that ETFMS expects the flight to become airborne: [...] - Non-integrated airports: ATOT-ETOT - Network integrated airports: ATOT-TTOT	Measurement PRD#M1 uses the same definition so the results (and conclusions) are fully comparable to those in the report.
2.5.1 Take-Off Accuracy	All CDM airports (and Advanced ATC Towers) have demonstrated significant improvements in take-off predictability which is observed as: - The convergence of the mean take-off accuracy towards zero. - A significant reduction in the standard deviation of the take-off accuracy.	PRD#M1 (Table 11) shows that solution 28.1 improves the take-off accuracy (predictability) by reducing both the mean and the standard deviation values.

³³ Similar conclusions can be also found in the previous study: EUROCONTROL Airport CDM Network Impact Assessment (2010) [21].



A.3.3 Consequence of Improved Take-Off Predictability	A more reliable picture of evolving traffic demand means that: • Sector over-delivery and traffic complexity spikes are far less likely. • FMP may increase declared capacities to be closer to theoretical capacity [...] • En-route delay is reduced as short term traffic bunching is mitigated at the pre-departure stage. Instances of ATFM delay are reduced as the forward traffic plan is both more reliable [...]. Clearly, a reduction in buffer capacity would also reduce the amount of ATFM regulation.	Solution 28.1 CBA monetises the reduction of the en-route capacity buffer by: • Reducing the ATFM delay during peak periods. • Reducing the ANS staff operating costs during the off-peak periods. The monetisation rationale is equivalent to a solution that targets increasing airspace capacity. However, the solution does not claim a gain in maximum airspace capacity, but a reduction in the capacity buffer (equivalent to an increase in the declared capacity).
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Table 35: Monetisation of take-off predictability (1/2) [21]

EUROCONTROL Benefits of Improved Predictability (2012) [23]

Section	Description	Relevance for PJ.04-W2-28.1
3.4.2 Benefits of improved predictability	• More capacity for planning. • Fewer ATFM delays. • Improved vertical flight efficiency. • Improved sector productivity. • Fewer occurrence of overloads.	The CBA (and PAR) translates the take-off predictability in a reduced en-route capacity buffer. This reduction is monetised as less ATFM delay (peak demand period, CAP2).
A.2 Analysis of sector occupancy data – Conclusions of analysis	The estimates made by ATFM experts are consistent with the amount of ‘buffer’ shown by the data analysis. In particular, this would appear to validate the estimate that monitoring values could be increased by 5-10% with increased predictability.	The CBA (i) estimates the average en-route capacity at 5.5% and (ii) translates the solution 28.1 take-off predictability gain into an increase in the ‘declared capacity’ of +0.15%.

Table 36: Monetisation of take-off predictability (2/2) [23]

Appendix C AAT airports do not transition to RNI

This Appendix simulates a different solution scenario where the medium and small airports that have implemented or have plans to implement AAT do not transition to RNI (in addition to those ACDM). In such a case, RNI would be deployed at 118 airports (24% traffic share) instead of 156 airports (35% traffic share), as per Table 5.

C.1 Overall results

Figure 9 shows the overall cash flow analysis for solution 28.1 during the 2022-2043 time horizon:

- Solution 28.1 achieves **€431m benefits (€123m)** and incurs **€258m overall costs (€99m)**, which are split between:
 - €99m (€50m) investment costs faced during 2025-2035, and
 - €159m (€49m) operating costs, starting in 2027 (IOC).
- Once the solution reaches the full operating capabilities in 2036, the operating costs are stabilised at €12m per year while the benefits reach €28m per year (continuously growing with traffic up to €47m in 2043). Therefore, from the FOC onwards the solution achieves a **>€15m (>€5m) annual surplus**.
- The project reached the **payback year in 2040**, once the discounted cumulative cash flow becomes positive. The payback period is fifteen (15) years from the initial investment (2025).
- The project develops the following indicators:

Net present value (NPV): €24m | Benefit to cost ratio (BCR): 1.2 | Internal rate of return (IRR): 14%

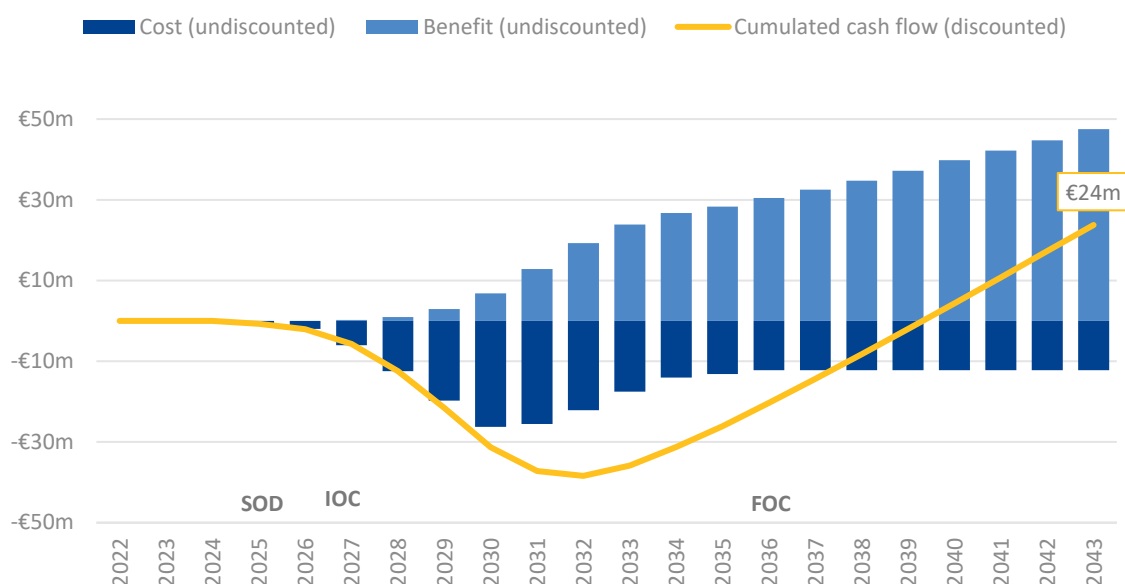


Figure 15: Cash flow analysis for solution 28.1 (8% discount rate) – AAT airports do not transition to RNI



The following table completes the graphical information and shows the yearly numerical results (undiscounted and discounted) for solution 28.1 CBA:

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Undiscounted results																						
Costs	-	-	-	(1.0)	(2.0)	(6.1)	(12.5)	(19.8)	(26.3)	(25.5)	(22.1)	(17.5)	(14.1)	(13.2)	(12.2)	(12.2)	(12.2)	(12.2)	(12.2)	(12.2)	(12.2)	(12.2)
Benefits	-	-	-	-	-	0.2	0.9	2.9	6.8	12.9	19.3	23.9	26.7	28.3	30.5	32.5	34.7	37.2	39.8	42.2	44.7	47.5
Cash flow	-	-	-	(1.0)	(2.0)	(5.8)	(11.5)	(16.9)	(19.5)	(12.6)	(2.8)	6.3	12.7	15.1	18.3	20.3	22.6	25.0	27.6	30.0	32.5	35.3
Cumulative cash flow	-	-	-	(1.0)	(3.0)	(8.8)	(20.3)	(37.2)	(56.7)	(69.3)	(72.1)	(65.8)	(53.1)	(38.0)	(19.7)	0.6	23.2	48.2	75.8	105.7	138.3	173.6
Discounted results (8% discount factor)																						
Costs	-	-	-	(0.7)	(1.3)	(3.8)	(7.3)	(10.7)	(13.2)	(11.8)	(9.5)	(7.0)	(5.2)	(4.5)	(3.8)	(3.6)	(3.3)	(3.1)	(2.8)	(2.6)	(2.4)	(2.2)
Benefits	-	-	-	-	-	0.1	0.6	1.6	3.4	6.0	8.3	9.5	9.8	9.6	9.6	9.5	9.4	9.3	9.2	9.0	8.9	8.7
Cash flow	-	-	-	(0.7)	(1.3)	(3.7)	(6.7)	(9.1)	(9.8)	(5.8)	(1.2)	2.5	4.7	5.1	5.8	5.9	6.1	6.3	6.4	6.4	6.5	6.5
Cumulative cash flow	-	-	-	(0.7)	(2.1)	(5.7)	(12.5)	(21.6)	(31.3)	(37.2)	(38.4)	(35.9)	(31.2)	(26.1)	(20.3)	(14.4)	(8.3)	(2.0)	4.4	10.8	17.3	23.8

Table 37: Cash flow analysis for solution 28.1 (EUR million) – AAT airports do not transition to RNI

C.2 Detail view on benefits

Figure 16 presents the solution benefits grouped by benefit mechanism, showing that en-route capacity buffer reduction brings around 70% of the solution's total benefits.

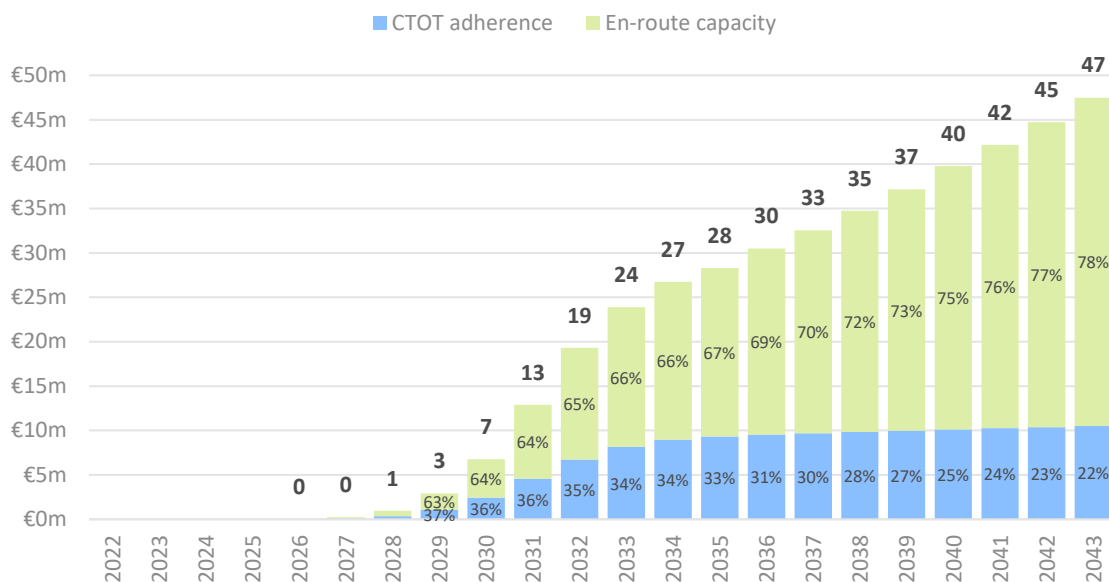


Figure 16: Benefit breakdown for solution 28.1 (undiscounted) – AAT airports do not transition to RNI

C.3 Detail view on costs

Figure 17 presents the solution capital (CAPEX) and operating (OPEX) annual expenses. CAPEX (€99m, undiscounted) spreads from 2025 (SOD) to 2035. OPEX grows up to €12m per year in 2036 (FOC).

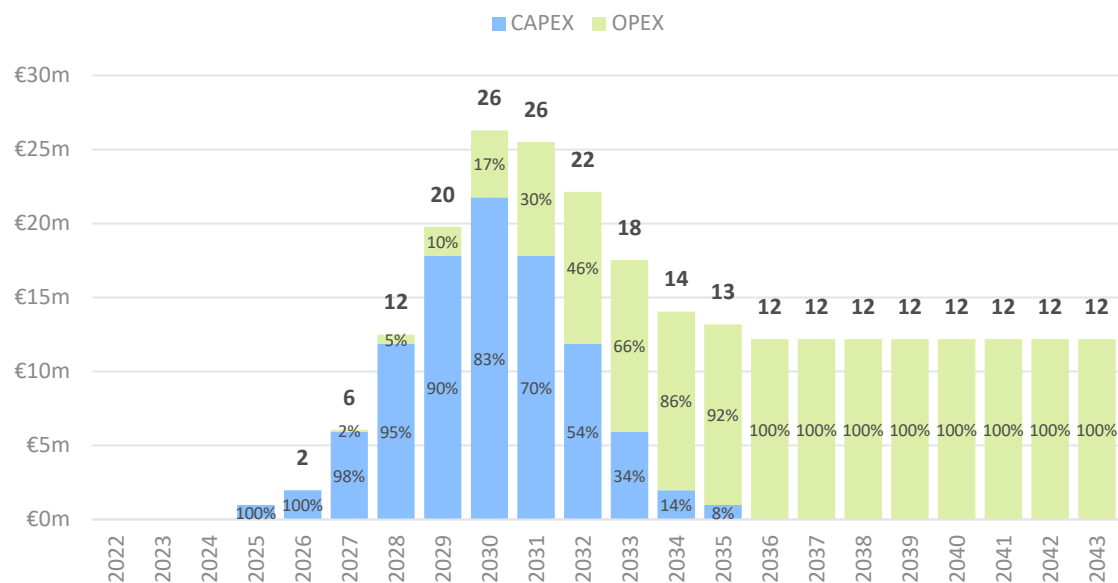


Figure 17: Cost breakdown for solution 28.1 (undiscounted) – AAT airports do not transition to RNI



C.4 Results per stakeholder

Table 38 summarises the CBA results per stakeholder. Note that the Network predictability benefit has been monetised as delay savings for airspace users, therefore the NM's benefits are null.

Stakeholder	ANSPs	AOs	NM	AUs	Total
Undiscounted results					
Total costs	(134)	(118)	(0)	(5)	(258)
<i>of which CAPEX</i>	(35)	(62)	(0)	(2)	(99)
<i>of which OPEX</i>	(99)	(56)	(0)	(3)	(159)
Total benefits	-	176	-	255	431
Discounted results (8% discount factor)					
Total costs	(48)	(49)	(0)	(2)	(99)
<i>of which CAPEX</i>	(18)	(31)	(0)	(1)	(50)
<i>of which OPEX</i>	(31)	(17)	(0)	(1)	(49)
Total benefits	-	50	-	73	123
Key project indicators					
NPV	(48)	1	(0)	71	24
Payback year	-	2043	-	2028	2040
BCR	-	1.0	-	38.1	1.2
IRR	-	9%	-	244%	14%

Table 38: Solution 28.1 CBA results per stakeholder (EUR million) – AAT airports do not transition to RNI

C.5 Results per airport grouping

Table 39 summarises the CBA results per airport grouping (medium or small). This view may support the decision on which airports to prioritise for investment.

Implementing airports	Only medium	Only small	Small & Med.
Undiscounted results			
Total costs	(92)	(166)	(258)
<i>of which CAPEX</i>	(35)	(64)	(99)
<i>of which OPEX</i>	(56)	(102)	(159)
Total benefits	252	180	431
Discounted results (8% discount factor)			
Total costs	(35)	(64)	(99)
<i>of which CAPEX</i>	(18)	(32)	(50)
<i>of which OPEX</i>	(17)	(31)	(49)
Total benefits	72	51	123
Key project indicators			
NPV	36	(12)	24
Payback year	2035	-	2040
BCR	2.0	0.8	1.2
IRR	28%	2%	14%

Table 39: Solution 28.1 CBA results per airport grouping (EUR million) – AAT airports do not transition to RNI

C.6 Results per traffic forecast scenario

This CBA calculates the net present value of the project for the three defined scenarios: low, base and high growth (see section 3.6.4).

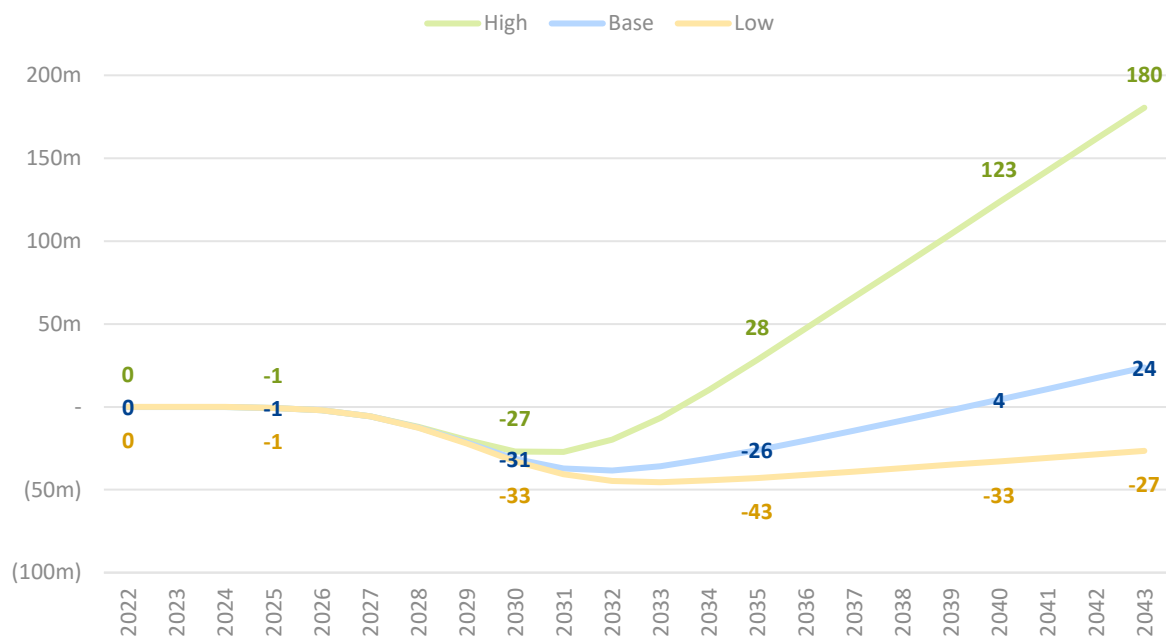


Figure 18: Discounted cumulative cash flow (CCF) for the three traffic growth scenarios (million EUR) – AAT airports do not transition to RNI



Appendix D Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs

Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs, source reference [12]

ATM Master Plan SESAR Performance Ambition KPA	ATM Master Plan SESAR Performance Ambition KPI	Performance Framework KPA	Focus Area	#KPI / (#PI) / <Design goal>	KPI definition
Cost efficiency	PA1 - 30-40% reduction in ANS costs per flight	Cost efficiency	ANS Cost efficiency	CEF2	Flights per ATCO hour on duty
				CEF3	Technology Cost per flight
Capacity	PA7 - System able to handle 80-100% more traffic	Capacity	Airspace capacity	CAP1	TMA throughput, in challenging airspace, per unit time
	PA6 - 5-10% additional flights at congested airports		Airport capacity	CAP2	En-route throughput, in challenging airspace, per unit time
				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 punctuality and	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



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

Table 40: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs



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