DES HE SESAR solution SIGN-AIR CBAT

Deliverable ID:	**D2.11.1**
Project acronym:	**SIGN-AIR**
Grant:	**101114845**
Call:	**HORIZON-SESAR-2022-DES-IR-01**
Topic:	**HORIZON-SESAR-2022-DES-IR-01-WA5-3**
Consortium coordinator:	**UPC**
Edition date:	**20 February 2026**
Edition:	**00.03.00**
Status:	**Draft**
Classification:	**PU**

Abstract

This document provides the Cost Benefit Analysis (CBA) related to the deployment of a SESAR technological solution SIGN-AIR, a platform that addresses the essential need for collaborative agreements (data sharing agreements and smart contracts) in multimodal transport by offering comprehensive contract templates and advanced communication tools for Transport Service Providers (TSPs). The proposed multimodal data exchange platform presents a unique opportunity to enhance aviation management through improved data accessibility. By facilitating seamless information exchange, aviation stakeholders can optimize scheduling, mitigate operational disruptions, and improve passenger experiences. Given the aviation-specific scope of SESAR, this document exclusively outlines aviation-related costs and benefits, while acknowledging that costs and benefits for other transport modes remain independent and outside the scope of this analysis

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FD	08/03/2024	19/03/2025	16/02/2026
SPA	08/03/2024	19/03/2025	16/02/2026
UB-FTTE	08/03/2024	19/03/2025	16/02/2026
AETHON	08/03/2024	19/03/2025	16/02/2026
ENAC	08/03/2024	19/03/2025	16/02/2026
EPF	08/03/2024	19/03/2025	16/02/2026
CARNET	08/03/2024	19/03/2025	16/02/2026

[1] Representatives of all the beneficiaries involved in the project

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TIMELEX	08/03/2024	19/03/2025	16/02/2026
ATM	08/03/2024	19/03/2025	16/02/2026
STA	08/03/2024	19/03/2025	16/02/2026
BLQ	08/03/2024	19/03/2025	16/02/2026
TPER	08/03/2024	19/03/2025	16/02/2026
AMTU	08/03/2024	19/03/2025	16/02/2026
HSP	08/03/2024	19/03/2025	16/02/2026

Rejected by[2]

Organisation name	Date

Document history

Edition	Date	Status	Organisation author	Justification
00.00.01	10/07/2023	draft	Cabañas/SPA	Working document
00.00.02	25/08/2023	draft	Ferran Larriba/SPA	Working document
00.00.03	28/08/2023	draft	Josep Lluis Larriba Pey/UPC Ismini Stroumpou/SPA	Review and comments
00.00.04	29/08/2023	draft	Eric Cabañas/SPA	Incorporation of comments
00.00.05	31/08/2023	draft	Eric Cabañas/SPA	Perceived value
00.00.06	29/09/2023	draft	Ismini Stroumpou/SPA	Annex 2
00.00.07	13/10/2023	draft	Eric Cabañas/SPA Dora Ramazzotti/BLQ Barbara Melloti/BLQ Alberto Bini/BLQ Elisa Ciatti/BLQ Mirco Armandi/TPER Daniela Cocchi/TPER	Review and comments of annex 2

[2] Representatives of the beneficiaries involved in the project

00.00.08	18/10/2023	draft	Ismini Stroumpou/SPA	Incorporation of comments
00.00.09	27/10/2023	draft	Ismini Stroumpou/SPA	Addition of stakeholders' description
00.00.10	27/10/2023	draft	Eric Cabañas/SPA	Addition of **¡Error! No se encuentra el origen de la referencia.**
00.00.11	14/12/2023	draft	Ismini Stroumpou/SPA	Stakeholders' workshop results
00.00.12	22/01/2024	draft	Ismini Stroumpou/SPA	Drafting of section 3
00.00.13	01/02/2024	draft	Josep Lluis Larriba Pey/UPC	Review and inputs on section 3
00.00.14	07/02/2024	draft	Antonio Silas/Eurocontrol	Review and comments
00.00.15	01/03/2024	Revised draft	Ismini Stroumpou/SPA	Comments integration
00.00.16	08/03/2024	Final draft	Ismini Stroumpou/SPA	Update on sections 3.2.1 and 1.1 based on the call with the CBA champions
00.01.00	11/03/2024	Release	Ismini Stroumpou/SPA	Handover to the S3JU
00.01.01	25/07/2024	Draft	Eva Bargalló/SPA	Working document for second iteration, including integration of S3JU comments.
00.01.02	21/01/2025	Draft	Ismini Stroumpou/UPC	Review and comments
00.01.03	30/01/2025	Draft	Eva Bargalló / SPA	Integration of CBA Champions' comments.
00.01.04	31/01/2025	Draft	Ismini Stroumpou/UPC	Update enablers, benefits and assumptions
00.01.05	14/02/2025	Draft	Eva Bargalló / SPA	CBA Model integration
00.02.00	19/03/2025	Release	Ismini Stroumpou/UPC	Handover to the S3JU
00.02.01	10/09/2025	Draft	Eva Bargalló / SPA	Working document for third iteration, including integration of comments made in June's Project Review.
00.02.02	16/02/2026	Draft	Eva Bargalló / SPA Ismini Stroumpou/UPC	Comments and final calculations of benefits
00.03.00	20/02/2026	Release	Ismini Stroumpou/UPC	Format and removal of Annex 2 & 3 as suggested bt the performance champions Handover to the S3JU

Copyright statement

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SIGN-AIR

IMPLEMENTED SYNERGIES, DATA SHARING CONTRACTS AND GOALS BETWEEN TRANSPORT MODES AND AIR TANSPORTATION

SIGN-AIR

This document is part of a project that has received funding from the SESAR 3 Joint Undertaking under grant agreement No 101114845 under European Union's Horizon Europe research and innovation programme.

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1 Executive summary

This document provides the Cost Benefit Analysis (CBA) related to the deployment of a SESAR Solution SIGN-AIR that has been matured through validation activities at TRL6.

In the landscape of multi-modal collaboration, the SIGN-AIR platform emerges as a dynamic solution focused on addressing challenges encountered by Transportation Service Providers (TSPs). With a commitment to promote seamless collaborative partnerships, SIGN-AIR encapsulates an ecosystem characterized by three interwoven modules. Plan, Collaborate, and Improve. Each module contains a set of functionalities designed to guide stakeholders through the intricacies of multi-modal collaboration.

The availability of two types of digital contracts is the base for the economic analysis that we are presenting in this CBA. As the previous version of CBA submitted did not include any cost analysis, therefore there is no background that will allow a comparison.

SIGN-AIR solution offers:

1. **Streamlined Contract Creation**
   The SIGN-AIR platform automates the creation of data-sharing agreements (DSAs) and smart contracts (SCs). Using predefined, standardized templates, it identifies the minimum required data, ensures regulatory compliance, and simplifies negotiations. This reduces the time and complexity associated with manual contract drafting.
2. **Enhanced Data Sharing Transparency**
   Through blockchain technology and smart contracts, the SIGN-AIR platform ensures accurate monitoring and verification of data-sharing activities. Operational rules (e.g., "if this happens, then do that") are embedded into smart contracts to support seamless data exchange and operational adjustments between stakeholders. For example: Integrated disruption management enabling single-ticket solutions across high-speed rail and airlines, on-demand operations for emerging transport modes like eVTOLs.
3. **Multimodal Timetable Synchronization**
   An external module processes and synchronizes timetables across different transport modes, calculating connectivity to offer feasible multimodal options. This supports integrated ticketing and optimizes journey planning.
4. **Access to the intermodal hub**

Calculation and enhance the total connectivity of airports by measuring the intermodal connectivity

5. **Intermodal Rerouting and Disruption Management**
   The external module calculates and proposes strategic or tactical multimodal rerouting options for specific origin-destination pairs. By standardizing and managing both planned and real-time data, it ensures reliable and efficient responses to disruptions.
6. **Data Standard Harmonization**
   A dedicated harmonization tool converts IATA SSIM data to GTFS format and vice versa,

facilitating interoperability between transport service providers (TSPs). This ensures data compatibility and streamlines operations across air and ground transport systems.

7. **Synthetic schedules for the introduction of evtols and seaplanes**

New ways to calculate the future connectivity of intermodal hubs introducing a way to generate schedules and produce what if scenarios for Advanced Air Mobility.

8. **Enhanced Travel Companion Features**
   New features extend Travel Companion applications, providing travellers with enriched information on multimodal journeys. These include integrated ticketing, real-time alerts, and rerouting options, all enabled by signed data-sharing agreements.

SIGN-AIR stakeholder(s) identification and deployment needs:

1. Airlines and Railway Operators – included in the scope of this CBAT

- Schedule Management Systems: Upload and synchronize planned schedules (IATA SSIM for airlines and GTFS/NeTEx for railways).
  Operations Control Systems (OCS) or Integrated Operations Control Systems (IOCS): Real-time integration of multimodal schedules and disruption updates for transfer time and passenger re-accommodation.

2. Airports (AOP/APOC/AOCC) – included in the scope of this CBAT served as hub airport for the single ticketing purposes.

Deployment Needs:

- Browser-accessible dashboards for monitoring passenger flow, disruptions, and operational adjustments.
- APIs for sharing multimodal disruption and passenger data with airlines, railways, and travel companions
- Third-Party MaaS (Mobility as a Service) and Travel Companion Platform Providers – not included in the scope of this CBAT: Journey planners and booking systems

Deployment Needs:

- APIs and new UI/UX for combined itineraries.

Finally, this document provides the cost benefit analysis (CBA) related to the ECAC level deployment of SESAR solution SIGN-AIR that has been matured through validation activities to TRL4.

2 Introduction

2.1 Purpose of the document

This document defines the cost benefit analysis (CBA) for SIGN-AIR solution. The objectives of this 2nd version of CBA document are to analyse the impact of using SIGN-AIR, a web platform designed to manage the contractual aspects of data sharing between Transport Service Providers (TSPs) and Service Providers of different modes with the ultimate focus on enhancing the traveller experience.

In the SIGN-AIR platform, we will provide templates for Data Sharing agreements that comply with national and European regulations, including the General Data Protection Regulation (GDPR). TSPs will use the platform's User Interface (UI) to manage contract signing and monitoring. The platform will guide TSPs using the triggers and actions (Smart Contacts) necessary for data sharing processes, ensuring that the ownership and storage location of their data are respected (outside SIGN-AIR platform).

In the CBA document, we analyse the cost for the companies using SIGN-AIR, which implies some additional headcount or a fee to use the platform (please refer at section 5), among other costs detailed in the specific chapters.

Additionally, companies have the option to synchronize schedules to improve multimodal trip timings. To facilitate the decision of TSPs (more specifically airlines and highspeed railway operators), SIGN-AIR offers an external module to identify the most promising combined itineraries**.** Furthermore, a converter is also offered to TSPs to allow them to visualize data and take decisions during negotiation, this converter is a web interface. The TSPs can upload IATA SSIM dataset, and they can convert them to GTFS files and vice versa. Finally, an external module for monitoring disruptions and provide suggestion of multimodal re-routing is developed.

Benefits analysed are related to contractual implications improvement, as currently there are no "monitoring" tools for TSPs to guarantee the contract is fully accomplished. With SIGN-AIR, TSPs can control data sharing, and avoid costly complaints in court.

2.2 Scope

As per the consortium participants, the geographical scope is, the ECAC region, specifically in the countries where companies' participants are located, but it is scalable to any other country (content of contracts should be reviewed according to local regulations).

Impacted stakeholders are airports (all sizes), airlines, highspeed railways and regional railways, additionally passengers are also impacted. It is important to remark that this CBA document will be focussed on ATM environments and will not include any cost analysis for the rest of the stakeholders.

Main enablers are specified in section 3.4.5 within this document.

2.3 Intended readership

This document is intended for use by SESAR 3 JU and the representatives of the transverse and federating projects. Additionally, it may be of interest to representatives of other multimodality projects such as MultiModX, MAIA, and Travel Wise. Furthermore, various sections of this report may be relevant to end users of the SIGN-AIR platform, including airports, airlines, railway operators, and other stakeholders.

Main output of SIGN-AIR platform will be the creation of digital contract templates to guarantee travellers multimodal transport success. The full digitization of such documentation requires significant technical development. This includes creating templates, registering triggers and actions for the Monitoring Dashboard, and ensuring that the templates meet the diverse requirements of stakeholders (each stakeholder may have unique needs based on their organizational requirements, as well as applicable bylaws and national legislation).

2.4 Background

SIGN-AIR project is the continuation/implementation of SYN+AIR (ID: 894116) exploratory research (ER4) project of SESAR. SYN+AIR project created the Smart Contract Framework (SCF).

The SCF is a business process that defines data exchange rules among Transport Service Providers (e.g., airlines, railway operators etc) (TSPs) that share the common goal (e.g. single ticketing, disruption management) of getting the passenger to the destination through a multimodal chain of trips. It provides a centralized hub for contracts management via a web platform that allows TSPs to create, modify, terminate, and validate signed contracts (both data sharing agreements and smart contracts). Most importantly, the storage of TSPs' data and, all the data sharing processes are executed outside of the platform.

As duly explained in SYN+AIR D3.3 TSPs' Collaboration and Data Sharing parameters[3], according to Gonzalez-Feliu[4], collaboration in transport may appear at different levels: transactional, informational, and decisional.

Transactional collaboration is characterized mainly by transactional data exchange, the techniques of which need to be standardized. Transactional collaboration is mostly considered as the basic condition; to establish a collaborative system Referring to the third level of collaboration (i.e., decisional), unified transactions need to be determined among different stakeholders in advance.
Informational collaboration concerns the mutual exchange of information among different stakeholders (mainly transport carriers, customers, users, and public authorities) and it is the most common type of collaboration in urban transport (Pohl 2001). Such an information can be used for

[3] SYN+AIR D3.2 TSPs' Collaboration and Data Sharing parameters, 2021, Konstantinos Mavromatis, Slavica Dožić, Michele Ottomanelli, Stella Noutsou

[4] Jesus Gonzalez-Feliu, Cristina Pronello, Josep Maria Salanova Grau, 2018, Multi-Stakeholder Collaboration in Urban Transport: State-Of-The-Art And Research Opportunities

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organizational issues (optimization-based information exchange), for customers' information or for service purposes – Mobility-as-a-Service (MaaS).
Decisional collaboration concerns the different possibilities of collaboration in transport planning and management and can belong to different planning stages (strategic, tactical, and operational).

Figure 1 demonstrates the collaboration schemes of each level in correlation with the different type for the stakeholders involved.

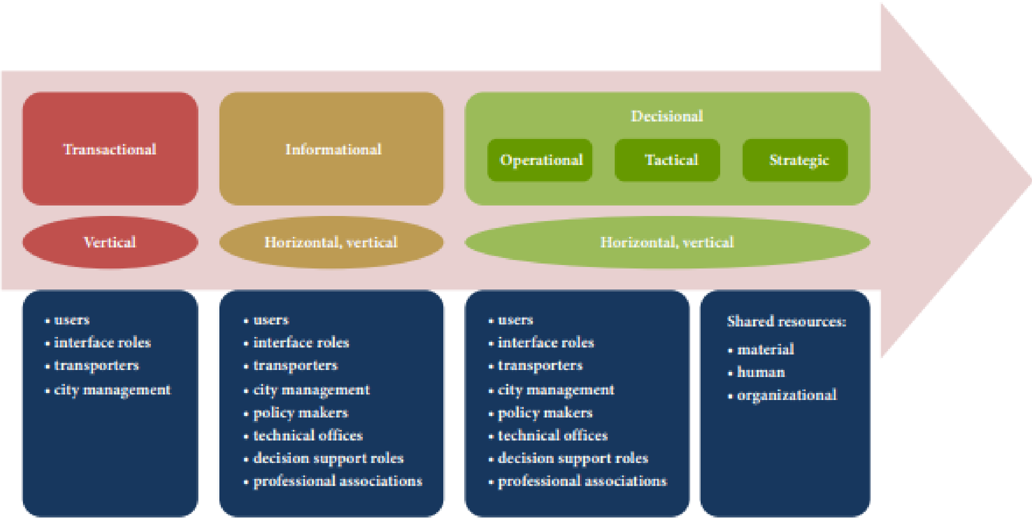

Figure 1: Types of collaboration and their links to urban transport planning (Reference: Gonzalez-Feliu et al. 2018[5])

The knowledge gained about the types of collaborations and existing examples of collaborations are presented in Figure 2.

[5] Jesus Gonzalez-Feliu, Cristina Pronello, Josep Maria Salanova Grau, 2018, Multi-Stakeholder Collaboration in Urban Transport: State-Of-The-Art And Research Opportunities

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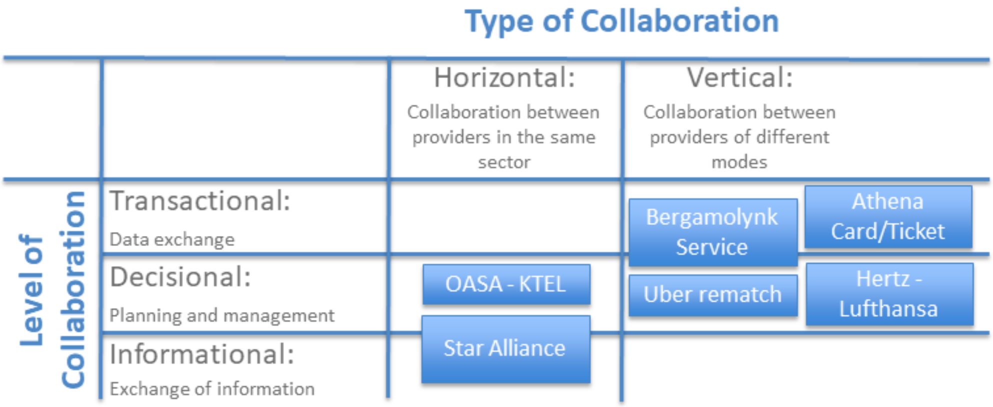

Figure 2: Types of collaborations and examples

Therefore, the SCF enhances stakeholders´ collaboration in a horizontal and vertical way. Additionally, it is crucial to mention that to achieve full integration between two transport modes there are 5 aspects that need to be addressed namely, physical, network, rate, information, and institutional integration. With the use of the SIGN-AIR solution (Smart Contracts Framework-SCF implementation), the network, information and institutional integration are enabled.

The SCF entails two types of contacts creating a fertile environment for collaborations to grow. Data Sharing Agreements are complementary to the Smart Contracts. While Data Sharing Agreements (DSAs) are arrangements between two, specifying the usage and handling of shared data, Smart Contracts (SCs) are fundamentally self-executing contracts with the terms of the agreement directly encoded into a computer program, ensuring that transactions are transparent and irreversible.

The table below summarizes main elements of DSA and SC.

Table 1: Data Sharing Agreements vs Smart Contracts

Data Sharing Agreements	Smart Contracts
"Who", "Why" and "What" is going to be shared.	"How" and "When" it will be shared.
Between Data Provider TSP and Data Consumer TSP.	Based on "external smarter contract model".
Legal, regulatory or contractual, written in natural language. (Example: **Terms and conditions for the allowed use of data**)	Digital and automated (using blockchain).
Flexible, as they can be amended through negotiation between parties, although specific obligations of DSA will prevail (negotiation and drafting).	They cannot be altered without consensus.

Govern how data is shared, ensuring compliance with laws like GDPR, HIPAA, or local regulations. (**Mandatory law must be taken into consideration**).	Automate transactions and enforce agreements without intermediaries.
Compliance is verified through audits or regulatory checks.	Executed automatically when conditions in the code are satisfied. Defines specific Triggers (a certain condition, event, choice) and Actions (obligation that must be fulfilled in case a Trigger is realized).
Example of use in SIGNAIR: Set out a Multimodal Transport Goal for data sharing (e.g., Single Ticketing, Synchronization of timetables etc.). The goal determines: a. the required datasets. b. the Triggers and Actions of the Smart Contract. c. the issues of Revenue Sharing and Responsibility Sharing.	**Example of use in SIGNAIR:** Contains terms of Revenue Sharing and Responsibility Sharing: • Revenue Sharing: how the revenue or benefit of Actions are shared between TSPs • Responsibility Sharing: how liability is shared (e.g. who will pay delay/cancellation compensation to a traveller in case of certain Triggers)

2.5 Structure of the document

This CBA document is structured in the following chapters:

1. Executive summary.
2. Introduction, providing with an overall view of both this document and the solution.
3. Objectives and scope of the CBA, where the CBA reference and solution scenarios are defined.
4. Benefits, where the main benefit mechanisms of the solution are shown.
5. Cost assessment, including the values derived from the stakeholders' analysis.
6. CBA model, where the attached Excel CBA model is widely described.
7. CBA results, where the main outcomes of the CBA model are shown and described.
8. Sensitivity and risk analysis, of the main uncertain parameters affecting the CBA results.
9. Recommendations and next steps.

2.6 Glossary of terms

This section identifies terms and their definition and shall include the reference to the source of the definition. The table below (Table 2), provides the common glossary terms of a CBA based on SESAR 3 JU.

Table 2: Glossary of terms

Term	Definition	Source of the definition
Benefit-cost ratio	The benefit-cost ratio (BCR) compares the present value of all benefits generated from the SESAR solution's implementation to the present value of all costs.	Investopedia & DES transversal CBA team
CBA reference scenario	The scenario against which the solution is compared, i.e. the situation without the proposed SESAR solution (but including other improvements which have been implemented in the meantime).	DES transversal CBA team
CBA solution scenario	The scenario with the proposed SESAR solution and other improvements which have been implemented in the meantime.	DES transversal CBA team
Cost benefit analysis (CBA)	A CBA is an objective study in which the costs and benefits of a particular project or set of projects are fully quantified in economic terms, taking full account of the times at which costs are paid and at which benefits accrue.	SESAR 16.06.06_D06_05 ATM CBA for Beginners, ed. 00.01.00
ECAC	Europea Civil Aviation Conference is an an intergovernmental organisation, which mission is the promotion of the continued development of a safe, efficient and sustainable European air transport system.	https://www.ecac-ceac.org/about-ecac
Implementation cost	All costs related to the acquisition and implementation of the SESAR solution.	SESAR 16.06.06_D26_03 Methods to Assess Cost and Benefits for CBAs, ed. 00.02.02
Internal rate of return	The internal rate of return (IRR) is the discount rate that makes the net present value equal to zero.	Investopedia
Investment cost	The investment cost covers the pre-implementation costs (e.g., feasibility studies) and the implementation costs (e.g., system integration). Note that the pre-implementation costs shall not consider the SESAR R&I costs.	DES transversal CBA team
Net present value	Net present value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.	Investopedia

Term	Definition	Source of the definition
Operating cost	All costs related to the change in daily operations that is brought about by the SESAR solution.	SESAR 16.06.06_D26_03 Methods to Assess Cost and Benefits for CBAs, ed. 00.02.02
Payback period	The payback period is the length of time it takes to recover the cost of an investment. The DES CBA model computes the payback period based on the year the discounted cumulative cash flow becomes positive.	Investopedia & DES transversal CBA team
Pre-implementation cost	All costs that need to be used up to define the needs, to develop solutions, and to decide which solution best serves the needs. Note that the SESAR R&I costs shall not be included as costs in any DES CBA.	SESAR 16.06.06_D26_03 Methods to Assess Cost and Benefits for CBAs, ed. 00.02.02
Risk-adjusted net present value	Risk-adjusted net present value (r-NPV) measures the SESAR solution's return after considering the degree of risk (i.e. solution's uncertainties) to achieve it. There are several methods to calculate it. The DES CBA model suggests performing a Monte Carlo simulation and calculating the mean NPV.	Investopedia & DES transversal CBA team
Stakeholder	1. Organisation or entity that oversees the deployment, the deployment timeframe and the operating environments where the changes will impact and deliver benefits. 2. An individual, a team, or an organisation (or classes thereof) with interest in, or concerns relative to, an enterprise (e.g., the European ATM). Concerns are those interests that pertain to the enterprise's development, its operation or any other aspect that is critical or otherwise important to one or more stakeholders.	DES requirements and validation / demonstration guidelines

In the following table (Table 3), we establish a clear understanding of key concepts that underpin the SIGN-AIR Business Architecture Plan. These definitions highlight the core components, relationships, and dynamics within the platform ecosystem. We delve into the meanings of the terms "Platform," "Platform Ecosystem," "Complementary Software Applications," "(Platform) Provider," "(Platform)

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User," "Developers," "Customers," "(Platform) Architecture," and "(Platform) Governance,". These definitions serve as the basis upon which the subsequent discussions and analyses are built.

Table 3: Glossary of terms specific to SIGN-AIR solution

Term	Definition
Data attributes	Data attribute are metadata of the data included in a dataset such as source of the dataset (the identity of the data provider TSP authorizing the cataloguing of the dataset), data properties, data categories, format and volume of the data, whether the dataset contains static or dynamic data, the levels of updates to be expected in the future, etc.
Data Catalogue	Data Catalogue is a description of a dataset in the form of data attributes that the data provider TSP authorizes to be included in the Catalogue of Catalogues. The cataloguing of a dataset implies the authorization to share, on the SIGN-AIR platform, data attributes of a dataset.
Data consumer TSP	Any TSP to which a data provider TSP provides data by the means of a data sharing agreement.
Data provider TSP	Any TSP that provides data to data consumer TSP by the means of a data sharing agreement.
Data standardization	Data standardization is defined as the critical process(es) of bringing data into a common format that allows for collaborative research, large-scale analytics, and sharing of sophisticated tools and methodologies.
Data sharing agreement	It is an e-contract that defines the data that a data provider TSP makes available to a data consumer TSP and that sets out the terms and conditions for the use of such data.
Ecosystem Governance	(Ecosystem) Governance refers to the management of structures and activities intended to influence or manage actors and systems beyond the direct control of the platform owner. Notably, secondary actors cannot be directly controlled through hierarchical power or authority, setting ecosystem governance apart from platform governance (**¡Error! No se encuentra el origen de la referencia.**).
Net Present Value	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.
Platform	The term "Platform" refers to a software-based infrastructure that forms the foundational core of a digital multi-sided market. Within such markets, the transaction volume is influenced not only by overall

Term	Definition
	platform fees but also by the distribution of these fees across various market participants. This core functionality is designed to be extensible, reusable, and to provide stable interfaces and rules for interaction, known as architecture and governance. The platform provider makes the platform accessible to secondary developers and end-users.
Platform Architecture	(Platform) Architecture encompasses the high-level design principles guiding the structure of the platform itself, along with the specified interfaces that outline how secondary software applications can interact with it.
Platform Ecosystem	The "Platform Ecosystem" encompasses the entire network surrounding the platform, encompassing the platform itself, secondary applications developed for it, the entities involved in extending, providing, and utilizing the platform and its applications, as well as the interactions and outcomes arising from these interactions. (Figure 3)
Platform Governance	(Platform) Governance pertains to the rules and mechanisms that determine decision-making authority within the platform. It involves the allocation of decision rights and the internal organizational structure of the platform provider. Distinctively, platform governance and ecosystem governance must be delineated. Ecosystem governance entails strategies aimed at influencing secondary developers and customers, in addition to platform governance.
Platform Provider	The (Platform) Provider is responsible for the creation, configuration, and availability of the platform to users. Configuration involves establishing the architecture, defining interfaces, and implementing governance mechanisms.
Platform User	(Platform) Users are individuals or entities within the ecosystem who are not directly engaged in providing or sponsoring the platform. This category includes both Developers and Customers. - Developers: Developers are users who expand the core functionalities of the platform by developing complementary software applications that enhance its capabilities. - Customers: Customers are end-users who engage with the platform and its complementary software applications, customizing and combining them to fulfil specific requirements. Customers might also simultaneously act as Developers and vice versa, contributing to a dynamic ecosystem.

Term	Definition
Responsibility Sharing	Responsibility Sharing are the rules defined in a smart contract that govern the manner in which the responsibilities or liabilities, resulting from actions, are shared between the parties of that smart contract.
Revenue Sharing	Revenue Sharing are the rules defined in a smart contract that govern the manner in which the revenues or benefits resulting from actions are shared between the parties of that smart contract.
Smart contract	Smart contract is an e-contract based on the “external smarter contract model” composed of a legal part and a software part. The general aim of a smart contract is to detail the objective of one (or more) data sharing agreement(s) by specifying the triggers and actions of TSPs. For example, if the general objective of a data sharing agreement is “single ticketing”, the smart contract might define more detailed obligations (actions) for TSPs (such as, in case of a disruption, informing the other party and Travel Companion (TC) and take specific remedial operational decisions) as well as legal consequences in terms of revenue and responsibility sharing.
Smart Contracts Framework (SCF)	It is a business process that defines data exchange rules among TSPs that share the common goal of getting the passenger to the destination through a multimodal chain of trips. The SCF is facilitated by a web platform that allows TSPs to create, modify, cancel, and validate signed contracts (both data sharing agreements and smart contracts). Designed in SYN+AIR project and the backbone of SIGN-AIR solution.
Transport Service Providers (TSPs)	a legal entity offering (a) service(s) for allowing a passenger to go from A to B, such as airports, airlines, railway operators and bus operators.
Travel Companion (TC)	A Travel Companion is platform, web and/or mobile app that allow a user to plan, book a trip from point A to point B, additionally these apps might provide auxiliary services to travellers such as cost calculations or re accommodation management.

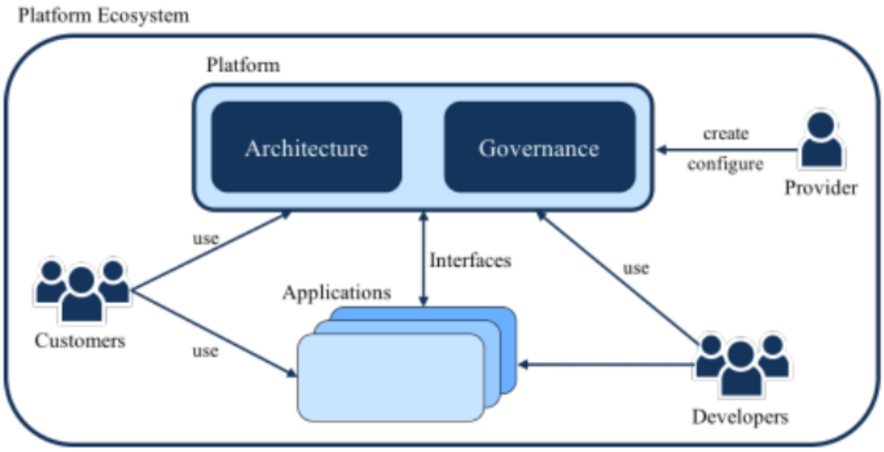

Figure 3: Platform ecosystem

2.7 List of acronyms

¡Error! No se encuentra el origen de la referencia. provides a list of acronyms used in this document.

Table 4: List of acronyms

Acronym	Definition
ACC	Area control centre
ACI	Advance Cargo Information
AOCC	Airport Control Center
AOP	Airport Operational Plan
API	Application Program Interface
APOC	Airport operations centre
ANS	Air Navigation Service
ANSP	Air navigation service providers
ATFCM	Air Trafic Flow and Capacity Management
ATCO	Air traffic control officer
ATM	Air traffic management

AU	Airspace user
AUC	Airspace user cost
BA	Business aviation
BCR	Benefit cost ratio
BIM	Benefit impact mechanism
CAA	Civil aviation authority
CAP	Capacity
CAPEX	Capital expenditure
CBA	Cost benefit analysis
CDM	Collaborative Decision Management
CEF	Cost efficiency
CISP	Common information service providers
DES	Digital European Sky
DIGI	Digitalization
DRT	Demand-responsive transport
DSA	Data Sharing Agreement:
EATMA	European ATM architecture
ECAC	European Civil Aviation Conference
ECO-EVAL	Economic evaluation
EMDS	European mobility data space
ENV	Environment
ERJU	Europe's Rail Joint Undertaking
EUR	Euro
eVTOL	Electric Vertical Take-off and Landing Aircraft
FAA	Federal Aviation Administration
FEFF	Fuel efficiency

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FOC	Final operating capability
FRD	Functional requirements document
FTI&U	Fast Track Innovation and Uptake
GA	General aviation
GA	Grand agreement
GDPR	General Data Protection Regulation
GDS	Global Distribution System
GTFS	General Transit Feed Specification
HC	High complexity
HE	Horizon Europe
IATA	The International Air Transport Association
ICAO	International Civil Aviation Organization
ID	Identifier
IFR	Instrumental flight rules
IOC	Initial operating capability
IOCS	Integrated Operations Control System
IRR	Internal rate of return
KPA	Key performance area
KPI	Keu performance indicator
LC	Low complexity
MaaS	Mobility as a Service
MC	Medium complexity
MDMS	Multimodal digital mobility services
NM	Network management
NPV	Net present value
NSA	National safety authority

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NeTEx	Network Timetable Exchange
OCS	Operations Control System
OPEX	Operational expenditure
PAR	Performance Assessment Results
PAX	Passenger Experience
PFMS	Passenger flow management system
PI	Performance indicator
PRD	Predictability
PT	Public transport
PUN	Punctuality
QMS	Queue management system
RBT	Reference business trajectory
REG	Regulatory deliverable
RES	Resilience
RFID	Radio Frequency Identification
ROC	Railway operating companies
RMS	Resource management system
RMS	Revenue management system
R&I	Research & innovation
SA	Scheduled airline
SA-M	Scheduled airline - mainline
SA-R	Scheduled airline - regional
SC	Smart Contract
SCF	Smart Contract Framework
SESAR	Single European Sky ATM Research Programme
S3JU	SESAR 3 Joint Undertaking

SOD	Start of deployment date
SPR-INTEROP/OSED	Safety and performance requirements - interoperability requirements / operational service and environment description
SSIM	Standard Schedules Information Manual
TC	Travel Companion
TEFF	Time efficiency
TMA	Terminal manoeuvring area
TRL	Technology Readiness Level
TS/IRS	Technical specifications / interface requirements specifications
TSPs	Transport Service Providers
TT	TransiTool
UAS	Unnamed aerial system
UI	User Interface
UIC	International Union of Railways (French: Union internationale des chemins de fer)
UITP	International Association of Public Transport (French: Union Internationale des Transports Publics)
UNIFE	European Rail Supply Industry Association (French: Union des Industries Ferroviaires Européennes)
USSP	U-space service provider
UX	User Experience
VFR	Visual flight rules
VHC	Very high complexity
VL	Very large

3 Objectives and scope of the CBA

3.1 Problem addressed by the SIGN-AIR solution

This section explains the problem addressed **without** introducing the SIGN-AIR solution.

As demonstrated in the previous project (SYN+AIR) and thoroughly analysed in numerous studies, multimodal transport faces several challenges. These challenges stem from the fact that the transport is managed as a series of services used sequentially, without inherent synchronization among them. This lack of coordination can lead to inefficiencies and disruptions, complicating the seamless integration of different transport modes and ultimately impacting the traveller's experience.

Multimodal transport is strongly supported by public administrations, beginning with the European Commission, which promotes it through policy initiatives aimed at achieving sustainability, energy efficiency, and environmental respect[6]. These policies are designed to encourage the integration of various transportation modes, reducing reliance on single-mode travel and fostering a more cohesive and efficient transportation network that benefits both the economy and the environment.

Despite the importance, private companies are a bit reluctant to cooperate in this solution, as some topics still need to be resolved:

a) Not clear visibility of profitability: Benefits in cooperation with other TSPs are difficult to monetarize, as they show no direct income for the companies.

b) Difficulty in Finding Collaborators and Establishing Negotiations: Engaging in multi-modal collaborations can be challenging due to the need to find suitable counterparts for collaboration.

c) Complex Data Sharing and Systems Integration (Data Standardization): From both a legal and technological standpoint, several factors make data sharing difficult for TSPs. Companies often maintain diverse data source standards, leading to varying formats, structures, and technologies. The lack of data harmonization and standardization poses a significant burden. Data quality can be problematic as datasets exhibit varying degrees of accuracy, completeness, and quality. Addressing data security and privacy is crucial to safeguard sensitive information during integration. Adopting intricate data sets demands substantial technical resources, including skilled data engineers and data scientists, among other profiles. Lastly, systems must be optimized to handle the required volume and complexity of data effectively.

d) Time-Consuming and Complex Process: Multi-modal collaboration among Transportation Service Providers (TSPs) can span several years until completion. Both parties must involve experts from various fields in the negotiation table, including transport engineers, lawyers, and key decision makers. Companies participating in these negotiations often pertain to different industries and must adhere to

[6]https://transport.ec.europa.eu/transport-themes/smart-mobility/road/its-directive-and-action-plan/multimodal-travel-information_en?utm_source=chatgpt.com

diverse legislations. The size of the companies also influences negotiation complexity due to internal communication channels and organizational intricacies.

e) Business logics-lack of trust: Many Transport Service Providers (TSPs) generate valuable data but are reluctant to share it due to a lack of trust and an inability to see the benefits of collaboration.

f) Complex Cross-border Negotiations from a Legal Standpoint: Engaging in collaboration across different industries and regions involves numerous considerations for TSPs. Diverse legal systems with unique frameworks and terminologies pose challenges. Conflicts of Laws may arise during negotiations, requiring careful resolution. Regulatory compliance introduces distinct requirements that must be met. Intellectual Property rights and communication challenges can also complicate negotiations.

3.1.1 High level potential Benefits from collaboration

Considering the challenges detailed in the preceding section, we now showcase the primary benefits that the SIGN-AIR platform can offer to TSPs. As we explore these advantages, we shed light on how the collaboration of TSPs within SIGN-AIR's ecosystem can yield remarkable outcomes for individual entities and the entire transportation network. Each benefit contributes to a narrative of innovation, efficiency, and shared success.

1. **TSPs can gain more customers:** TSP collaboration offers the potential for substantial customer expansion, leading to remarkable increases in individual profits. Collaboration with other TSPs can result in a marked growth in customer reach, driving up revenues by up to 800% [7]
   a. **Expansion of customer base**: Collaboration enables TSPs to tap into new customer segments, leveraging each other's strengths to offer comprehensive and enticing solutions.
   b. **Synergistic marketing**: Joint marketing efforts can amplify brand visibility and attract a broader audience, driving customer acquisition.

2. **Unlocking data value with SIGN-AIR:** The SIGN-AIR platform empowers TSPs to fully capitalize on their data resources, transforming data into a valuable asset.
   a. **Data monetization**: By facilitating secure and standardized data sharing, SIGN-AIR enables TSPs to derive monetary value from their data assets.
   b. **Data-driven insights**: Shared data can uncover insights that lead to informed business decisions and enhanced operational efficiency.

3. **Comprehensive smart contract tool for multi-modal collaboration:** SIGN-AIR serves as an all-in-one Smart Contract Framework tool that promotes seamless collaboration among TSPs operating across different modes of transportation.

[7] Schulte, F., Lalla-Ruiz, E., Schwarze, S., González-Ramırez, R. G., Voß, S.: Scalable core and Shapley value allocation methods for collaborative transportation. In: Interna-tional Conference on Computational Logistics, p. 3. (2019).

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   a. **Unified platform:** SIGN-AIR offers a unified digital space where TSPs can find collaborators, start negotiations, and streamline the creation and settlement of Data Sharing Agreements and Smart Contracts.
   b. **Streamlined workflows:** The platform streamlines complex multi-modal collaboration processes, enhancing operational efficiency and reducing bottlenecks throughout the entire negotiation process.

4. **Reduced data sharing complexity:** SIGN-AIR simplifies the data sharing process, establishing minimum data requirements for data sharing contracts and facilitating collaboration between TSPs.
   a. **Standardized Data Sharing:** By setting minimum data requirements, SIGN-AIR ensures that data sharing contracts are straightforward and aligned, reducing negotiation complexities.
   b. **Enhanced Collaboration:** Streamlined data sharing processes remove barriers to collaboration, encouraging TSPs to engage in mutually beneficial partnerships.

3.2 SESAR solution description

The air transportation stakeholders (i.e., airports, Air Navigation Service Providers-ANSPs, airlines) that traditionally work in silos must share data to be able to perform a flight, in a similar way in railways a rail operator must share data with the infrastructure manager to operate the train. There are a few bright examples of data sharing among stakeholders of different transport systems, although the integration level is often low due to business, legacy, legislation, and technical barriers.

Making use of the SCF concept, **SIGN-AIR provides a contracts management platform streamlining multimodal collaboration for passenger door-to-door journey**. TSPs use SIGN-AIR platform to provide their services to different legs of a trip chain and to create and monitor data sharing agreements and smart contracts.

SIGN-AIR Orchestration core business function is to identify (discover) and match the data attributes that need to be shared between different stakeholders and generate a data sharing agreement (DSA) and a smart contract. The usage of a smart contract will allow TSPs to monitor the data sharing processes and reassure that the clauses of the data sharing agreement are met

Additionally, in certain cases, Travel Companion services are necessary to interface with the traveller. The connection between the SIGN-AIR and TC offers the journey planner services for the identification of a specific itinerary, the communication of disruption and rerouting to the traveller.

The core functionalities of SIGN-AIR orchestration management are to manage (generate and monitor) the contractual aspects of DSAs and SCs between two TSPs. The generation of contracts, both data sharing agreements and smart contracts, is a streamlined process thoroughly explained by the steps of the solution (Figure 4).

Figure 4: **Sign-Air solution structure**

All these steps and their technical explanation are deeply explained in TS/IRS document (deliverable D2.10.1 v00.04.05).

As mentioned, SIGN-AIR solution develops a **web platform**, operating in google cloud, that will allow 3rd parties to connect to each other and agree data content to be shared. This solution does not interfere with or alter the core functionalities of air navigation or control systems. SIGN-AIR is non-intrusive to basic air operations, ensuring that air traffic management and flight safety systems remain unaffected while delivering benefits in passengers experience.

Core Stakeholders, as end users of the SIGN-AIR platform, will improve their capacity to make agreements among them, reducing their costs on legal expenses during the process. There are no SA Airbone costs involve, but only some AS Ground costs (specifically linked to the AOP – Airport Operational Plan, and if desired to the CDM – Collaborative Decision-Making platforms).

Directly involved stakeholders, the ones that can provide or consume data from the SIGN-AIR platform, will see their benefits in having an easier way to get the data by connecting to the APIs of SIGN-AIR.

Indirectly involved stakeholders, affected by the results of the DSAs and/or the SCs, are the ones getting all the benefits from the solution without any effort, as they will not participate or even download the App to interact with it.

Table 5: SIGN-AIR enablers

Enabler ID (from common taxonomy/SESAR architecture)	Enabler title (from common taxonomy/SESAR architecture)	Type of integration/Integration needs	Enabler coverage	Applicable stakeholders
AOC-ATM (or FOC)-01853	Advanced route planning for the identification of appropriate air–rail connections	Light integration. User-friendly web interface or API for schedule uploads.	Full, Required, Developed	Airlines
AOC-ATM (or FOC)-01876	Assessment Airports accessibility via Intermodal	Light integration. API-based data feeds from the airline(s), airport(s) and ground	Full, Required, Developed	Airports

	Connectivity calculation	modes operators for feeding real time data and alerts the external module of disruption management Standalone browser-accessible dashboard for minimal dependency on internal IT systems.		
AOC-ATM (or FOC)-01877	Enhance airlines passenger Notification System and Travel Companion (TC) with multimodal information and intermodal alternative itineraries.	REST APIs for integration with disruption management tools or Travel Companion apps.	Full, Required, Developed	Airport
HUM-01855	Modify responsibility of a Data Maintenance Officer for fragmented data models and ownership of data attributes across departments/systems	Training	Full, Required, Developed	Airline
HUM-01878	Passenger Services Desk (within Operations Control Center- OCC) staff able to propose intermodal itineraries.	Training	Full, Required, Developed	Airport
HUM-01879	Network Planning Department able to analyse rail-air and air-rail connectivity index to propose intermodal appropriate itineraries	Training	Full, Required, Developed	Airline

			Full, Required, Developed	Airport
HUM-01880	Update the role for Passenger Notification and Multimodal Updates	Training	Full, Required, Developed	Airline

3.2.1 SESAR solution interdependencies

There is a new project TRAVEL WISE (Transformation of Aviation and railway Solutions towards Integration and Synergies), which might be considered connected to SIGN-AIR, as it will use SIGN-AIR solution as a base to achieve its goals.

Travel Wise will support the shift from traffic management in silos to intermodal traffic orchestration by putting in place a methodology, a roadmap and the related technologies to allow for i) sharing of information between air and rail operators, ii) intermodal collaborative decision making both in nominal situations and in case of disruptions, iii) optimisation of passenger experience.

The Travel Wise solution will define the interface between the ATM system (in particular regarding airport-rail connection) and the rail traffic management system (TMS), both for planning purposes and operations, including disruptions. The solution will be an operational procedure, a sort of umbrella that will define the common requirements for the interaction between the two worlds. Following this common operational procedure the three scenarios will then implement the solution using different technologies. The idea is to extend somehow the AOP/APOC/TAM concept to rail. We need to understand how things are being managed on the two sides at the moment.

The Travel Wise solution will be implemented and tested in three scenarios, which will be the starting point of a scalable system, and that is the main reason for choosing diverse environments to capture as much as possible the challenge of intermodal networks. SIGN-AIR solution is going to be tested in scenario 2 and scenario 3 of Travel Wise project.

3.3 Objectives of the CBA

The objective of this CBA is to help build an assessment of whether SIGN-AIR is worth deploying, across ECAC, from an economic perspective for the involved stakeholders. This CBA provides a consolidated assessment of the costs and benefits of deploying SIGN-AIR in ECAC Airports (with highspeed railway connections) included in the CBA solution scenario (see section 3.5.2).

This CBA will assess whether the benefits of the deployed solution are expected to exceed the costs over the CBA time horizon. TheCBA includes the evidence gathered in terms of impacts, benefits, and costs of the solution. The output is the overall net present value (NPV), the NPV per stakeholder group, sensitivity analysis, and the CBA model, report, and recommendations.

The primary objective of this Cost-Benefit Analysis (CBA) is to illustrate that the costs associated with inter-company collaboration are relatively low when compared to the substantial benefits gained from such partnerships. Specifically, this analysis aims to highlight how fostering collaboration and encouraging the use of multimodal transport across Europe can lead to significant advantages. These benefits include improved efficiency, reduced environmental impact, and enhanced economic growth. By thoroughly examining both the costs and the benefits, this CBA seeks to provide a comprehensive understanding of why collaboration between companies and the promotion of multimodal transport should be prioritized as a strategic initiative for sustainable development in Europe.

3.4 Stakeholder[8] identification

SIGN-AIR has conducted an extensive analysis of stakeholders' mapping, and the reason is that it belongs at the multimodality flagship therefore the stakeholders using SIGN-AIR platform and being affected by its usage either positively or negatively are extended to other transport fields.

3.4.1 Stakeholder map

The stakeholder mapping overview provides a comprehensive perspective on the individuals, organizations, and entities that play pivotal roles in shaping the success and resonance of collaborative initiatives within the SIGN-AIR platform. By mapping out these key stakeholders (Figure 5), we gain insight into their interests, expectations, and roles, thereby laying the groundwork for informed engagement, strategic partnerships, and the realization of multi-modal collaboration.

SIGN-AIR' stakeholders can be divided based on their interaction with the system in three categories:

- **Core stakeholders:** The end users of the SIGN-AIR platform, organization that sign the contracts either as data provider or as data consumers which are Transport Service Providers (TSPs) (e.g., airports, airlines, railway operators, bus operators, etc.).

- **Directly involved:** Stakeholders that are part of SIGN-AIR's ecosystem for specific reasons such as to demonstrate the contract's results or to update the data catalogues or to facilitate standardization and harmonization data processes, provide or consume data. These are Software companies related to data management (i.e., storage, transformation, sharing), Mobility as a Service (MaaS) operators and Travel Companion companies, Transport Alliances (e.g., ACI, IATA, UITP, UIC, UNIFE, etc.).

- **Indirectly affected:** Stakeholders that are affected by the results of the data sharing agreements and/or the smart contracts to a different extent which are the travellers and policy makers.

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

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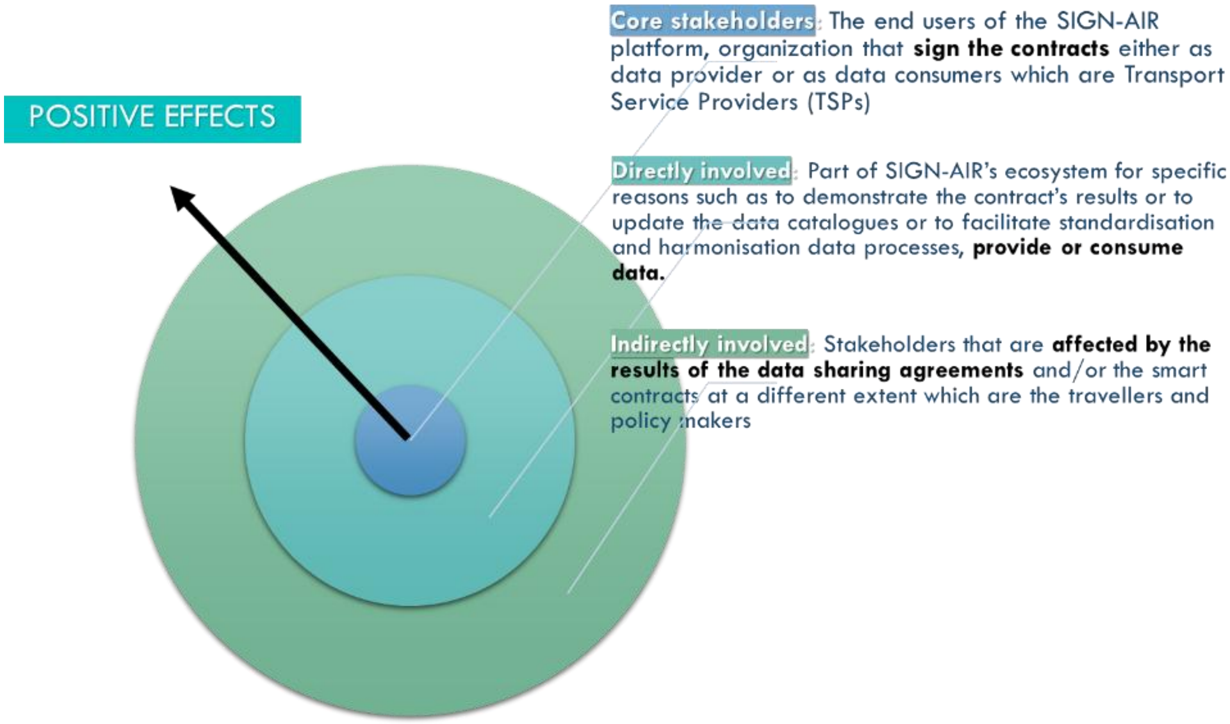

Figure 5: Stakeholders map

By diving deeper into our **core stakeholders** and based on our analysis of who our customer segment is we find that these can be further subdivided into the three following clusters based on their services that they provide.

- **Cluster 1:** Infrastructure managers managing transport hubs: airports, ports, railway stations and bus central stations.
- **Cluster 2:** Traffic controllers providing permissions to the transport carriers: Companies managing ERTMS.
- **Cluster 3:** Transport carriers operating fleets of vehicles: Airlines, ferries operators, Railway operators, bus operators, Demand Responsive Transport operators, micro mobility providers.

The following sections are dedicated to the different stakeholders and their role in the transportation system. Table 6 shows a comparison between the roles of actors per transport segment the main reason of such a clustering is that based on the role and services the actors generate similar data hence; it is a way to identify the goals of data sharing agreements and smart contracts that they can achieve using the platform.

Table 6: Comparison between roles of core stakeholders

Type of transport	**Cluster 1:** Infrastructure managers managing transport hubs	**Cluster 2:** Traffic controllers providing permissions to the transport carriers:	**Cluster 3:** Transport carriers operating fleets of vehicles
Air transport	Airport		Airlines
Maritime transport	Port Authorities (port)		Ferries operators
Railways	Infrastructure manager		Railway operator
Road transport	Transport authorities		Bus operators
	Transport authorities		Taxi operator

3.4.2 Core Stakeholders

As mentioned, they are the end users of the SIGN-AIR platform.

3.4.2.1 Air transport

Starting from the Airport Collaborative Decision Making (Airport CDM, A-CDM) which already involves all participants in the data sharing process. A-CDM is the concept which aims at improving ATFCM at airports by reducing delays, improving the predictability of events, and optimizing the utilization of resources (Eurocontrol, 2017). Eurocontrol (2017) also stated that implementation of A-CDM allows each partner to optimize their decisions in collaboration with other A-CDM partners, knowing their preferences and constraints and the actual and predicted situation. The partners included in A-CDM are airlines (aircraft operators), airport operators, handling agents, different service providers such as de-icing companies, meteorological office, fire, police, customs, fuel, etc.

The seamless service within air transport system requires effective information management and sharing, which enables a strong partnership between following participants:

- **Airport operators** also have direct involvement in air transport service provision, since they have the central role in the connectivity provided by airlines. For large airports in particular, the main problem is related to capacity constraints and congestion arose from increased traffic demand. From the collaborative perspective, the airport operators are expected to provide inputs necessary to declare airport capacity and update on any activities (such as construction, maintenance, repairs, or snow removal) that could affect the flow of traffic or airport capacity. The airport can be divided into different categories based on their i. size: regional,

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international, ii. business type: civil, military, private, iii. mode: conventional airport (passengers), vertiport, heliport, seaport.

- **Airlines** provide passenger transport service and as such they are essential stakeholders in seamless Gate2Gate service. In the collaborative environment they need to deliver planned flight schedules, to update flight plans information and any other change in flight schedule. There are different kinds of airlines based on business model: Full-Service Carrier (Legacy), Low-Cost Carriers (LCC) and Holiday Carriers (Charters), Business aviation (taxi airline. Additionally, airlines can be categorized by the Available seat-km (ASK) and revenue-passenger-km (RPK). Safety certificates of EASA and IOSA play a crucial role in their operations.

- **Other support service providers (stakeholders)** are responsible for providing handling services to airlines (ground handling), providing information on meteorological conditions that could affect traffic (meteorological provider), the provision of emergency services in the event of such an occurrence (emergency service provider) and security.

3.4.2.2 Railways

The railway network is a complex system with several technologies and a multitude of stakeholders working together to solve problems created by the increasing demands for the transportation of passengers.

- **Infrastructure Managers:** They are responsible for the railway infrastructure and for allocating its capacity to the ROCs. (Railway operation companies) Some of their main functions are pricing and marketing of train paths, traffic management and control, network maintenance, network modernization, planning and development to create new capacity, production and allocation of capacity. Infrastructure managers are also responsible for ensuring the safe operation of the railway infrastructure, decreasing the costs of maintenance of the railway infrastructure and the traffic management, and setting up new strategies for a more efficient function of the railway system.

- **Railway operating companies (ROCs):** Businesses that operate passenger trains on the railway systems. They are responsible for creating the timetables of the trains. ROCs are a customer facing part of the rail industry – working with passengers. They generally apply to the Department for Transport for franchises to run routes and normally lease trains from rolling stock companies. Railway operating companies can be divided into regional or highspeed (long distance) operators.

In many cities and regions, a Public Transport Authority (PTA) has a lot of power, and this restricts freedom of Public Transport Organizations (PTOs). Only in very specific cases, Public Transport Authority is the same with the Public Transport Operator (e.g., OASA in Athens metropolitan area).

Some crucial aspects that we need to consider as they are in progress are:

1. Most countries in Europe are working on nation-wide ticketing or at least harmonization of local and regional ticketing, data exchange and common solutions. France even already has a law for mobility that sets boundaries for these subject matters.

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2. On a European level, transnational requirements for data exchange and ticketing and competition rules are coming up – although some crucial aspects of this are still unknown for now.
3. Legislation like GDPR and NIS 2.0 will probably lead to far stricter requirements in dealing with data within and between organizations.

For the safe operation of a rail service, the control system that is used across Europe is the European Railway Traffic Management System (ERTMS). This is a major industrial project being implemented by the European Union which is contributing to interoperable railways throughout Europe. The deployment of ERTMS enables the creation of a seamless European railway system since it allows multiple operators to provide railway transport service on a single railway network. ERTMS has two basic components:

a) ETCS (European Train Control System), a train control standard, based on onboard equipment able to supervise train movements at all times and to stop the train if it moves beyond the permitted stopping point. Information sent to the cab is received from the trackside equipment, Eurobalises or radio, depending on the operation level. The driver's response is continuously monitored and, if necessary, ETCS takes control and activates the emergency brakes.
b) GSM-R (Global System for Mobile Communications - Railways) is the European radio communications standard for railway operations. Based on GSM radio technology, GSM-R uses exclusive frequency bands for communications between the train and traffic control centres.

3.4.2.3 Road transport

Road transport can be divided in Public Transit (buses) and Demand Responsive Transport (DRT).

Public Transit has two main stakeholders which are the public transport authorities (see previous chapter and the bus operators.

In many European countries we encounter the term public transport operators which are companies-carriers that operate both railways (i.e., train, light rail, trams, metro) and bus fleets.

The DRT comprised variety of services offered by demand-responsive service providers, such as the dial-a-ride, on-demand, ride-hailing, and taxi services (National Academies of Sciences, Engineering, and Medicine, 2020). For example, the Last mile project investigated the opportunities for DRT for connecting transport hubs and touristic destinations considering the sustainable mobility of rural areas.

3.4.2.4 Maritime transport

The maritime transport has an analogy of actors with the air transportation. The main stakeholders and their role are presented below.

- **Port authority** is responsible for the overall administration of the property, terminals, and other facilities on the port complex. In the context of both passenger and cargo transport, operations at marine terminals are of utmost importance. A marine terminal is an assigned area with equipment for loading and unloading ships, and space for staging cargo until it is

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loaded on the ship or transferred to overland modes of transport. Some port authorities operate some or all of their marine terminals, but more commonly operations are outsourced to terminal operating companies, i.e., tenants/port operators. The port terminals are usually leased for a long-term period, in range from 10 - 30 years (Frittelli et al., 2006). It mainly focuses on evaluating the concession agreements in the port sector, it provides some insights in the current organization, the role that different stakeholders play and even some of the conflicts. But exists a huge heterogeneity in the European seaports policies. Nonetheless, we can conclude that every country counts with a port authority, in some countries may be more government dependent while others apply a more liberalized model, in charge of creating the policies that apply within the port.

- **Vessel Traffic Control (VTC):** Similarly, to air traffic controllers, vessel traffic services or controllers (VTC) are the services implemented by the port operators and are in charge of coordinating ships within ports, harbours or other waterways. Their task consists in managing ship movements from a control centre with the help of Vessel Traffic Control. For that, VTC not only needs to take traffic into account but other relevant conditions such as the weather. The procedure consists of each ship entering a VTC area reporting to the VTC, usually via radio system, to be tracked. VTC mainly relies on the Automatic Identification System (AIS), a maritime navigation safety communications system standardized by the International Telecommunication Union (ITU) and adopted by the International Maritime Organization (IMO). AIS provides vessel information, including the vessel's identity, type, position etc.

- **Ferry operators** oversee operating all kinds of vessels from merchant vessels to passenger vessels. They are in charge of establishing the routes and ticket fares.

3.4.2.5 In land water transportation

Inland water transport or canal transport is a special category of maritime transport which in most of the cases in European cities such as Amsterdam and Lisbon are handled by the Public Transport Authorities.

3.4.3 Directly involved

Stakeholders that can provide or consume data from the SIGN-AIR platform.

3.4.3.1 MaaS providers

MaaS, are defined as **MaaS operator/provider**, public and private operators/providers, public authorities, while the other actors are data providers, IT companies, ticketing and payment service providers, telecommunication companies, financing companies, Dimitriou et al. (2020). The role of the MaaS operator is to provide mobility service through the MaaS platform, while the role of the public and private operators/providers is to provide transportation service to the users e.g., public transport (PT), car sharing, taxi operators, demand responsive transport (DRT) operators. Usually MaaS operators/providers power **Travel Companions apps and are called intermediaries** in some cases. Some examples are Traffi, Skedgo, Hacon etc.

3.4.3.2 Data Spaces companies

Data spaces are flexible and open IT infrastructures that enable trustful and transparent use of decentrally organised data according to previously defined scopes of use while guaranteeing the full sovereignty of the actors involved. They are based on a federal organisational principle. Data spaces create equal framework conditions for the sovereign exchange of data. This also means that every actor can benefit from the use of the data in the same way.

3.4.3.3 Data sharing platforms companies

Data sharing platforms are cloud environments that stakeholders can upload and access data from other stakeholders that is valuable from their business interests.

3.4.4 Indirectly involved

Stakeholders that are affected by the results of the DSAs and/or the SCs.

3.4.4.1 Passengers

Passengers are the end users of the whole SIGN-AIR ecosystem hence the effects and benefits of data sharing are indirectly affecting them. Passengers can be further divided based on archetypes (e.g., business flyer, holidayer, Golden senior flyer, commuter, frequent flyer, low-cost traveler) based on different criteria and tradeoffs.

3.4.4.2 Policy makers

The European Commission and more specifically DG Move have launched initiatives that are related to SIGN-AIR project. These are Multimodal Digital Mobility Services-**MDMS** and European mobility data space-**EMDS** initiatives.

3.4.5 Stakeholders' impacts

This section lists the stakeholder categories previously identified, (excluding some categories and focusing on the stakeholders more relevant to the project execution and use cases) that are affected by implementing, operating, and benefiting from the SESAR solution under analysis. The table below shows the impact per stakeholder.

Again, we need to point out that the list included is to have a picture of all the stakeholders involved and their costs and benefits, but we are only analysing those related to aviation in this CBA document.

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Table 7: SIGN-AIR CBA stakeholders and impacts

Stakeholder	Type of stakeholder / applicable sub-operating environment	Costs and benefits in operations	Involvement in the CBA analysis	Quantitative results available in the current CBA version
Airport operators	Core/ APT Very Large APT Large APT Medium APT Small	Cost: To invest in Queue Management Systems (QMS) in the Airport Operations Control Centre, to be able to improve the efficiency of airport operations and the overall passenger experience. Benefit: To increase clientele, optimize passenger experience, manage delays of passengers, reduce costs, and operate planes in full capacity	Involved	Estimated costs associated to the usage of the platform.
Scheduled airlines (mainline and regional)	Core /	Costs: To invest in new tool, invest in establishing converters or standardization mechanisms, invest in upgrading data sharing infrastructures Benefits: To increase clientele, optimize passenger experience, open new destinations that are not directly served by an airport. Manage delays	Not involved in the second loop of the document	Estimated costs associated to the use of the platform.

Stakeholder	Type of stakeholder / applicable sub-operating environment	Costs and benefits in operations	Involvement in the CBA analysis	Quantitative results available in the current CBA version
		of passengers and reduce costs. Operate planes in full capacity.		
Railway infrastructure Managers	Core/ High-Speed Rail Corridors with connection to Airports Cross-Border Rail Networks Multimodal Travel Hubs	*Costs: invest in new tool, invest in establishing converters or standardization mechanisms, invest in upgrading data sharing infrastructures* *Benefits: Increase reliability and handle better disruption and passengers' flows. Comply with the new legislation of Europe.*	Not involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation
Regional Railway operators	Core/ High-Speed Rail Corridors with connection to Airports Cross-Border Rail Networks	*Costs: invest in new tool, invest in establishing converters or standardization mechanisms, invest in upgrading data sharing infrastructures* *Benefits: Increase reliability and handle better disruption and passengers' flows. Comply with the new legislation of Europe.*	Involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation

Stakeholder	Type of stakeholder / applicable sub-operating environment	Costs and benefits in operations	Involvement in the CBA analysis	Quantitative results available in the current CBA version
Highspeed Railway operators	Core Airport-Centric High-Speed Rail Operations Cross-Border High-Speed Rail Corridors Urban-to-Airport HSR Links	*Costs: invest in new tool, invest in establishing converters or standardization mechanisms, invest in upgrading data sharing infrastructures* *Benefits: Increase reliability and handle better disruption and passengers' flows. Comply with the new legislation of Europe.*	Involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation
Public bus transport	Core/ Airport Shuttle Services Multimodal Hubs (connecte to train stations, airports or ferry terminals)	Costs: invest in new tool, invest in establishing converters or standardization mechanisms, invest in upgrading data sharing infrastructures Benefits: Increase reliability and handle better disruption and passengers' flows. Comply with the new legislation of Europe.	Involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation
Port Authorities	Core/ Intermodal Logistics Hubs (Ports that serve as key nodes in the global supply	Costs: Benefits:	Not involved	Not considered in CBA document, as this document specifically

Stakeholder	Type of stakeholder / applicable sub-operating environment	Costs and benefits in operations	Involvement in the CBA analysis	Quantitative results available in the current CBA version
	chain, linking maritime transport with rail, air, and road logistics)			addresses costs and benefits related to aviation
Vessel Traffic control	Core/ Port Approaches and Harbor Areas (managing multiple vessel movements in a confined space with heavy traffic)	Costs: Benefits:	Not involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation
Ferry operators	Core/ Passenger ferries	Costs: invest in new tool, invest in establishing converters or standardization mechanisms, invest in upgrading data sharing infrastructures Benefits: Increase reliability and handle better disruption and passengers' flows. Comply with the new legislation of Europe.	Not involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation
MaaS operators and TC software companies (Intermediaries)	Directly Involved/ Last-Mile Connectivity (MaaS solutions focused on the final leg of a journey, providing users with	Costs: invest in new functionalities Benefits: Provide Door2 Door journeys including air transportation	Not involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation

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Stakeholder	Type of stakeholder / applicable sub-operating environment	Costs and benefits in operations	Involvement in the CBA analysis	Quantitative results available in the current CBA version
	options to move from transport hubs -e.g., train stations, bus terminals- to their final destinations) Multimodal Transport Planning Software (Software tools designed to help passengers plan, book, and pay for trips using a combination of transport modes)			
Data Spaces companies	Directly Involved/ Intercity and Regional Multimodal Transport Data Spaces Airport and Aviation Data Spaces Port and Maritime Transport Data Spaces	Costs: invest in new functionalities Benefits: To have data from all traffic management companies, including air space.	Not involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation

Stakeholder	Type of stakeholder / applicable sub-operating environment	Costs and benefits in operations	Involvement in the CBA analysis	Quantitative results available in the current CBA version
	Railway and Train Networks Multimodal Data Spaces Real-Time Data Aggregators for Multimodal Travel Regulatory and Policy Data Spaces			
Data sharing platforms companies	Directly Involved/ Traffic and Mobility Management Data Space	Costs: invest in new functionalities Benefits: To have data from all traffic management companies, including air space.	Not involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation
Policy makers	Indirectly Involved Transport Infrastructure and Network Planning (this environment enables policy makers to access data from different transport modes to plan, optimize, and invest in transport infrastructure -	Costs: invest in promotional activities Benefits - See their policies implemented. - The results of the contracts are in favour of the policies - See the results of performance exercises and use cases.	Involved	Not considered in CBA document, as this document specifically addresses costs and benefits related to aviation

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Stakeholder	Type of stakeholder / applicable sub-operating environment	Costs and benefits in operations	Involvement in the CBA analysis	Quantitative results available in the current CBA version
	e.g., rail, road, air, maritime- that connects various modes seamlessly)			
Travellers	Indirectly Involved/ Multi-Mode Journey Planning and Booking Real-Time Travel Information and Notifications Smart Ticketing and Identification Accessibility and Inclusivity	Cost: None, as SignAir is not an App for travellers to manage it.Benefits: If TSPs reach an agreement, Travellers experience will improve substantially in terms such as have accommodation in a case of an incident or delay, minimize their total travel time or reduce their transfers, among others.	Not involved	none

3.5 CBA scenarios and assumptions

This section describes the scenarios that are compared in the CBA. The aim is to reflect the delta (difference) between the CBA reference scenario (where the SESAR solution is not deployed, bottom box in **¡Error! No se encuentra el origen de la referencia.**) and the CBA solution scenario (reflecting the proposed deployment of the SESAR solution across ECAC, box in **¡Error! No se encuentra el origen de la referencia.**). The comparison between the CBA scenarios considers the point in time when the solution is available to be deployed and hence differs for each solution.

The delta approach means that the focus is on identifying the impact of the changes between the CBA reference and CBA solution scenarios. For example, new systems to be deployed, training requirements or changes in operating costs.

Defining the CBA reference scenario has proven to be challenging because of the assumptions that need to be made regarding the 'ongoing deployments' that are relevant for the solution and their impacts.

To avoid being blocked by this issue, some elements of this CBA focus on the difference between the current situation and the CBA solution scenario. This is reflected in the following scenario descriptions.

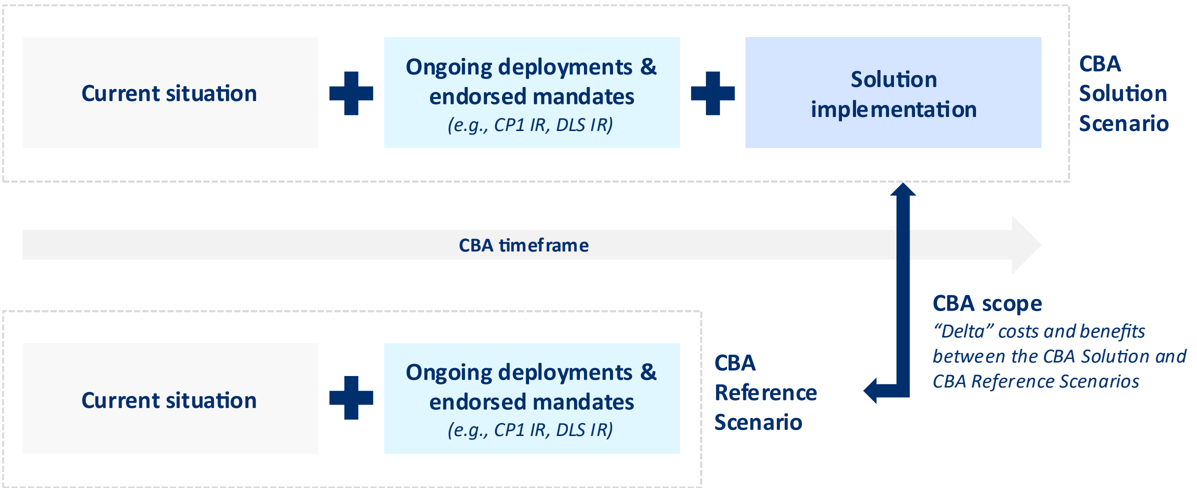

Figure 6: CBA scenario overview

3.5.1 CBA reference scenario

This sub-section describes the CBA alternative reference scenarios can be analysed, reflecting different possible situations at the start of implementation with assumptions about what enablers are deployed, what data items are available, and how deployment is likely to evolve without these solutions during the time horizon of the CBA.

For this second version of CBA, we have used as a reference scenario the situation where TSPs do not have a data sharing agreement nor a smart contract in place.

As a solution scenario, all stakeholders involved in SIGN-AIR have accepted the use of the tool for DSA and SC signature, but they are still not prepared to do all the potential improvements in their operations, as explained on each stakeholder cost analysis below.

3.5.2 CBA solution scenario

The new infrastructure is the SIGN-AIR cloud platform, which is a stand-alone platform, however a connection with the TSP's monitoring dashboard should be established after the signature of the DSA and SC. The TSP's do not have to modify their technical systems or infrastructures to create the contracts, but they will have to make adaptations for the data sharing processes with their counter party of the contract.

TSPs will have 3 generic costs categories:

1) Generating and signing a DSA and SC (fixed price)
2) Monitoring DSA with the execution of SC (registration times)
3) Deploy APIs for data sharing and maintenance costs.

SIGN-AIR could be deployed in all ECAC airports. Nevertheless, a distinction needs to be made between the different pairs of TSPs and the data sharing goals that they can achieve. Even though the SIGN-AIR platform does not have a limit in geographical scope it has specifications which allow its deployment to make more sense and provide benefits to its stakeholders. These specifications can be divided into two categories the general and the goal specific.

General specifications

TSPs, to establish a meaningful collaboration they need to operate in a common area and at a similar timeframe to be able to create multimodal chains. For example, a common area is defined as a transport hub (e.g., an airport, a central railway station.) and the time frame the operations/services time. In other words, data sharing facilitates the travellers' journey from A to B using different transport modes (e.g. train-airplane-bus, metro-highspeed train-taxi etc.)

Goal specific (also refer at ***¡Error! No se encuentra el origen de la referencia.****)*

Table 8: Geographical scope vs data sharing goals

<table>
<tr><th>Goal</th><th>Geographical scope</th><th>Supporting sources</th></tr>
<tr><td>G1.1: Seasonal tickets</td><td>Large airports with good access by public transport means

Medium airports with good access by public transport means

Small airports</td><td rowspan="3">According to EUROCONTROL's latest forecast, European flight traffic is projected to grow by 3.7% in 2025, reaching approximately 11.1 million flights. This increase reflects an improved economic outlook and optimistic airline schedules for winter 2024-2025. Notably, traffic levels are expected to return to pre-pandemic figures, with variations across different regions (https://www.eurocontrol.int/sites/default/files/2024-10/eurocontrol-seven-year-forecast-2024-2030-october-2024.pdf?utm)

To average 1.5% per year in the base forecast, owing to the greater uncertainties within the 7-year horizon (higher inflation, pressure on oil prices, environmental concerns…). As downside risks prevail, the number of flights in the low forecast stagnates from 2025 onward (source: Eurocontrol)

The European Commission is revising the package travel directive to Stronger passenger rights. "The proposal on passenger rights in the context of multimodal journeys also sets out for the first time, new rules to protect passengers using different types of transport, like buses, trains, and planes, all in one trip. Passengers will enjoy better information rights before and during such travels, including minimum connecting times between different transport services. In addition, where they bought the multimodal journey under one transport contract, they will be entitled to assistance by the carrier in the event of missed connections. Special attention is paid to the needs of passengers with disabilities or reduced mobility. (https://ec.europa.eu/commission/presscorner/detail/en/ip_23_6110)

France has announced a single ticket for all the Public Transport of the country (source)</td></tr>
<tr><td>G1.2: Combined tickets</td><td>Large airports with good access by public transport means

Medium airports with good access by public transport means

Small airports

Central train stations</td></tr>
<tr><td>G1.3: Single tickets</td><td>Large airports connected with a highspeed railway operator. (9)

Large airports connected with long distance bus operators.

Large or medium airports located in less than 50km to cruise ports (15)</td></tr>
</table>

G2.1: Reach more flights.	Large airports connected with a highspeed railway operator (9) Medium airports connected with long distance bus operators	Change in travellers' behaviour towards sustainability and "flygskam," (shame about flying) (source)
G2.2: Reach more passengers	Large airports of connected with a highspeed railway operator (9) Large and medium airports in Belgium, the Netherlands, Germany, Czech Republic) connected with a highspeed railway operator that has a night sleeper train. Medium airports connected with long distance bus operators. Large or medium airports located in less than 50km to cruise ports (15) Small airports located in less than 25km to a cruise port (37)	Night sleeper again a trend in Europe (source: AoI, timeout,) New night services Barcelona, Stockholm (source: sleeper) Cruises not to miss (source)
G2.3: Substitution of short haul flights	Large airports and regional airports in the following countries: France, Belgium, Spain, Germany, Austria	Austria and France banning short-haul domestic flights where trains are available (source Eurocontrol) Can Europe's trains compete with low-cost airlines? (source: financial times)

G3.1: Event detection and classification	Large airports with implemented A-CDM Large airports Medium airports using a light version of A-CDM Medium airports Small airports	The European Union has been working to improve advance communication and notification systems for travellers when disruptions are known. One key area where this is addressed is in the European regulations on passenger rights and operator obligations. **EU Regulation 2027/2019 (Travel Information Transparency):** This regulation emphasizes the obligation of operators (airlines, rail companies, etc.) to inform passengers as soon as possible when a disruption is expected. It requires that real-time updates on delays, cancellations, or other issues be provided via electronic means, such as SMS, email, or apps, if contact details have been provided. **Multimodal Digital Mobility Services Proposal (MDMS):** A recent EU proposal aims to integrate multimodal travel information systems to ensure travellers receive consistent and timely updates across all transportation modes in case of disruptions. This is part of the broader push for a seamless multimodal passenger journey experience. **Regulation (EC) No 1371/2007 (Rail Passenger Rights):** Rail operators are required to notify passengers promptly in the event of service disruptions, delays, or interruptions. **Regulation (EU) 181/2011 (Bus and Coach Passenger Rights):** Includes provisions for informing passengers of delays or cancellations as soon as the carrier becomes aware of them.
G3.2: Event Response Coordination	Large airports with implemented A-CDM	The European Commission has proposed a regulation to enhance passenger rights for multimodal journeys—trips that involve multiple

	Large airports Medium airports using a light version of A-CDM Medium airports Small airports	forms of transportation under a single contract. This proposal introduces new rules to protect passengers using different types of transport within a single trip, addressing areas such as assistance for passengers with disabilities or reduced mobility during connections, and ensuring clear information and assistance at connecting points. As of January 2025, this proposal is under consideration and has not yet been adopted into law. https://transport.ec.europa.eu/transport-themes/passenger-rights_en?utm_source=chatgpt.com https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52013PC0130

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Figure 7: Overlap of goalsFigure 7 ¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.shows that certain goals have an overlap can be combined to offer better benefits to the stakeholders. The focus of this figure is the collaboration between airlines and highspeed railway operators. For this pair of TSPs to achieve Single ticketing goal, synchronization of timetables is a prerequisite and by achieving a single ticketing and having the passenger identified in each leg of his/her journey disruption management is more targeted.

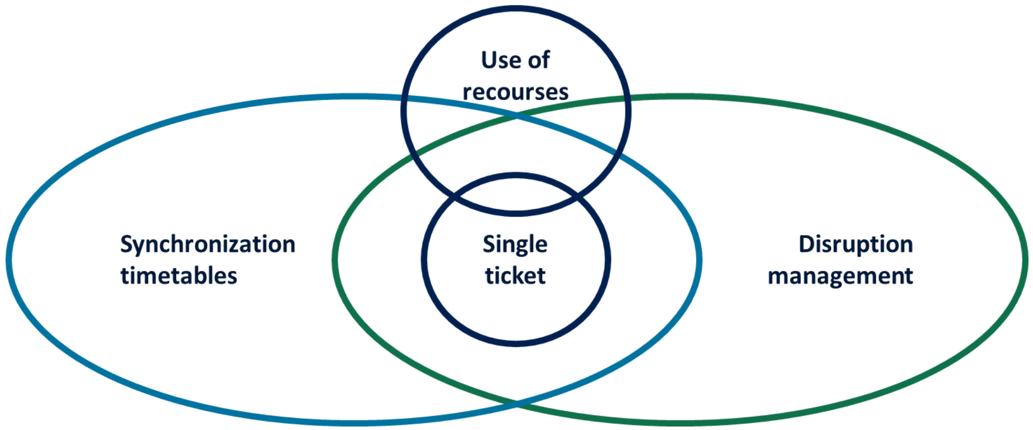

Figure 7: Overlap of goals

SIGN-AIR has designed certain use cases to demonstrate its developments.

The discount rate in line with the latest applicable version of the DES performance framework document available in the program library is 8%.

CBA timeline

The CBA covers the period from 2026 to 2050 as defined in the common assumptions.

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Table 9: CBA investment and benefit dates

Dates	SOL0375 D2.11.1
Start of deployment date (SOD): the start of investments for the first deployment location	2026
End of deployment date: the end of the investments for the final deployment location, same as FOC	2028
Initial operating capability (IOC): the time when the first benefits occur following the *minimum deployment* necessary to provide them. Costs continue after this date as further deployment occurs at other locations.	2027
Final operating capability (FOC): maximum benefits from the *full deployment*[9] of the SESAR solution at applicable locations. Investment costs are considered to end[10] here although any operating cost impacts would continue.	2028

[9] Where ***full deployment*** means deploying the SESAR solution in all the locations where it makes sense to deploy it (i.e. it does not mean it has to be deployed everywhere)

[10] The basic assumption is that infrastructure does not need to be replaced during the CBA period.

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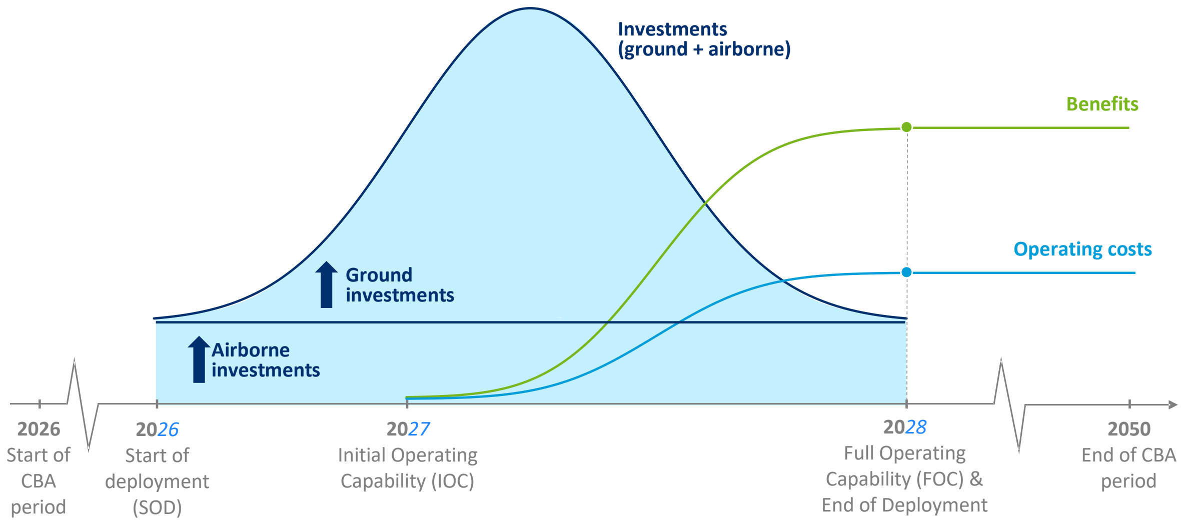

Figure 8: overview of CBA dates

Figure 8: overview of CBA dates Figure 8 shows that:

- Investment costs are the addition of the (i) ground investment costs (spread following a bell curve[11] between the start and end of deployment dates), and (ii) airborne investment costs (spread linearly between the start and end of deployment dates).
- Benefits ramp-up following an 'S' adoption curve[11] between IOC and FOC and then continue up to the end of the CBA period.

[11] The bell curve is based on the diffusion of innovation theory (see Investopedia for further reference).

- Operating cost impacts (increases or decreases) would also start at IOC and ramp-up following an ‘S’ adoption curve to FOC before continuing for the rest of the CBA duration.

3.5.3 Assumptions

Although the platform facilitates data exchange across multiple transport modes, the target audience for this document is SESAR organization, which is solely concerned with aviation-related improvements. Additionally, costs and benefits for other logistic operators, such as railway and bus services, are independent and disconnected from the aviation ecosystem. Under these premises, the cost analysis of the rest of TSP participants will not be provided. **This document specifically addresses costs and benefits related to aviation.**

One of the main goals of this SIGN-AIR solution is to improve passenger experience a better access to the airport.

1. ECAC Airports with highspeed railway connections (synchronization of timetables and single ticket)
2. ECAC Airports with regional railway connection (combined ticket)

These airports are all in the category of Very Large and Large.

In each of the airports, we have selected the airlines that use them as a hub.

It is necessary, though, to assume that the other TSP participants will have a certain maturity level in technologies, or they are willing to invest in digitalization and data sharing technologies, such as converters etc.

Additionally, we assume that all participants in the agreements want to unlock value of their data, and they are looking for collaborations.

For some use cases proposed in Sign-Air project, Railway operators need to have a disruption detection system deployed in advance.

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4 Benefits

4.1 Benefits overview

The core functionalities of SIGN-AIR orchestration management are to manage (generate and monitor) the contractual aspects of DSAs and SCs between two TSPs, which has two key benefits:

● Optimises time and automates processes.

● Uses smart contracts as a complement of the DSA to monitor data sharing processes, which is not currently used in multimodal transport systems' data sharing processes.

The adoption of a templating mechanism for contracts brings transformative benefits across various dimensions, including customization, scalability, accuracy, compliance and collaboration. One of its key advantages lies in the ability to create tailored contracts that cater to the unique goals of multimodal data-sharing agreements. With customizable templates and dynamic clauses, agreements can be adapted to suit specific scenarios and stakeholders. This flexibility is further enhanced by adjustable preferences and dynamic content updates, ensuring that contracts remain relevant and aligned with the evolving needs of the parties involved.

Efficiency and cost savings are central benefits of the templating mechanism. By reducing the reliance on extensive manual drafting and legal reviews, organizations can lower operational costs and streamline the negotiation process. Additionally, the platform accessibility from everywhere supports international agreements and collaborations.

Synchronize ground and air timetables: By providing a web tool to digest and process timetables data from different transport modes and calculates multimodal connectivity to propose feasible multimodal options for single ticketing. TSPs have a user-friendly interface that they can use to decide the most promising multimodal itineraries.

Nevertheless, this web tool could be used to calculate the rail-air, air-rail connectivity index apart of the air connectivity index of a certain hub and allow the airport to improve its access or to better manage its resources based on the different analytics.

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Manage intermodal rerouting/disruptions management: SIGN-AIR provides an external module/web interface that allows TSPs to calculate the impact of disruptions based on alerts. This module proposes a number of feasible strategic and/or tactical multimodal options for a given Origin Destination pair. This includes standardization and data management of planned and real time data.

Extent Travel Companion (TC) apps features: SIGN-AIR contracts provide new information concerning multimodal journeys (integrated tickets, alerts & rerouting) based on signed contracts to TC apps that interface travellers.

In line with these benefits, the Expected Performance Contributions (EPC) allocation, together with their qualitative impact levels (1–3 / YES), have been validated with the KPA champions in December 2025. The final agreement is presented in Table 10

Table 10: SIGN AIR Expected Performance Contributors

SOL. CODE	SAF	FEFF1	TEFF1	CAP1	CAP2	PRD1	PUN1	CEF2	CEF3	HP	DIGI
(ID 0375) SIGN-AIR-SOL-01	NSI	N/I	0	N/I	N/I	N/I	0	N/I	N/I	NO	YES

Additionally, it has been agreed that SIGN-AIR includes passenger experience (PAX) as a performance domain.

4.2 Benefit summary

This section shall list the values extracted from the performance assessment report (PAR). It shall provide the values used in the CBA model along with an explanation of why those values were used (e.g. low values, high values, average values, most likely scenario). The table below includes examples of some benefits and values. It shall be updated to only include the benefits and values relevant to the solution.

Table 11: solution performance benefitsTable 11 summarises the solution benefits showing the estimated performance contribution, the low and high values from the PAR the values used as inputs for the CBA model and the cumulative value of the benefit over the CBA period.

Table 11: solution performance benefits

KPI / PI	Estimated performance contribution	PAR value	PAR to CBA rationale	CBA input value	CBA cumulative total (M€)	Monetisation mechanism
DIGI1 Digitalisation	Qualitative	100%	TRL6 exercises calculation	100%	---	No monetization
DIGI2 Connectivity	Qualitative – YES/NO	80%	TRL6 exercises calculation	76%	---	No monetization
DIGI3 Data Sharing	Qualitative – YES/NO	60%	TRL6 exercises calculation	100%	---	No monetization
PAX	Qualitative – YES/NO	YES	TRL6 exercises calculation	YES	---	No monetization
Total					xx M€	

The following sections briefly explain how the SIGN-AIR solution will produce the benefit (i.e., summary of the logic explained in the Benefit and Impact Mechanism-BIM) and it shall provide an overview of how the benefit is consideres, although it can not be monetised in the CBA, following DES SESAR ATM CBA Model.

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4.2.1 Operational Efficiency (PUN1)

It is important to explain why we have finally rejected to use PUN1 as one of the SIGN-AIR KPIs.

The SESAR Key Performance Indicator PUN1 (Average Departure Delay per Flight) measures the average delay in flight departures, expressed in minutes per flight, caused by air traffic management (ATM)-related factors, reactionary delays from previous flights, and meteorological conditions. It is calculated as the difference between the Actual Off-Block Time (AOBT) and the Scheduled Off-Block Time (SOBT), focusing specifically on the operational efficiency of flight schedules. As such, PUN1 is inherently flight-centric, capturing delays that impact the aircraft's departure rather than the individual passenger journey or pre-flight processes.

Our project, however, addresses the specific issue of punctual passenger delays caused by disruptions in prior transport modes, such as delayed connecting flights or trains, which prevent passengers from reaching their departure gate on time. These delays are passenger-centric and multimodal, occurring before boarding and outside the scope of flight operations. Since PUN1 does not account for passenger flow, ground processes, or multimodal transport disruptions (e.g., train delays), **it is not the primary KPI for assessing the benefits of our solution**. Using PUN1 in the Cost-Benefit Analysis would fail to capture the direct impact of reducing passenger delays and missed connections, which are the core objectives of our project.

This decision has been confirmed by ATM Performance Experts, who have confirmed that *"SIGN-AIR remains a technological solution, and the validation activities performed (contract creation and signature workflows, partner identification, schedule upload, algorithmic connection feasibility, and disruption management processes) do not allow for deriving a measurable PUN impact. Any influence on punctuality would be indirect and dependent on future uptake or operator behavioural changes."*[12]

4.2.2 Digitalization (DIGI)

The SIGN-AIR platform, designed to orchestrate digital contract signatures for data-sharing among Transport Service Providers (TSPs) in multimodal travel, directly contributes to the SESAR Digitalisation (DIGI) Key Performance Area as defined in the Digitalisation Companion Document (PJ19_04_D_1_0003).

Although operating at the ground/multimodal level and not directly influencing airspace operations, SIGN-AIR aligns with the Data Sharing pillar (DIGI3) and Connectivity pillar (DIGI2) through automated governance, legal licensing, and interoperable data exchange protocols. These elements are explicitly identified as Secondary Performance Indicators (PIs), enabling measurable progress in digital maturity. The document emphasizes digitalisation as a transversal enabler across the entire aviation ecosystem—from concept to service provision—including external stakeholders like TSPs. By accelerating standardized agreements and reducing contract processing latency from days to minutes, SIGN-AIR generates quantifiable digital-specific benefits (e.g., reduced administrative costs).

[12] Agrrement confirmed on December 2025, 11th by ATM Performance Expert, Katerine Cliff.

Inclusion of DIGI in the SIGN-AIR CBA is mandated by the Companion Document's requirement to assess "monetisation of cost and benefits stemming directly from this dimension" within SESAR3 activities.

Using the SESAR Digitalisation Index (SDI) methodology, we can prepare the following **¡Error! No se encuentra el origen de la referencia.** with a proposal of an average use of SING-AIR for TRL6.

Table 12 :Digitalisation Index (SDI) calculation

KPI	Achievement	Weight
DIGI1.1: Data Origin	1	1
DIGI1.2: Data Existence	1	1
DIGI1.3: Data Quality	1	2
DIGI1.4: Data Integrity	1	2
DIGI1.5: Data Standards	1	1
DIGI1.6: Data Validation	0,83	1
DIGI2.1: Data Availability	1	2
DIGI2.2: Data Accessibility	0,83	2
DIGI2.4: Data Latency	0,83	1
DIGI2.5: Data Processing Time	0,65	1
DIGI2.6: Data Refreshing Time	0,75	1
DIGI2.9: Connectivity Interoperability	1	2
DIGI3.1- Data Governance	1	1
DIGI3.2 – Data Licensing	1	1
DIGI3.3: Data Sharing Interoperability	1	2
DIGI3.5: Data Cybersecurity	1	2

Thus, the value of each pillar (digitisation, connectivity, and data sharing) will be calculated as follows:

$$DIGI1 = \frac{\sum_{i=1}^{n}(w_i \cdot DIGI1._i)}{\sum_{i=1}^{n} w_i} = 98\%$$

$$DIGI2 = \frac{\sum_{i=1}^{n}(w_i \cdot DIGI2._i)}{\sum_{i=1}^{n} w_i} = 88\%$$

$$DIGI3 = \frac{\sum_{i=1}^{n}(w_i \cdot DIGI3._i)}{\sum_{i=1}^{n} w_i} = 100\%$$

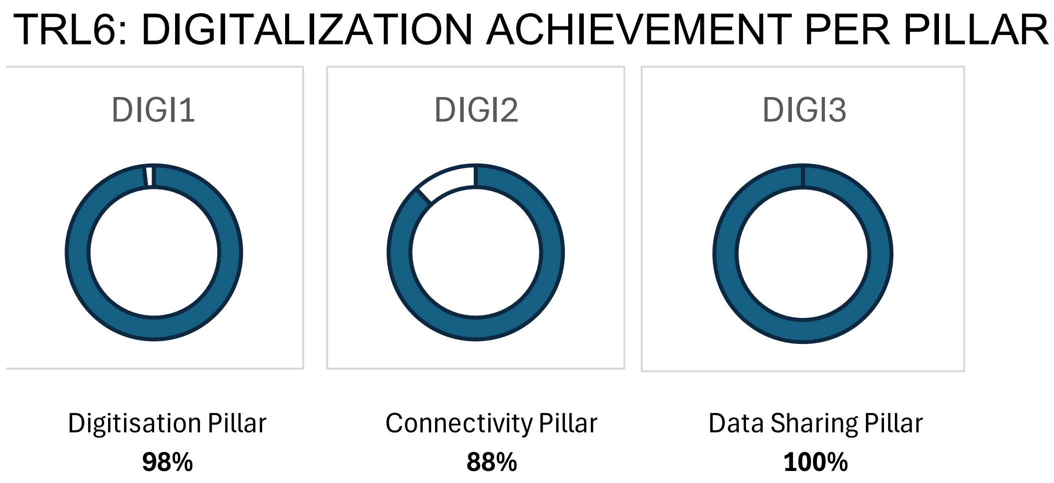

Figure 9 Digitalisation achievement per pillar

$$SESAR\ Digitalisation\ Index\ (SDI) = \frac{DIGI1+DIGI2+DIGI3}{3} = 95\%$$

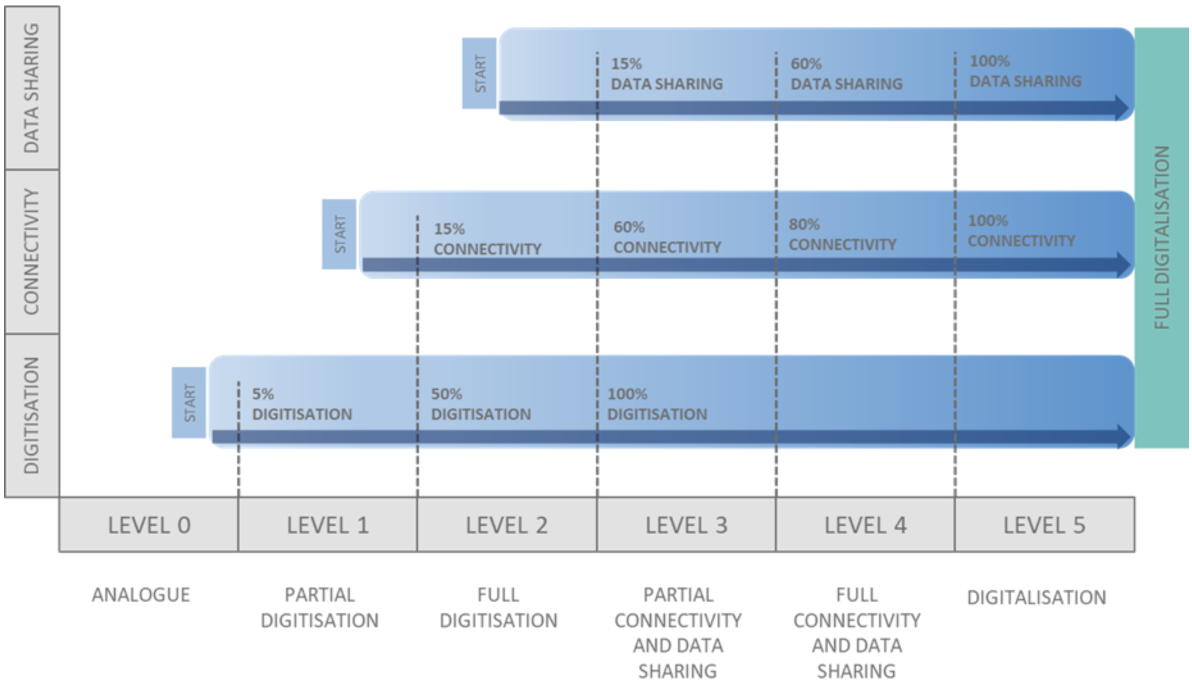

Figure 10: Achievement percentages of the three digitalisation Primary PIs in each of the five levels defined

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Considering DIGI1 is almost 100% and both DIGI2 and DIGI3 are very high, we can say that the solution is at LEVEL4 of connectivity at TRL6.

Excluding DIGI would underestimate SIGN-AIR's disruptive potential. The platform's outputs—faster, secure, and standardised data-sharing—are not subsumed under traditional KPAs like Capacity or Fuel Efficiency but represent digital-specific value (e.g., € savings via reduced legal overhead, monetary value created through TSP partnerships).

These gains could enable new multimodal services and feed indirect ATM improvements (e.g., real-time ground data enhancing trajectory predictability), supporting the EU Digital Single Market and ATM Master Plan 2020 objectives.

4.2.3 Passenger Experience (PAX)

SIGN-AIR is a passenger centric solution and intents to measure the benefits of passengers. Although the new KPI of passenger experience will be part of SESAR´s performance framework, SIGN-AIR will adopt more PIs concerning passenger experience, as per those which are presented in the table below.

Table 13: KPA passenger experience and PIs applied to SIGN-AIR

KPA	PI	Detail	How to calculate	How to evaluate
PAX1 – Travel Time represents the efficiency of a passenger's total journey across all travel modes. It encompasses the time from the start of the first leg to the end of the last leg, including transfers and waiting periods. The objective is to minimize total travel time and ensure competitive multimodal alternatives	PAX1.1: Total Travel Time	Total Travel Time for a given alternative refers to the travel time from starting point of 1st leg to ending point of last leg	Total time < 240 minutes	YES/NO
	PAX1.3: Ratio Total Travel Time vs transfer time	Ratio Total Travel Time vs transfer time (transfer time being the time to connect from one travel mode to another one and also includes the waiting periods)	Transfer Time/ Total Travel Time < 0,33	YES/NO
	PAX1.4: Ratio Total Travel Time vs fastest alternative	Ratio Total Travel Time vs fastest alternative: refers to a % comparing the total travel time (PAX1.1) of the alternative retained and the total travel time of the fastest alternative. It can be null if the	TTT - TTTbest / TTT	YES/NO

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		retained alternative is the fastest one. (it is a benchmark between Origin & Destination)		
PAX3 – Resilience reflects the ability of the multimodal travel chain to recover from disruptions and maintain service continuity. It assesses whether passengers have feasible tactical alternatives and whether their arrival time adheres to planned schedules despite disturbances.	PAX3.2: Number of tactical alternatives	Number of tactical alternatives for a given Origin Destination pair	num > 1	YES/NO
	PAX3.4: Destination Arrival Time Adherence	Destination Arrival Time Adherence: measures the delay after the last leg arrival compared to planned arrival time after the last leg	Time arrival - Time arrival planned < minimum connection time	YES/NO
PAX4 - Ease captures the simplicity and intuitiveness of a multimodal journey. It refers to the degree to which passengers can complete their trip with minimal effort, transfers, and confusion.	PAX4.1: Number of minimum legs of the total travel journey	Number of minimum legs of the total travel journey from 1st leg to last leg, including the number of connecting legs.	num <= 2	YES/NO
PAX6 – Robustness represents the structural stability and predictability of the transport offer under normal and perturbed conditions. It evaluates the availability of strategic options and the frequency of services in the multimodal network as well as potential replacement or extension of air	PAX6.1: Number of strategic options	Number of strategic options for a given Origin Destination pair	Connectivity Index > 0,7	YES/NO
	PAX6.2: Strategic Frequency of service:	Strategic Frequency of service: number of services per hour during peak and off-peak time	num peack > 4 num off-peck > 2	YES/NO

network services due to environmental policies or disruptions.				

TRL6 exercises presented the PAX as fully achieved in different situations, as it allows TSP's to manage contracts according to different time-schedules available in the platform, in a way that they can comply with the PI's.

5 Cost assessment

Readers should note that in this section the costs assessment is split into the investment costs (pre-implementation costs and implementation costs) and annual operating costs changes. In the CBA results section these are referred to as, respectively, CAPEX (capital expenditure: one-time costs for development or setup) and OPEX (operating expenditure: recurring costs such as maintenance or hosting) to simplify the presentation.

The cost analysis within this document focuses solely on aviation-related expenses, with information relative to the air-traffic stakeholders, such as airport operators and airlines.

- Investment costs:
    - **Platform Integration:** Initial investment in system infrastructure and integration with existing aviation data networks.
- Annual operating costs**:**
    - **Operational Costs:** Maintenance, data security, and ongoing support for aviation stakeholders.
    - **Compliance and Governance:** Ensuring alignment with regulatory requirements and aviation-specific data-sharing protocols.

Table 14: Cost analysis

Category	Unit/ Instance	CAPEX (€)	OPEX (€)	Description	Source for data cost estimation
AO	5	€ -	€ 50,000 /year	Staff training and data coordination	Extrapolated from similar airline training programs
		€ 150.000,00	€ 20,000 /year	Integration with ground systems for airports	Based on open data from stakeholder consultations and previous SESAR project reports
SA Ground	15	€ -	€ 50,000 /year	Staff training and data coordination	Previous SESAR-funded pilot programs and workflow assessments
		€ -	€ 2.500,00	Generating and Signing DSA and SC (to consider 4 per year)	SIGN-AIR price proposal
		€ -	€ 1,000 /month	Monitoring DSA and SC Execution	SIGN-AIR price proposal
		€ 150.000,00	€ 50,000 /year	Integration with airline systems	Cloud provider pricing (AWS, Azure) and SESAR hosting guidelines

5.1 ANSPs costs

Not applicable, as they are not impacted by the solution.

5.2 Airport operators' costs

5.2.1 Airport operators cost approach

The involvement of Airport operators has been through the partner "BLQ" (Aeroporto Guglielmo Marconi di Bologna SpA).

They have participated in several discussions at solution level, providing general feedback to all the documentation presented.

Additionally, at the 2nd stakeholders workshop representatives of the 2 VL (IST, CDG), 2L (BRU, ATH) and as mentioned above 1 M (BLQ) airport tested SIGN-AIR platform either by providing data or just with pre-defined historical datasets.

5.2.2 Airport operators cost assumptions

The assumptions taken for the Airport operators' cost are:

- Modifications to integrate the platform information, so time schedules for ground-based multimodal operators (such as train operators and bus services IT systems) is visible.
- Integration with ground systems in the airports, for ground operators to manage the agreements.

Not considered at this stage:

- Passenger Flow Management System (PFMS): not being modified yet, so the Airport operators would not be able to change current passenger flows.
- Queue Management System (QMS): not being modified yet, not allowing the Airport to change current flows.

5.2.3 Number of investment instances (units)

Table 15: number of investment instances – airports

Airport			
VL	L	M	S
2	2	1	

5.2.4 Cost per unit

Table 16: cost per unit – airports

Cost category	Airport			
	VL	L	M	S
Pre-implementation costs	€ 0	€ 0		
Implementation costs	€ 150,000	€ 150,000		
Annual operating cost change	€ 70,000	€ 70,000		

Enabler	Enabler title	Implementation costs (M€)	Operating costs (M€/year)
AOC-ATM (or FOC)-01853	Advanced route planning for the identification of appropriate air–rail connections	Included in global cost	Included in global cost
AOC-ATM (or FOC)-01876	Assessment Airports accessibility via Intermodal Connectivity calculation	Included in global cost	Included in global cost
AOC-ATM (or FOC)-01877	Enhance airlines passenger Notification System and Travel Companion (TC) with multimodal information and intermodal alternative itineraries.	Included in global cost	Included in global cost
	Total	**0.15 M€**	**0.07 M €**

Table 17: cost per enabler and total cost per unit (investment and operating) – airports

5.2.5 Airport total costs

Investment costs (pre-implementation and implementation costs)

Table 18: airport investment cost summary

Sub-operating environment	Cost per unit		Deployment locations		Cost
Very large airports	*0.15* M€	x	*2*	=	*0.3* M€
Large airports	*0.15 M€*	x	*2*		*0.3 M€*
Medium airports	*0.15* M€	x	*1*	=	*0.15* M€
			Total investment costs		*0.75* **M€**

<u>**Annual operating cost changes**</u>

Table 19: airport operating cost summary

Sub-operating environment	Annual costs		Deployment locations		Cost
Very large airports	*0.07* M€	x	*2*	=	0.14 M€
Large airports	*0.07 M€*	x	*2*	=	0.14 M€
Large airports	*0.07* M€	x	*1*	=	0.07 M€
			Annual operating cost change		*0.35* **M€**

5.3 Network manager costs

Not applicable, as they are not impacted by the solution.

5.4 Airspace user costs

This CBA is taking into consideration the Scheduled Airlines.

5.4.1 Airspace user cost approach

We do not have any scheduled airline in the consortium, which makes difficult the possibility to get economic information. Nevertheless, BLQ will assist and engage airlines to revise the costs provided.

5.4.2 Airspace user cost assumptions

The assumptions are like the Airport operators' ones:

- Modifications to integrate the platform information, so time schedules for ground-based multimodal operators (such as train operators and bus services IT systems) is visible.
- Integration with airline systems, for them to manage the agreements.

We assume that there will be an average of 4 DSA/SC per year.

No changes on Baggage management are included in this document.

5.4.3 Number of investment instances (units)

Table 20: number of investment instances – AUs

Scheduled airlines (SA-M) mainline		Scheduled airlines (SA-R) regional		General aviation (GA)		Business aviation (BA)		Rotorcraft	
Ground locations (e.g. FOCs)	Airborne (air vehicles)	Ground locations (e.g. FOCs)	Airborne (air vehicles)	Airborne IFR vehicles	Airborne VFR vehicles	Ground locations	Airborne (air vehicles)	Ground locations	Airborne (air vehicles)
2	0	2	0			1[13]	0		

5.4.4 Cost per unit

[13] Sea-planes Flight Operations Centres (FOCs) considered as Business Aviation.

Table 21: cost per unit – AUs

ost category	Scheduled Airlines (SA-M) Mainline		Scheduled Airlines (SA-R) Regional		General Aviation (GA)		Business Aviation (BA)		Rotorcraft	
	Ground locations (e.g. FOCs)	Airborne (air vehicles)	Ground locations (e.g. FOCs)	Airborne (air vehicles)	IFR	VFR	Ground	Airborne	Ground	Airborne
Pre-Implementation Costs										
Implementation costs	0.15 M€		0.15 M€				0.15 M€			
Operating costs	0.12 M€		0.12 M€				0.12 M€			

5.4.5 Airspace users' total costs

For implementation, we need to calculate the cost of integrate the system to the current work systems used (150k€) and train the people to be able to use it (50k€).

For operation costs, we need to consider, the cost of generating and signing DSA and SC 10€ (we calculate 4 per year), the cost od monitoring such agreements 12k€ and all the infrastructure needed for data hosting: 50k€.

Table 22: Annual operating

Cost Category	Total annual **costs**		Investment instances		**Cost**
Implementation costs	*0.15*M€	x	*5*	=	0.75 M€
Operating costs	*0.12* M€	x	*5*	=	0.6 M€
Annual operating cost change					**1.35 M€**

5.5 Military costs (N/A)

Not applicable, as they are not impacted by the solution.

5.6 U-space stakeholder costs

Not applicable

5.7 Other relevant stakeholders (N/A)

No other stakeholders considered in the CBA, that affect air navigation.

5.8 Overall costs

This section gathers all the costs for each of the stakeholders impacted by the deployment of the solution.

5.8.1 Investment costs (pre-implementation and implementation costs)

Table 23: overall investment costs per category and stakeholder group

Stakeholder	Unit investment cost	Investment instances	Total investment cost (M€)
Airport operators	0.2m €	5	0.8 M€
Airspace users	0.2m€	5	0.8 M€
		Total	1.5M€

5.8.2 Annual operating costs

Table 24: overall operating costs per category and stakeholder group

Stakeholder	Unit operating cost	Investment instances	Total annual operating cost change (M€/y)	Total cumulative operating cost change (M€)
Airport operators	70 k€	5	0.4 m€	8.2 m€
Airspace users	0.1 m€	5	0.6 m€	14.1 m€
		Total	1.0 m€	22.3 m€

6 CBA model

6.1 Data sources

At this stage of the project, we have developed a preliminary cost estimate, which will be further refined in collaboration with key stakeholders in the next phase to ensure accuracy and alignment with real-world requirements

6.1.1 Cost inputs

In Table 14**¡Error! No se encuentra el origen de la referencia.** we have explained the origin of the costs used.

6.1.2 Benefit inputs

As no monetary inputs available in CBA Excel file assumptions document, we have not considered them in this document.

6.1.3 Other input parameters

No other input parameters used for the benefit.

7 CBA results

The following sections provide the results of the SIGN-AIR solution TRL4 ECAC level CBA that has assessed the deployment of a cloud platform at airports and scheduled airlines as described in the CBA solution scenario.

7.1 Discounted values

This section provides the discounted CBA results.

The values shown in **¡Error! No se encuentra el origen de la referencia. ¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.**below are discounted to account for the time value of money**14**.

The net present value (NPV) for SIGN-AIR is 10.1 m€. This is calculated with an 8% discount rate over the period 2026 to 2050.

The payback year is 2050 as shown in Figure 11: SIGN-AIR discounted cash flow analysis where the discounted cumulative net benefits line crosses back over the x-axis.

Table 25: SIGN-AIR discounted CBA results (per stakeholder and overall)

Discounted (8%, M€)	Net present value (NPV)	Investment cost	Operating cost	Benefits
Airport operators	3.9 m€	0.6 m€	3.3 m€	
Scheduled aviation	6.2 m€	0.6 m€	5.6 m€	
Overall	10.1 m€	1.3 m€	8.9 m€	

[14] The time value of money reflects the idea that 1€ received today has more value than 1€ received in 2040 because it could be invested and earn interest over that period.

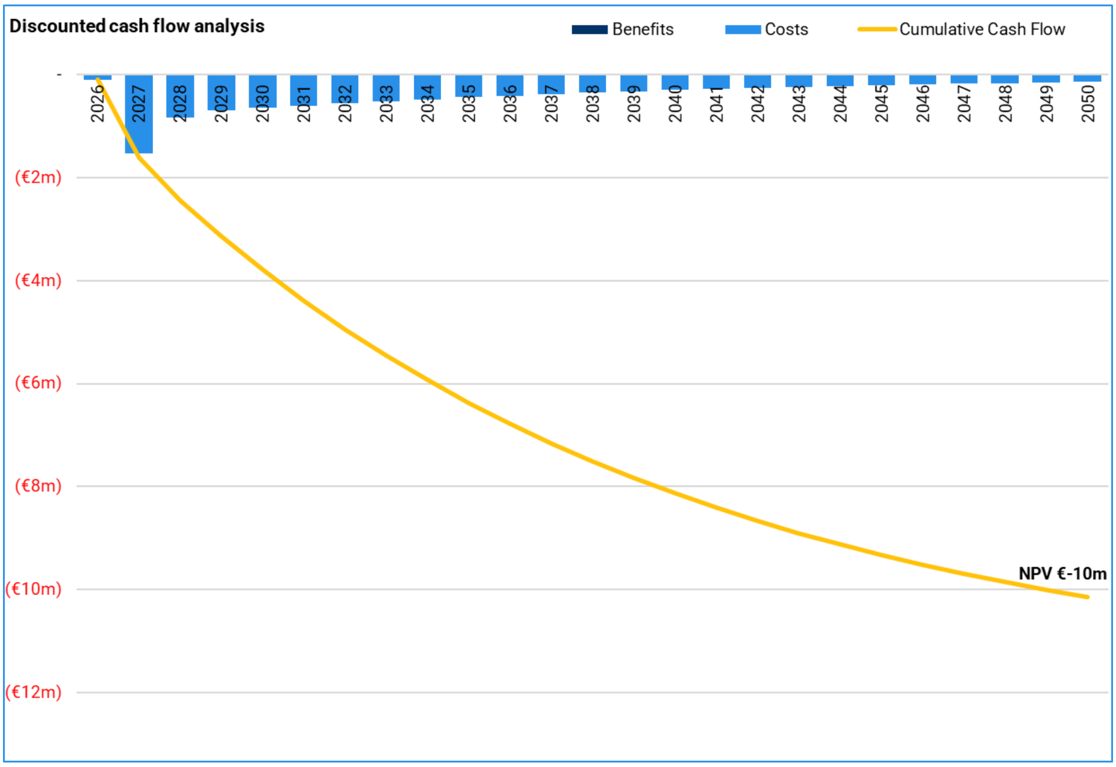


Figure 11: SIGN-AIR discounted cash flow analysis

7.2 Undiscounted values

The values shown in this section do not consider the time value of money, so one unit of currency spent or received in 2050 is considered to have the same value as one unit of currency spent or received today.

¡Error! No se encuentra el origen de la referencia. ¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.contains the undiscounted values, which show that without discounting, i.e. doing the CBA calculation with a discount rate of 0%, the overall net benefits are 23.8 m€.

Table 26: SIGN-AIR undiscounted CBA results (per stakeholder and overall)

Undiscounted (M€)	Net benefits	Investment cost	Operating cost	Benefits
Airport Operators	9.0 m€	0.8 m€	8.2 m€	
Scheduled Aviation	14.9 m€	0.8 m€	14.1 m€	
Overall	23.8 m€	1.5 m€	22.3 m€	

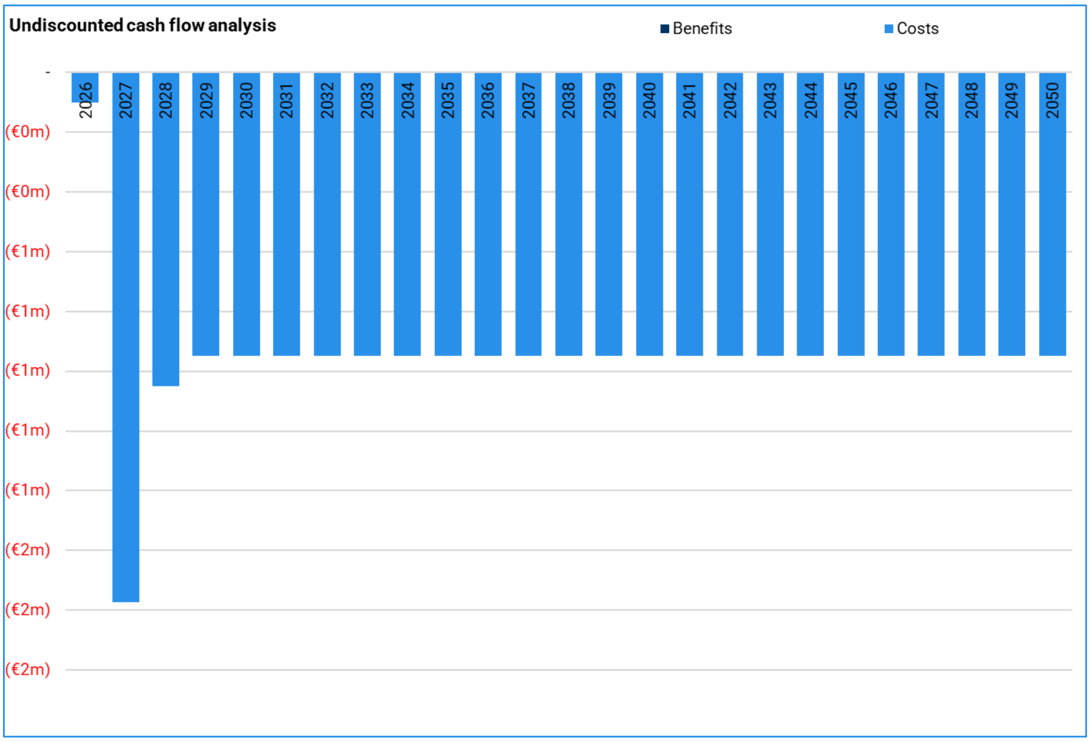


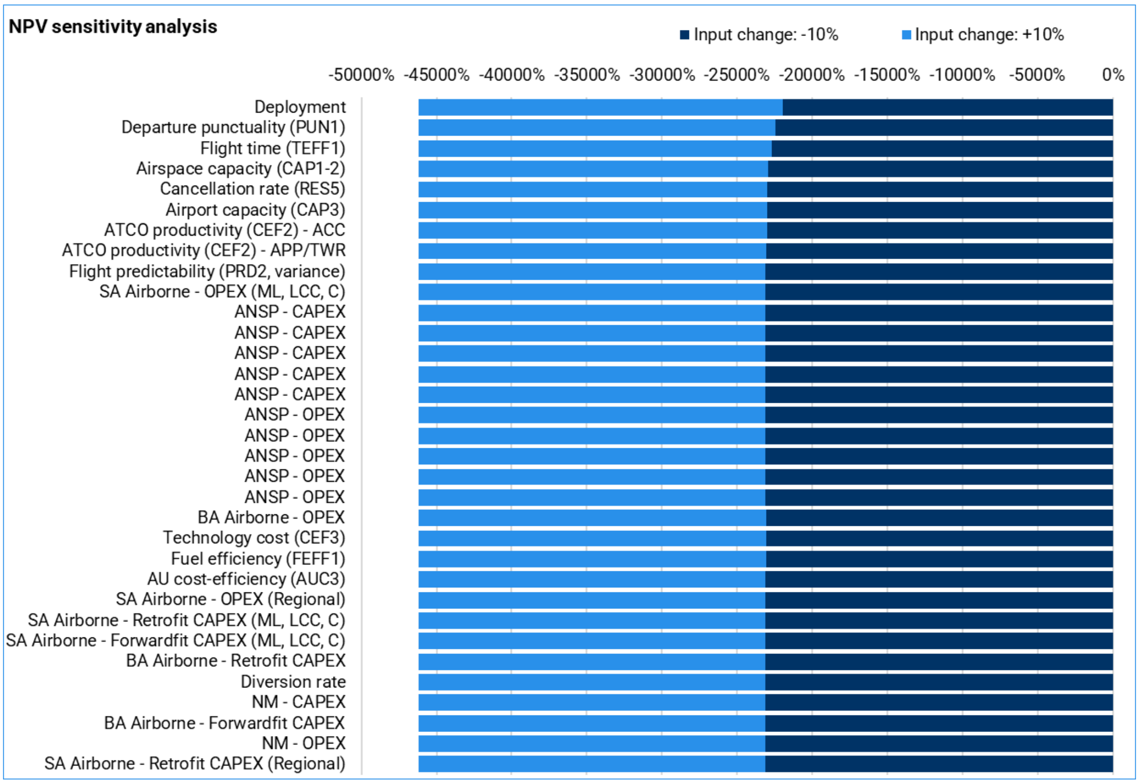
Figure 12: SIGN-AIR undiscounted cash flow analysis

8 Sensitivity and risk analysis

8.1 Sensitivity analysis

The sensitivity analysis addresses the individual effect of each input parameter to the CBA model on the net present value (NPV) of the solution. It varies the parameters ‘ceteris paribus’, i.e. it modifies only one parameter while keeping the rest constant at their base value.

In this CBA version, data for risk analysis has not been modified from the one appearing in the model.



summarises the calculation steps.

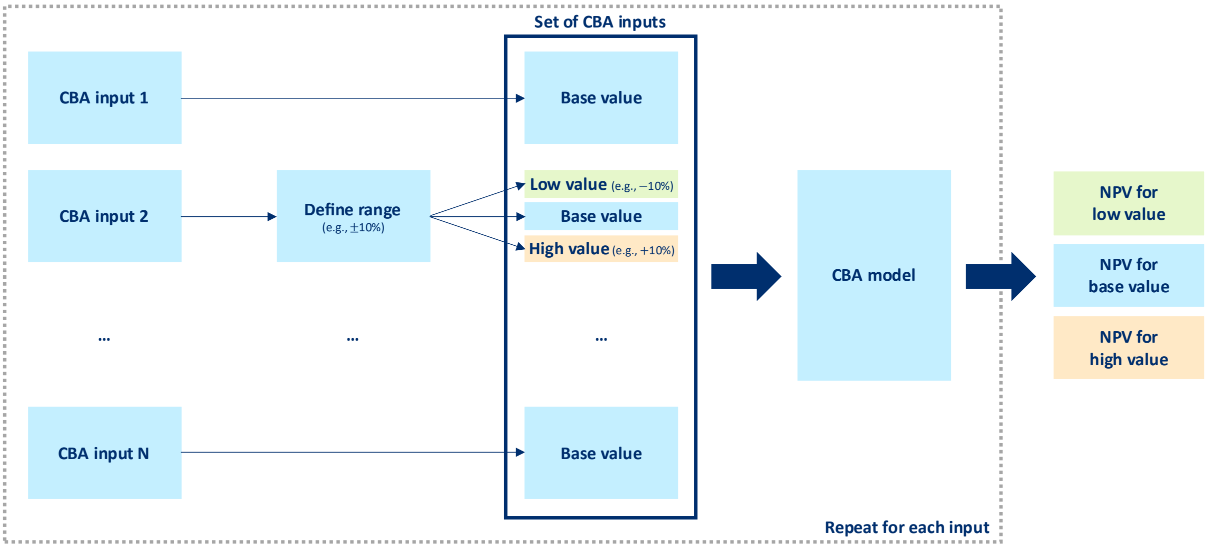


Figure 13: sensitivity analysis methodology

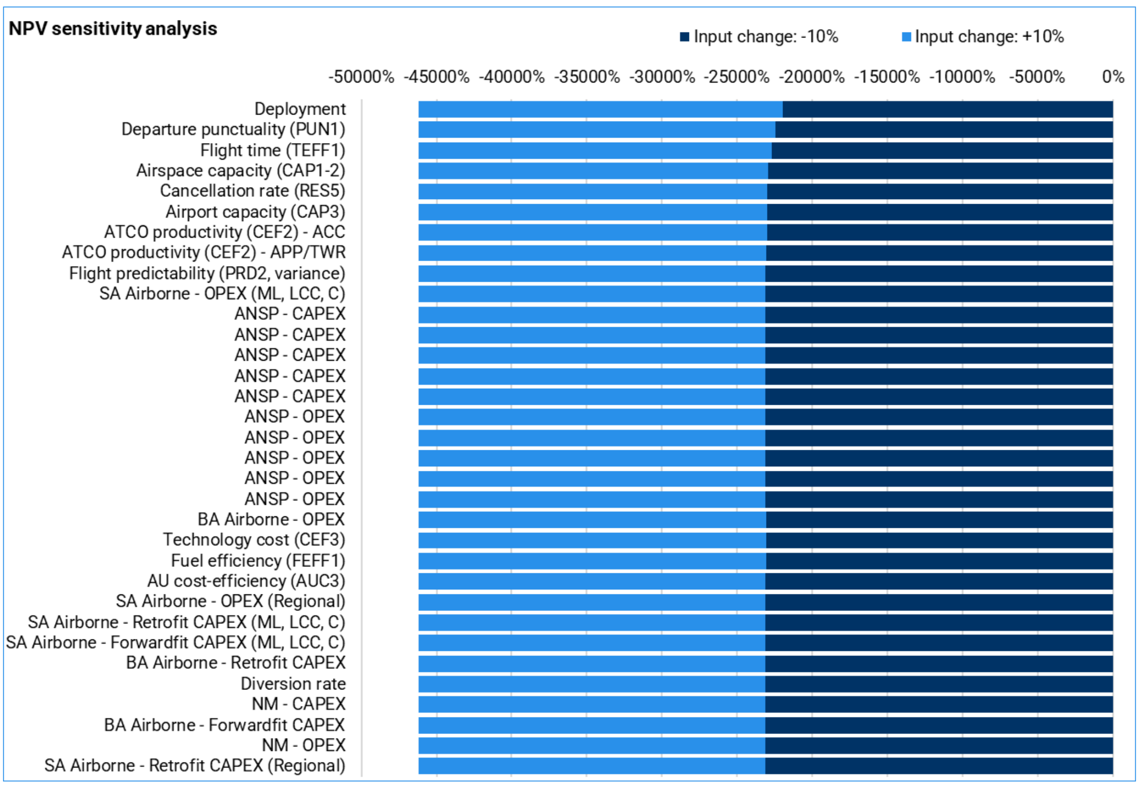


Figure 14: SING AIR sensitivity analysis (tornado diagram)

8.2 Scenario analysis

8.3 Risk analysis

The risk analysis runs a Monte Carlo simulation of the CBA model to estimate the NPV risk profile based on the uncertainties of the solution.

Figure 15 shows the calculation steps of the simulation:

1. The algorithm creates a new set of CBA inputs, where each parameter takes a pseudorandom value between pre-defined limits around the base value.
2. The algorithm runs the CBA model with the new set of inputs and calculates the resulting NPV.
3. The algorithm repeats this process for 1500 iterations.

Finally, the model uses the dataset of 1500 'possible' NPVs to calculate (i) the risk adjusted NPV and (ii) the probability of achieving the base results.

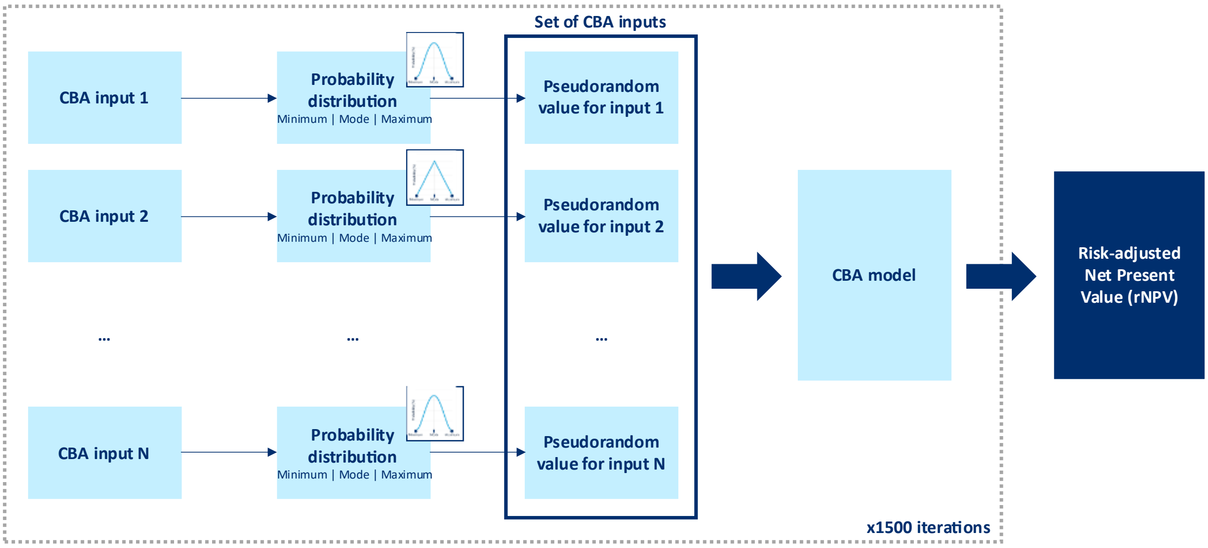


Figure 15: risk analysis methodology

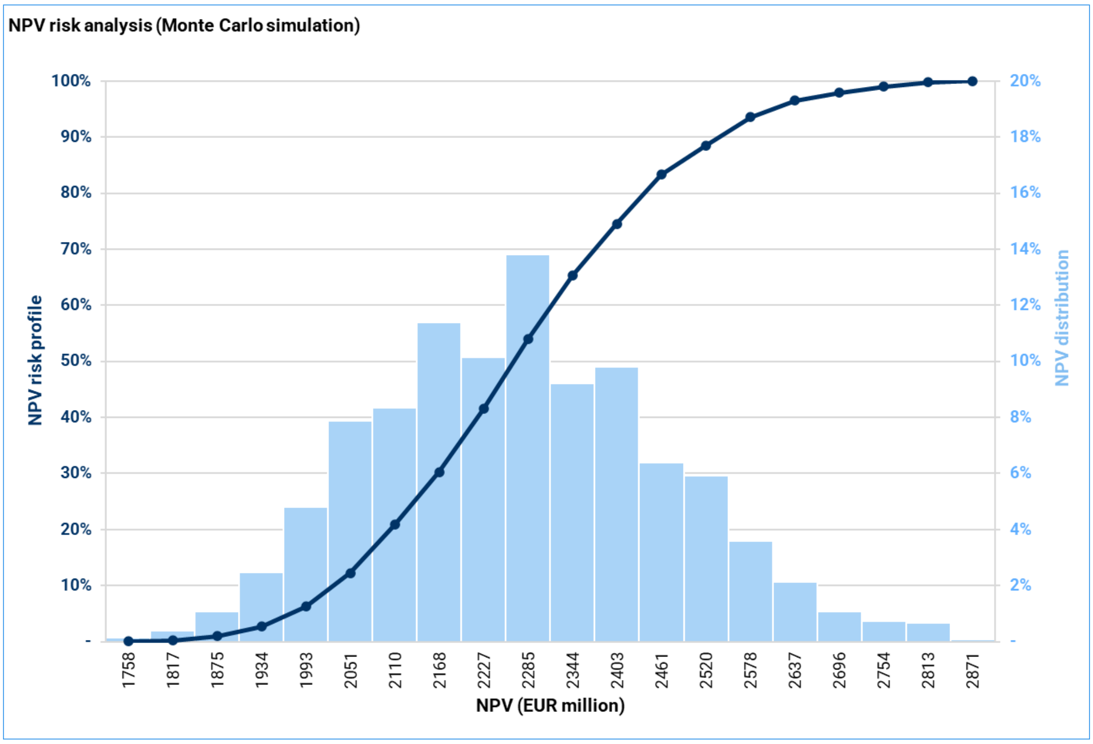


Figure 16: SIGN-AIR risk analysis (Monte Carlo simulation)

9 Recommendations and next steps

The SIGN-AIR platform, being a multimodal data-sharing solution, does not generate quantifiable benefits within the Air Traffic Management (ATM) domain. None of the Key Performance Areas (KPAs) covered by the DES-SESAR-ATM-CBA-Model are directly affected by the solution. For this reason, the standard ATM cost-benefit analysis framework – while highly effective for ATM-centric solutions – is not the most appropriate tool for capturing the platform's impacts. This is reflected in several of the charts produced by the model, where the outputs are either empty or do not fully represent the solution's value.

Considering the above, it is respectfully recommended that the DES-SESAR-ATM-CBA-Model not be applied as the primary assessment method for solutions such as SIGN-AIR, whose primary contributions lie outside direct air-traffic operations. A complementary qualitative assessment, or a broader system-level socio-economic analysis, would better reflect the platform's benefits in the multimodal and passenger-centric domains.

9.1 Applicable documents

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

SESAR solution pack

[1] DES HE CBA template

[2] DES SESAR ATM CBA Model

Content integration

[3] DES HE SESAR solution SIGN-AIR TS/IRS– Part I v.00.07.00

Performance management

[4] DES Performance Framework - Digitalisation Companion Document

Validation

[5] SIGN-AIR technological validation plan– part I

Programme management

[6] 101114845 Grant Agreement, [07/06/2023]

[7] SESAR 3 JU Project Handbook – Programme Execution Framework, [11/04/2022], [edition number 01.00]

9.2 Reference documents

- EUROCONTROL Standard Inputs for Economic Analyses (https://ansperformance.eu/economics/cba/standard-inputs/latest/)

10 Maturity criteria (self-assessment)

Summary of the applicable criteria, as defined in the programme library, for TRL4:

ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments	Criticality	Link between Maturity Criteria and SESAR Architecture
PER.TRL4.3	Does the TRL4 CBA contain a quantitative assessment of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the economic feasibility of the Technological solution? Are the following elements clearly described in the TRL4 CBA report: (1) A quantitative CBA model shall be produced using the PEARL DES CBA model, unless agreed otherwise with the S3JU, (2) a clear description of the CBA scenarios (deployment assumptions) including the solution scope, interdependencies and impacted stakeholders, (3) quantitative assessment of costs (ideally per enabler), (4) quantitative assessment of the benefits, (5) net present value (NPV), (6) Recomme	Achieved	Yes, a quantitative CBA model shall be produced using the PEARL DES CBA model with the guidance of the CBA champions. It includes a clear description of the CBA scenarios (deployment assumptions) including the solution scope, interdependencies and impacted stakeholders. Additionally, includes a quantitative assessment of costs and quantitative assessment of the benefits. The net present value (NPV) is provided according to the CBA model.	CRITICAL	-

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11 Annex 1 Existing collaborations

The following table presents some examples of existing collaboration between some TSPs of air and rail transportation.

Table 27: Existing collaborations between air and rail transportation

Name	Contract Parties	Characteristics
AIRail (Austria)	Austrian Federal Railway (ÖBB) Austrian Airlines	• The service is provided from Linz and Salzburg main train stations to Vienna airport; • From Linz and Salzburg there are hourly AIRail connections; • Single ticket for the train ride and the flight; • Members of the Miles and More loyalty program earn awards and status miles on all AIRail trips.
City Airport Train (CAT)	CAT Airlines-Austrian, Lufthansa Eurowings, Swiss Brussels Airl.	• A rapid non-stop connection between the city center and Vienna airport (travel time is 16 min); • Very important airport transfer alternative due to high punctuality rate (close to 98%); • 'City Check-In' service—a check-in hall within the CAT City Terminal with all the amenities of an international airport; the passenger receives a boarding pass and hands over flight luggage, free of charge;

		• Austrian ticket counter in the city terminal for rebooking or buying tickets, as well as free parking at the Wien Mitte car park.
Fly Rail Baggage Check-in	Swiss Railway Zurich airport, Berne airport, Geneva airport	• Check-in flight luggage at 56 train stations in Switzerland and the boarding pass reception; the checked luggage receives its own IATA-Code; • At the destination, the luggage can be delivered to the specified address, or the passenger can collect it from the local station; • The service is charged with fixed price for each bag.
Train + Air	French National Railway (SNCF), Air France	• Available for international departures and arrivals at Charles de Gaulle and Orly airports; • Single ticket for the arrival or departure with the high-speed train (TGV) and the flight; • In case of late arrivals, it is guaranteed that the passenger will be rebooked for the next flight or train; • Members of the Flying Blue loyalty program earn miles on the train route;

		Taxi transfer between Paris-Orly airport and Massy TGV train station is provided by Air France free of charge.