ATM & Airports Consultancy

Role of Markets in the AAS Deployment (RoMiAD)

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Document Title	RoMiAD - Role of markets in AAS deployment
Abstract	Project RoMiAD has developed an understanding of the high-level benefits of deploying the distributed architecture proposed by SESARs Airspace Architecture Study (AAS) and potential mechanisms to incentivise the organisational reengineering necessary to achieve a Digital European Sky whilst ensuring national sovereignty over airspace.
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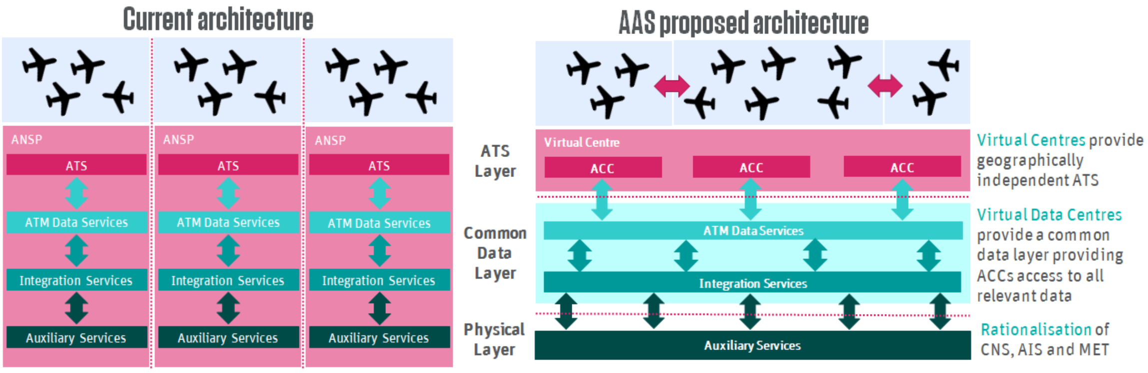
Executive Summary

Objective

The European ATM system is in need of modernisation – in particular to increase performance, resilience and sustainability. The current system is a patchwork of national ANSPs operating vertically integrated systems. A single organisation therefore typically provides all the necessary services – from the auxiliary services to air traffic services.



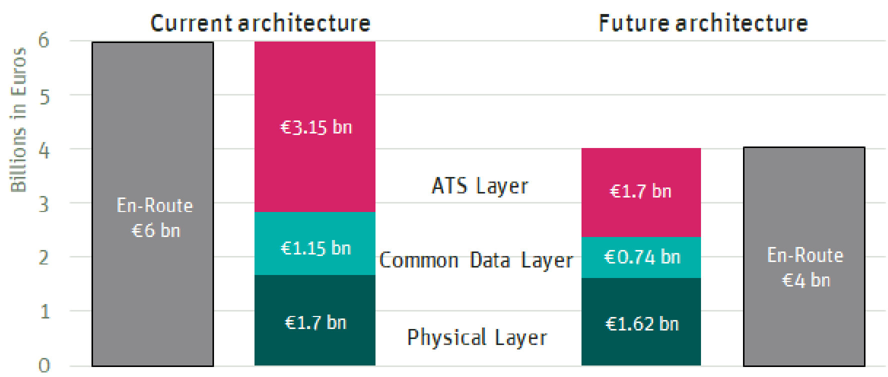
The future system proposed by the Airspace Architecture Study (AAS) breaks down the current vertically integrated systems to enable a more efficient set of services to be integrated horizontally. The architecture is based on three layers: air traffic services (ATS) layer, common data layer and physical layer. The common data layer enables real time ATM data for all flights to be accessed by all the stakeholders – network manager, ANSPs, airports and airlines – and obtained from a processing of raw data from the auxiliary services.

Market Analysis

This new architecture enables new business models to operate with several distinct markets as shown below. Project RoMiAD focussed in the evolution of the ATS, Common Data and Physical Layer for en-route ATM.

ATS Layer	Common Data Layer	Physical Layer
ATS Services Excludes ATM Data Services	ATM Data Services (including Integration Services) Currently Part of ATS	Auxiliary Services (including CNS, AIS, MET)
Ground-Ground Comms Transversal Services (SWIM Services, Cyber Security)		
Network Functions		

We estimated the current size of the market in these three layers and the potential cost reductions achievable through virtualisation. The benefits are significant particularly in the ATS layer.



ATS Layer: The ATS layer is the largest market and has the greatest scope for improvement with the potential to reduce the current costs of €31.5 bn by up to 60%. In order to maintain national infrastructures it is likely that collaboration will drive best value in this layer.

Existing costs	Rational transformation of costs	Revised costs
Market size: € 3,150 m OPEX: 90% CAPEX: 10%	Reduction in costs as a result of: • Increased ATCO productivity enabled by Operational Excellence and increased automation. • The reduced capacity buffer that the dynamic capacity sharing enables.	Market size: € 1,660 m Reduction: -50%

Common Data Layer: The market size is in the order of €1 bn per annum, potentially reduced by 35% if the infrastructure is sufficiently harmonised. The flexibility provided to the ATS layer has three times the benefits available from rationalisation within the Common Data Layer itself. Competition in this layer is likely to drive best value.

Existing Costs	Rational transformation of costs	Revised Costs
Market Size: € 1,150 m OPEX: 75% CAPEX: 25%	• Initial saving from rationalisation of infrastructure and systems. • Further saving from "commercialisation" of ATM data centres.	Market size: € 740 m Reduction: -35%

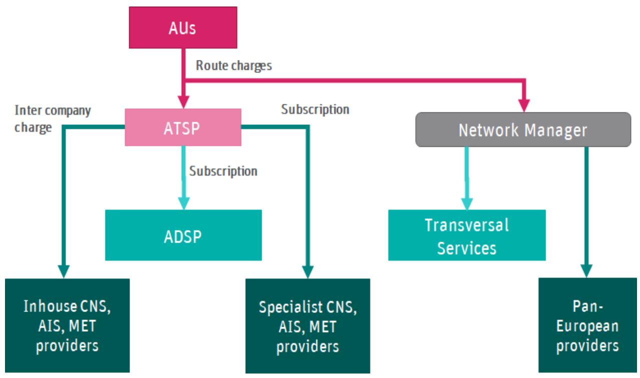
Physical Layer: The physical layer is different to the other two markets due to the range of services involved in addition to the CNS considered in this report, there is also AIS and MET. We see limited benefits within in the traditional CNS markets but much high potential when considering the transition of iCNS and deployment of new technologies.

Existing Costs	Rationale transformation of costs	Revised Costs
Market Size: € 1,680 m OPEX: 65% CAPEX: 35%	• The limited benefits in the physical layer come from CNS rationalisation for legacy issues and of doing so at a pan-EU level. • Increased benefits when considering deployment of new technology.	Market size: € 1,620 m Reduction: -3%

Incentivising the transition

Realization of these benefits as much about new business models as technology adoption. From an ATSP perspective, the level of CAPEX is significantly reduced but overall expenditure is remains high due to subscriptions.

To realize the benefits ANSPs need to adopt collaborative models and support the Network Manger where Pan-European collaboration is most advantageous.



Contents

1 Introduction

1.1 Project RoMiAD

Project RoMiAD – Role of Markets in ATM Deployment – is a catalyst funding project conducted under contract with the University of Westminster as the coordinator of multiple beneficiaries who have collectively received funding from the SESAR Joint Undertaking under grant agreement No.783287 under European Union's Horizon 2020 research and innovation programme, for Engage KTN project. Project RoMiAD was funded under the second call of engage catalyst funding under the Engage KTN and specifically, on the thematic challenge 4 which involves novel and more effective allocation markets in ATM.

Project RoMiAD's aim is to establish a framework for identifying the benefits deploying the distributed architecture proposed by SESAR's Airspace Architecture Study (AAS) [1] and potential mechanisms to incentivise the organisational reengineering necessary to achieve a Digital European Sky whilst ensuring national sovereignty over airspace. Our analysis focusses on the following questions:

- What does adoption a distributed architecture mean in organisational terms?
- What are the tangible benefits?
- How do we incentivise the transition to maximise benefits?
- How can future R&D best further investigate the issues?

The Airspace Architecture Study proposed transition to a distributed architecture based on the layers (described in Section 2) including the notion of a new form of service provider– the ATM Data Services Provider (ADSP) - which would enable certain services currently provided within an Area Control Centre (ACC) to be provided remotely such that ATS may be provided from multiple locations increasing flexibility, resilience and reducing costs.

Project RoMiAD (Role of Markets in AAS Deployment) contends that different approaches could be deployed at each layer to optimise cost efficiency. Previous studies have considered the existing vertically integrated ANSP business model(for example COCTA [2] and COMPAIR [3]) whilst the European Commission's ADSP Study [4] considered only the Common Data Layer.

This study is different. In Project RoMiAD, we have considered the architecture proposed by the AAS [1] to analyse how cost efficiency and performance improvements can be achieved across all layers. The objective is not to promote a single solution, but rather to provide a policy level analysis to help guide future work to support the necessary transition. It is the all-rounder setting up the work of the specialists.

1.2 State of the art

Project RoMiAD was designed to enable a better understanding of ATM cost-efficiency in the transition to a distributed architecture by exploring areas which have not been previously researched. It builds on existing concepts and analysis which ensure it is well aligned to the industry's perspective to improve the potential deployment of new concepts and technologies.

The distributed architecture concept used and described in RoMiAD was defined in the AAS [1] which was to some extent based on the skyguide's Virtual Centre Concept [5]. As the industry reached initial consensus, the concept was introduced in the ATM Masterplan [6].

1.2.1 SESAR Industrial Research studies

There are a number of SESAR projects maturing the architecture and operational principles of ATM virtualisation and, in particular, Virtual Centres including:

- SESAR 1 – WP B4.4 proposed a change of perspective in addressing the ATM architecture from a service-oriented approach (SOA) with a focus on the Controller Working Position (CWP).
- SESAR 2020 W1 – PJ15 [8] addressed the notion of Common Service as a means to harmonise the provision of air navigation services (ANS) wherever possible to improve cost effectiveness.
- SESAR 2020 W1 – PJ16 [9] aimed to deliver innovative and increased automation solutions. A workstation, service interface definition & virtual centre concept for separating the CWP from the datacentre where the data is produced to increase interoperability; and a human machine interface (HMI) to increase controller productivity, reduce workload, stress level, and enable the use of SESAR advanced tools, safely facilitating performance-based operations.
- SESAR 2020 W1 – PJ10.06 [10] explored generic (non-geographical) Controller Validations refer to the development of advanced tools and concepts to allow Air Traffic Control Officers (ATCOs) to operate in any airspace classified as a particular type.
- SESAR 2020 W2 – PJ10-W2-73 [11] covers the concept of collaborative ATC for current boundaries and without reference to geographical sectors to enable flight-centric ATC and research potential redistribution of responsibility.
- SESAR 2020 W2 – PJ10-W2-93 [12] has the objective to explore the different possibilities of delegation of airspace amongst air traffic service units (ATSUs) based on traffic/organisation or contingency needs.
- SESAR 2020 W2 – PJ09-W2-44 [13] explores an improved use of dynamic airspace configurations for both civil and military users to enable a flexibility of airspace configuration and management within and across Air Navigation Service Providers (ANSPs) areas of responsibilities.
- SESAR 2020 W3 – PJ32-W3 VC [14] addresses the technical infrastructure (Virtual Centres) to validate delegation of airspace amongst ATSUs, including Air Traffic Flow and Capacity Management (ATFCM) aspects of such airspace delegation amongst ATSUs.
- SESAR 2020 W3 – PJ33-W3 FALCO [15] aims to optimise ATC capacity by investigating and validating technical and procedural means to re-organise the endorsement of air traffic controllers working in lower and upper area control service (excluding approach control service) and air-ground communications.

The current status of these SESAR projects, we recognise that a number of technical issues need to be resolved (see Section 2). Project ROMIAD helps to prioritise the types of solutions that have short term benefit whilst enabling the longer term transition.

1.2.2 Economic studies

A number of studies have also considered the economic and organisational modernisation of European ATM including:

- The impact of fragmentation in European ATM/CNS [16] - The main objective of this Performance Review Commission study was to establish the order of magnitude of the impact of fragmentation, and in which areas the impact was most important. The focus of this study is mainly on the physical layer.
- COCTA [2] – To tackle the demand/capacity problem in European ATM, this SESAR study developed innovative and coordinated economic measures aiming to pre-emptively reconcile air traffic demand and airspace capacity, by acting on both sides of the inequality and offering a more flexible and effective provision of services. To make this possible, amongst other ideas, COCTA envisages a new role for the network manager (NM), supported by re-designed regulatory setting.
- COMPAIR [3] – SESAR project that studied different ways to increase overall efficiency of ATM with a focus on competition as a trigger for change in en-route services. It evaluates four different ways to introduce competition: yardstick competition and Governance, unbundling, tendering of licenses and flight centric/sector-less operations.

These studies focussed on the current ANSP structures. Only one study, Legal and economic aspects of ATM data service provision [4], has considered the proposed architecture and that was limited to the Common Data Layer.

We have also explored the success and failure of other industries that have introduced different economic approaches to maximise their cost-efficiency. For example, the UK Water industry and their regulation with price-controlled periods [17] or the UK & Italy Utilities industry using a total expenditure (TOTEX) approach [70].

In conclusion, from the economic side, previous studies either look at the vertical integrated concepts or more recently focus on the ADSP. This study looks at the applicability given the new infrastructure in a comprehensive approach. Furthermore, given the status of the state of art, one of the goals is to highlight areas for future research.

1.3 Approach

Project RoMiAD (Role of Markets in AAS Deployment) is looking into the potential economic benefits enabled by implementing the recommendations of the Airspace Architecture Study [1] to deliver the digitalisation of the European Air Traffic Management (ATM) system. To investigate the deployment of the AAS the study has followed the approach described in Figure 1.

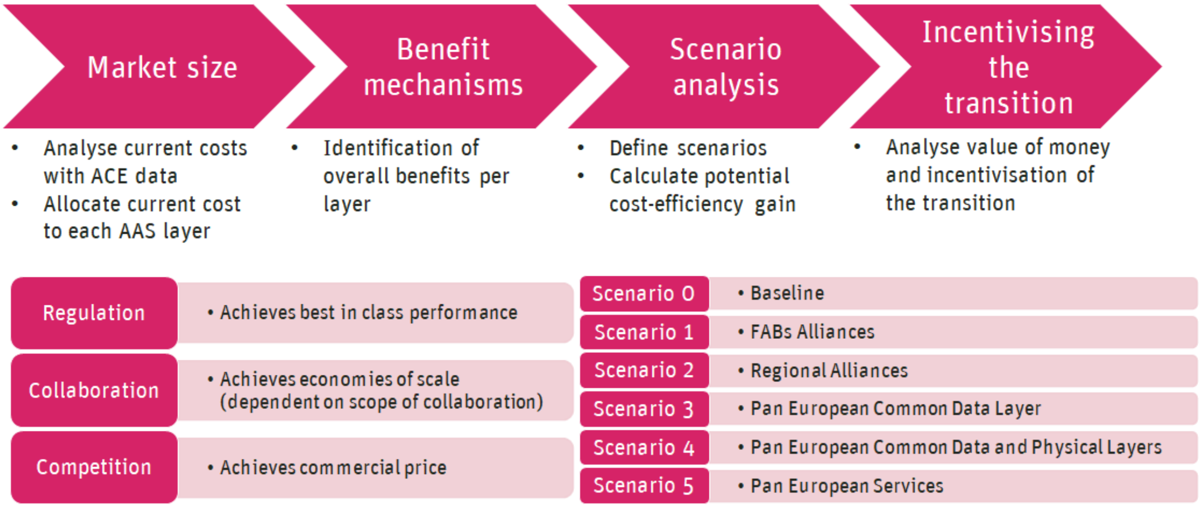


FIGURE 1: ROMIAD APPROACH

The approach is summarised in Table 1.Given the exploratory nature of the project we have been careful to limit scope to the projects budget. In particular:

a) We focus on En-route ATM, we do not consider airport Air Traffic Services (ATS) or direct airline benefits from access to a common data layer. Nor do we consider ATFM and ASM.
b) We assume that the ATM community is able to agree on a single and harmonised concept of operations and underlying infrastructure.
c) We exclude analysis of Aeronautical Information Service (AIS) and Meteorological services (MET) .
d) Throughout the report, we use data from 2018. All monetary values are expressed in 2018 Euros. We chose 2018 because ACE, Performance Review Report (PRR) [35] and PRB data and reports were available from the start of the project.
e) We focus the study on the 30 European States covered by the SES Performance Scheme in RP2 [29]: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Part	Objective	Approach
Part A Market Size	How much does it currently cost to provide the services in each layer?	• Definition of virtualisation, the layers and their interfaces taking into consideration previous research and definitions. • Using ATM Cost-Effectiveness (ACE) [27][30]and Performance Review Body (PRB) [28] data to identify current costs bringing important insights into how virtualisation changes the financial requirements of Air Traffic Services Providers (ATSPs). • Allocation of the current costs into the different AAS layers, following the definition previously mentioned, to determine the market sizes including the Capital expenditure (CAPEX)/Operational Expenditure (OPEX) distribution.
Part B Benefit Mechanisms	How does horizontal integration lead to benefits in each layer? How much would it reduce the costs in each layer?	• Description of the problem, solutions, and calculations of the benefits for each layer and allocation to understand where they are delivered in a high-level transition to the deployment of the AAS, which is also described. • Development of a benefit model in Excel that allows to calculate the cost savings introduced by a given layer in a particular geographical scope.
Part C Scenarios Analysis	How do the potential benefits vary according to deployment approach?	• Description of five scenarios that combine different layers applied to different geographical scopes and how that might enable the application of different market mechanisms. • The previously explained benefit model allows to identify the cost savings of implementing the scenarios and its impact on the market size and CAPEX/OPEX distribution.
Part D Incentivisation	How could the organisations be best incentivised to achieve the identified benefits?	• Consideration of collaboration and contestability within each layer in terms of market size, benefit mechanisms and cost of market entry. • Consideration of national ANSP models for implementing services across all three layers. • Definition of future research topics required.

TABLE 1: APPROACH IN SECTIONS

1.4 Definitions

As will be discussed in Part A, virtualisation is a specific form of digitalisation that encourages horizontal collaborations within different layers. Our current language for discussing ATM is however based on existing vertically integrated organisations and systems. It has become clear during the course of this study that new definitions (or additional precision of existing definitions) are necessary to discuss virtualisation.

Table 2 therefore provides a summary of the terms used in this report.

ANSP	The certified provider of one of more Air Navigation Services (ANS). This is the regulatory definition of ANSP.
National ANSP	The organisation charged with the provision of ANS within a member state. This is the common usage meaning of ANSP.
Digitisation	The process of turning analogue signals into digital representations. Digitisation in ATM has been on-going for many decades but is not yet complete. Many voice-only ATCO instructions still exist, and key agreements such as the letters of agreement (LoA) between ACCs are not digitised.
Digitalisation	The transformative process of organisations taking advantage of digital technology. ATM is only scratching the surface of digitalisation. The AAS proposes one specific form.
Virtualisation	The specific form of digitalisation proposed by the AAS whereby organisational collaborations exist at the ATS, Common Data and Physical Layers mediated by digital infrastructure (and transversal services).
ATS Layer	The layer of the AAS where Air Traffic Services are provided.
ATSP/ATSU	ATS is provided by the ATSP from one or more ATS Units. ATSU can be ACC or terminal control (TC) or airport towers.
Common Data Layer	The layer of the AAS where ATM Data Service are provided. The Common Data Layer allows for greater interoperability and harmonisation by ensuing timely and accurate data is available to all stakeholders.
ATM Data Service	The services provided by ATM Data Service Providers (ADSPs) operating in the common data layer (see Section 2.2).
Integration Services	The integration services for Aeronautical Information Management (AIM), surveillance (SUR) and weather combine the geographically constrained scope of the underlying provision services in a service with a broader geographical coverage.
Virtual Centre	A collaboration of ATSUs in the ATS Layer. A Virtual Centre (VC) consumes services of ADSPs operating in a common data layer. Whilst the nature of the collaboration within the VC depends on organisational and technology choices, in theory a VC operates seamlessly as if it was one physical location.
Virtual Data Centre	A collaboration of one or more ADSPs to ensure data availability for all VCs served.
ATM System	The ATM system is the technical infrastructure within the current ATSU, traditionally comprising CWP, Flight Data Processing system (FDP), Surveillance Data Processing system (SDP), Voice Communication (and) Control System (VCCS) and numerous other systems that support the Air Traffic Controllers. As will be explained in Chapter 2, the split of the ATM system between the ATS Layer and the Common Data Layer is not fully defined yet.

TABLE 2: GENERAL DEFINITIONS

Table 3 summaries the key definition for the three layers.

Layer	Service	Provide	Operational Unit	Collaboration
ATS Layer	ATS	ATSP	ATSU	Virtual Centre
Common Data Layer	ATM Data Services	ADSP	Data Centre	Virtual Data Centre
Physical Layer	CNS, AIS, MET	CNSP, AISP, METP	Infrastructure	Shared infrastructure

TABLE 3: DEFINITION PER LAYER

1.5 Report structure

Part	Section	Rationale
Part A Market Size	2. What is virtualisation?	Description of the modernisation process that the industry will undertake.
	3. How big is the market?	Estimation of the market sizes in the current system.
Part B Benefits Mechanisms	4. Identified benefits	Identification of the overall benefits.
	5. ATS Layer benefits	Description of the benefits in the air traffic services layer.
	6. Common Data Layer benefits	Description of the benefits in the provision ATM data services.
	7. Physical Layer benefits	Description of the benefits in the provision of specific auxiliary services.
Part C Scenario Analysis	8. Deployment scenarios	Introduction to the organisational models and geographical scopes that lead to the identified scenarios and their characteristics.
	9. Discussion of scenarios	Assessing the cost reduction obtained in each deployment scenario.
Part D Incentivisation	10. Market analysis	Analysis of each identified market in terms of potential to create a contestable market.
	11. Future role of ANSPs	Discussion of how different choices by ANSPs can be enabled through the regulatory framework.
	12. Conclusions and future research	Topical guide for future studies required as a result of the findings.
Annexes	A. Scenario descriptions	Detailed description of the deployment scenarios and their results.
	B. Acronyms	List of acronyms used in the document.
	C. References	List of references used in the document.

TABLE 4: REPORT STRUCTURE

Part A

Market Size

2 What is virtualisation?

2.1 Current architecture

Virtualisation is a specific form of digitalisation proposed by the SESAR Joint Undertaking in the Airspace Architecture Study [1] whereby organisational collaborations (or horizontal integration) exist at the ATS, Common Data and Physical Layers mediated by digital infrastructure (and transversal services). In order to explain virtualisation, it is worth first considering the current architecture and its shortcomings.

Currently, the ATM system is a patchwork of national air navigation service providers operating vertically integrated systems (see Figure 2). A single organisation therefore typically provides all the necessary services – from the auxiliary services[1] to air traffic services. Airspace is predominantly organised by national boundaries. Flight data is held locally in the ATM System (or FDP) – with limited sharing of data between neighbouring centres leading to restricted interoperability between ACC.

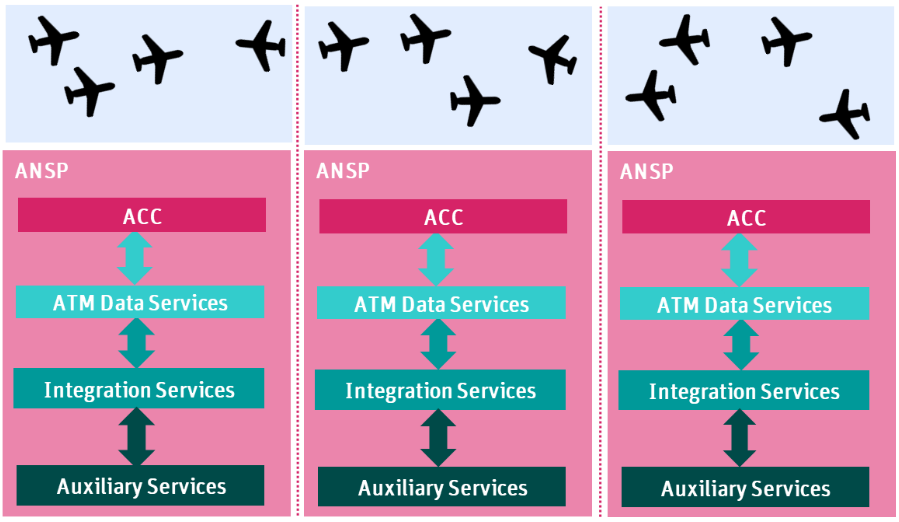


FIGURE 2: CURRENT ARCHITECTURE

The technical limitations of the current architecture, summarised in Table 5, limit overall capacity as well as flexibility, scalability, and resilience. In addition, the current architecture limits opportunities for deployment of new ATM functionalities – which often requires the coordinated update to the full range of ATM Systems operated by the national ANSPs. The national ANSPs have however formed different forms of alliances to support collaborative modernisation, including common procurement alliance such as COOPANS[2,3] and iTEC[4] supporting development of harmonised products and Operational Alliances such as the Borealis Alliance[5] supporting harmonised airspace and operational procedures.

[1] Auxiliary services are defined by the AAS as services with a geographical dependency such as Communications, Navigation, Surveillance, AIS and MET.
[2] https://www.coopans.com/Home
[3] COOPANS members can save up to 30% compared to buying a standalone product (https://onboard.thalesgroup.com/thales-count-nav-portugal-new-customer-joins-coopans-alliance/)
[4] https://itec.aero/
[5] https://borealis.aero/Home.19.aspx

The AAS, as described in the next section, proposes a new architecture that builds on the success of these alliances.

Factors limiting overall capacity	
Non-optimal organisation of airspace	• The current airspace organization is not yet fully optimised to network flows and makes limited use of cross border cooperation.
Limited use of data communications	• The current voice-intensive process to high saturation of radio frequencies can lead to voice communications constraining sector capacity. • More sophisticated interactions between controllers and pilots require datalink communication that can support time and safety critical instructions.
Limited opportunity to create new sectors	• Each sector creation requires a new frequency and there is already limited frequency availability in congested areas. • Some sectors are already very small and cannot be further split unless creating operational issues.
Limited automation support for controllers	• Current technology deployed in most ACCs does not provide an optimal level of automation that would support extra capacity. • Limited automation support means significant human effort is still required to manage traffic. The system as a result also lacks scalability to meet growing demand.
Factors limiting flexibility, scalability, and resilience	
Limited predictability	• High buffers across the planning and execution phases due to limited predictability reduce the actual usage of existing capacity. • Lack of end-to-end trajectory optimization during both planning and execution phases means that the capacity potential cannot be achieved at network level.
Limited information sharing and interoperability	• Current limits on interoperability and data sharing lead sub-optimisation. • Suboptimal view and usage of effective available airspace at network level.
Limited flexibility in the use of ATCO resources across ACCs	• ATCO qualification is limited to a number of sectors or combinations of sectors typically within a specific ACC. This limits their ability to support additional configurations that include sectors from another ACC.
Geographical constraints on air traffic services provision	• The location of all (technical) services that support the provision of air traffic control to an aircraft in today's architecture is tightly coupled to the location of where an aircraft is flying. • This limits the possibility for an ANSP to provide air traffic services beyond its current area of responsibility, • It also limits the possibility to share technical services between multiple ANSPs.

TABLE 5: IDENTIFIES LIMITING FACTOS FOR CAPACITY IN CURRENT ARCHITECTURE (FROM AAS[1])

2.2 Future architecture

The future system (see Figure 3) proposed by the AAS [1] breaks down the current vertically integrated systems to enable a more efficient set of services to be integrated horizontally.

The future system is based on a common data layer that enables real time ATM data for all flights to be accessed by all the stakeholders – network manager, ANSPs, airports and airlines – and obtained from a processing of raw data from the auxiliary services.

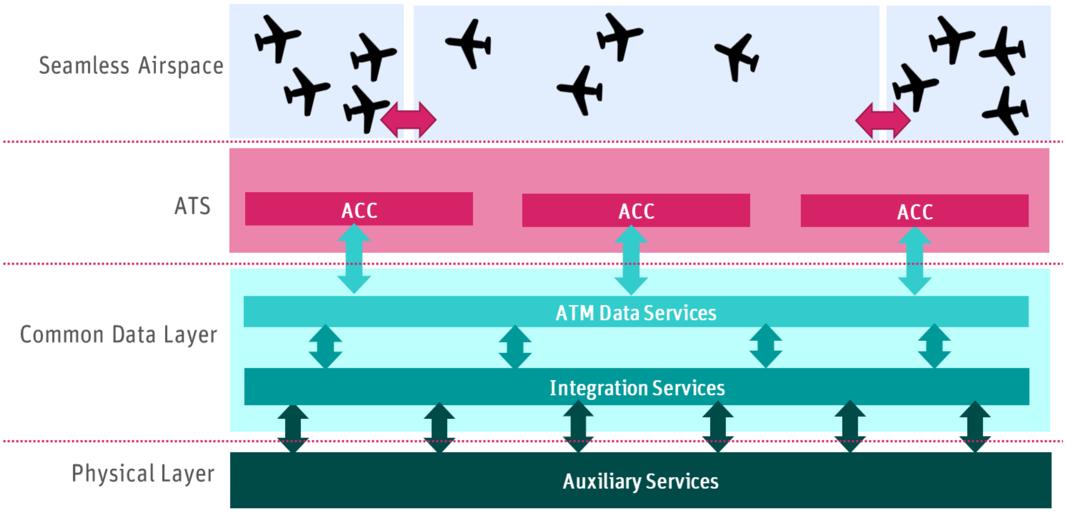


FIGURE 3: PROPOSED AAS ARCHITECTURE

The long-term goal is to realise a single gate-to-gate Trajectory Based Operations (TBO) concept enabling optimised, predictable, cost-efficient, and sustainable flights. It provides increased interoperability and harmonisation of ATS across Europe and optimisation of airspace from a network perspective. This set up takes advantage of economies of scale and allows a flexible capacity demand balancing.

The proposed architecture envisages three levels with the potential to create markets:

- ATS Layer (Airspace and ATS): In the new architecture, Virtual Centres, which are made up of various ATSUs that provide ATS services collaboratively using concepts such as "Capacity on Demand"[6] by subscribing to real time data services in the common data layer.
- Common Data Layer (ATM Data Services): The common data layer, effectively a set of Data Centres operated by ATM Data Service Providers, provides ATSUs (and other operational units) access to all the relevant up-to-date data services required for their operations.
- Physical Layer (Auxiliary Services): The physical layer contains radio, radars and sensors which are geographically dependent to provide the raw data for the auxiliary services (Communications, Navigation, Surveillance, Meteorological Services and Aeronautical Information Service) which can be rationalised.

The full provision of ANS across Europe will also include Network Management Services and Transversal services. Network Management Services include Flow Management and are currently provided by EUROCONTROL as the Network Manager. New network management or pan-European auxiliary services could be required as part of the process of virtualisation.

[6] Capacity on Demand is a specific operational concept defined in the AAS[1] that allows an ATSU to provide ATS services in a sector nominally controlled by a different ATSU in order to minimise ATFM delay.

The architecture builds on recent developments in transversal services to support increased bandwidth and lower latency in ground-ground networks, including:

- **System Wide Information Management (SWIM):** The current assumption is that the distribution of processed data will be enabled by SWIM, mostly supported by the Yellow Profile but depending on the criticality of ATM data services, the Blue Profile may be required for certain services[7].
- **Ground-Ground Communications:** The current assumption is that pan-European network service (PENS) [18] will be upgraded to provide the required ground-ground communications, which requires detailed work on Quality of Service (QoS) and sizing.

2.3 Organisations and services

Before describing the layers in detail, it is worth first considering the services provided and the organisations that may provide them from a regulatory perspective as this will help explain the choices that ANSPs will need to make.

In regulatory terms, an ANSP (Air Navigation Service Provider) is a provider of one or more Air Navigation Services (see Figure 4). In common usage ANSP also refers to the national ATS provider – we use national ANSP for this meaning.

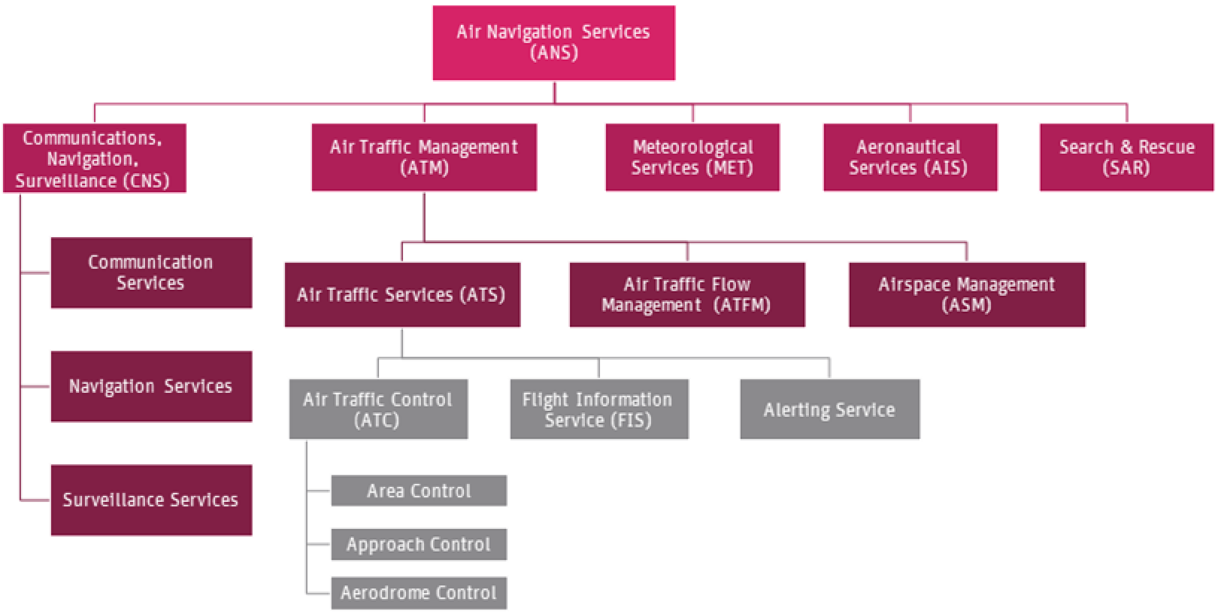


FIGURE 4: ICAO TAXONOMY OF AIR NAVIGATION SERVICES (ADAPTED FROM [19])

ANSPs require a certificate[8] in accordance with Article 7 of service provision Regulation [20] and the common requirements Regulation EU 2017/373 [21] which currently define requirements for: ATS - Air Traffic Services, CNS, AIS and MET.

[7] The Yellow Profile is contains requirements for system interfaces (e.g. protocols) and for IT infrastructure capabilities required to enable a reliable, secure and efficient exchange of information. The Blue Profile is primarily intended for Real-time or near real time uses demanding high availability with severe constraints with respect to the available resources [22].

[8] Alternatively, auxiliary services may be provided as sub-contract to the ATSP under the ATSP's certificate. This is the nominal case for air-ground datalink services provided by ARINC and SITA.

Member States are required to designate an Air Traffic Service Provider (ATSP) for “airspace under their responsibility” in accordance with Article 8 of the service provision Regulation. Designation is not required for CNS and AIS. Designation may be applied to MET providers (Article 9 of the service provision Regulation).

Whilst the physical layer services are currently considered separately from ATS in the regulations, there is no current legal definition of ATM Data Services or ATM Data Service Providers (ADSPs). The current regulations assume that they are part of ATS. The European Commission has proposed a definition in the proposals for a recast of SES2:[9]

> *‘air traffic data services’ means services consisting in the collection, aggregation and integration of operational data from providers of surveillance services, from providers of MET and AIS and network functions and from other relevant entities, or the provision of processed data for air traffic control and air traffic management purposes;*

EASA plans to develop an amendment to Regulation EU 2017/373 in order to introduce the common requirements for the provision of ATM Data Services (e.g. new Part - ADS) [23] . Hence, in this report we defined ADSP as the provider of ATM Data Services operating in the common data layer which is broader that the EC definition because it does not limit the use to ATC and ATM.

There is a current lack of clarity of what an ATM Data Service actually is (see Section 2.2). Whilst greater clarity will be necessary going forward, for this report it is more important to recognise that a single organisation may be certified to provide more than one Air Navigation Service. Hence a national ANSP could decide to operate as an ATSP and as an ADSP for themselves and one or more other ATSPs.

2.1 The ATS Layer and Virtual Centres

The aim of the ATS layer is to enable ATS to be provided at wider geographical scope leading to improved performance and resilience. The proposed method is grouping ATSUs into Virtual Centres (VC). The concept enables efficiency and resilience benefits from collaboration rather than consolidation of ATSUs or ANSPs.

Certain requirements must be fulfilled by a Virtual Centre depending on the depth of collaboration agreed on, for example:

- No collaboration – The benefits are limited to the traditional methods of collaboration (e.g. ATFM) and outsourcing benefits of the Common Data Layer.
- Limited Collaboration – the ATSUs have a fixed set of predefined resource allocation strategies (for example an ability to provide ATS in sector normally covered by different ATSU).
- Full collaboration – the ATSUs appear as a single centre, and the ATSP is able to optimise resource usages across the full area of responsibility.

In order to be perceived operationally as a single centre (full collaboration), the following would be required:

- Handover between ACCs must be identical to handovers within an ACC;
- Controller Working Positions (CWPs) must be configurable to replicate any sector; and
- Either
    - ATCOs being validated on a range of sectors across the full area of responsibility; or
    - Sector independent controller validations.

[9] Article 2(6) of [59]

2.2 The common data layer and Virtual Data Centres

To enable the benefits available in the ATS layer, the common data layer needs to ensure that ATSPs (and other stakeholders) are able to subscribe to data for all concerned airspace. This requires integration of all necessary data using an accessible and secure Information and Technology (IT) infrastructure so that any ANSP, airline or airports can access the data and collaboratively make the best decisions for individual flights and the network.

The common data layer provides two types of services - the ATM data services and the integration of services (of the raw data taken from the auxiliary services) as summarised in Table 6.

Example ATM Data Services	Example Integration Services
• flight correlation • conflict resolution • trajectory prediction • safety nets • conflict detection • arrival management planning	• weather • surveillance • aeronautical information

TABLE 6: COMMON DATA LAYER SERVICES (SOURCE: DERIVED FROM AAS [1])

The services of the Common Data Layer are provided by ATM Data Service Providers (ADSPs). ADSPs will operate systems to provide these services remotely from ATSPs (although an ADSP could be collocated with an ATSP). To the ATSP, the ADSPs will appear as a virtual data centre. An individual ATSP may decide to subscribe to services from one or more ADSPs, but it is also expected that ADSPs will collaborate to ensure data availability.

An ongoing debate within the industry[10] is centred on the precise definition of ATM Data Services, and in particular the split between ATS Services (in the ATS Layer) and ATM Data Services (in the Common Data Layer). The debate is similar to the different functional splits between Controller Screen/CWP and FDP in today's architectures and can be considered as a "Thin" or "Thick" client.

In the Thin Client scenario, the boundary between ATM data services and air traffic services is initially defined at the point where the data/information/application is presented on the screens of the controller working positions [4]. On the other hand, a Thick Client would set the boundary such that some local controller tools that require local adaptation such as the Short-Term Conflict Alert (STCA) are provided locally or even such that the Common Data Layer is restricted to data correlation and all controller tools are implemented locally. There are good reasons to carefully consider the split:

- Ability to meet Technical Requirements (Latency / Security / Resilience)
- Ability to meet local specifications (e.g. STCA)
- Ensuring competition for both services and infrastructure
- Supporting innovation by both ATSP and ADSPs

At this stage further R&D is required to assess the different options. From an architectural perspective it is possible to define all the business services required of both the ATS and Common Data Layers and assign them to the layer according to the ATSP preferences, with the split changing as confidence grows in the ability to outsource different types of service.

[10] For example, within EUROCAE WG-122 on Virtual Centres.

2.3 The physical layer

The physical layer contains radio, radars and sensors which are geographically dependent to provide all the raw data and products from the auxiliary services (Communications, Navigation, Surveillance, MET and AIS). Current arrangements for these services are based on the needs of the national ANSP and managed from the ATSUs.

The common data layer integrates this data into a single point of truth for every flight and enables auxiliary services to be operated independently from the ACCs enabling a more resilient and scalable system. Hence, the existence of a common data layer increases the ease of benefits of such arrangements, and in particular would allow provision of services over a greater geographical region and use of specialised providers to reduce costs.

2.3.1 CNS

By CNS we mean air-ground communications (voice and data), navigation and surveillance. Each plays an important role in ATM, and the national ATSP is responsible for ensuring the CNS performance and coverage is consistent with the ATM operational concepts.

Historically this has often meant the national ANSP owning and operating the assets. There have always been notable exceptions – particularly ARINC and SITA for air-ground communications, ESSP[11] for EGNOS Navigation Services and more recently the advent of space-based ADS-B by Aireon[12]. These pan-European service providers point the way to the future integrated system, where a national ATSP is able to subscribe to a range of specialist services required to meet their CNS requirements (using the Integrated CNS concept which enables a resilient architectural design that combines satellite and ground-based services to meet overall operational requirements).

The AAS allows for specialist ADSPs – so for example an ADSP could be established to integrate the data from all surveillance sensors in a given geographical area to provide a surveillance service to the ATSUs (or ADSPs providing ATM data services).

2.3.2 AIS and MET

The common data layer also enables new business models for the provision of AIS and MET. In terms of the Aeronautical Information Service (AIS), the European AIS Database (EAD)[13] already provides the benefits of integrated AIS provision. This does not imply that greater benefits are not available from modernising the infrastructure, widening the scope or through additional data sources (for example digitising the Letters of Agreement between control centres). It does however imply that Member States and national ANSPs already have choices over the production and distribution of AIS data.

Within ATM, Meteorological services are provided by a range of organisations including by the National ANSPs themselves and national MET providers including some competition for certain services [25]. As the Performance Review Commission's report from 2004 [26] makes clear there is room for optimisation of service provision – not just within aviation but also by considering the most appropriate organisational structures for all users of weather data and how a fair proportion can be allocated to the ATM cost base. The digitalisation and virtualisation concepts discussed in this report are also transforming the provision of met data[14] - Thematic Challenge 3 of Engage KTN[15] is also currently addressing potential efficient provision and use of meteorological information in ATM .

Due to the limited scope of the study we have excluded further consideration of AIS and MET from our analysis.

[11] https://www.essp-sas.eu/
[12] https://aireon.com/
[13] https://www.eurocontrol.int/service/european-ais-database
[14] https://community.wmo.int/activity-areas/aviation/emerging-issues/atm is a useful summary of ongoing R&D.
[15] https://engagektn.com/thematic-challenges/

3 How big is each layer?

3.1 Current costs

In this section we calculate the market size of each layer by considering current costs of ANS providers using PRU[27] and PRB [28] for the 30 States covered by the SES Performance Scheme in RP2 [29].

The full costs of ANS provision were approximately €9.5 bn in 2018 [30] for the 38 ANSPs that provide data to the EUROCONTROL Performance Review Commission (PRC).This included en-route and terminal ATS as well as NSA, EUROCONTROL and External MET costs as depicted in Figure 5.

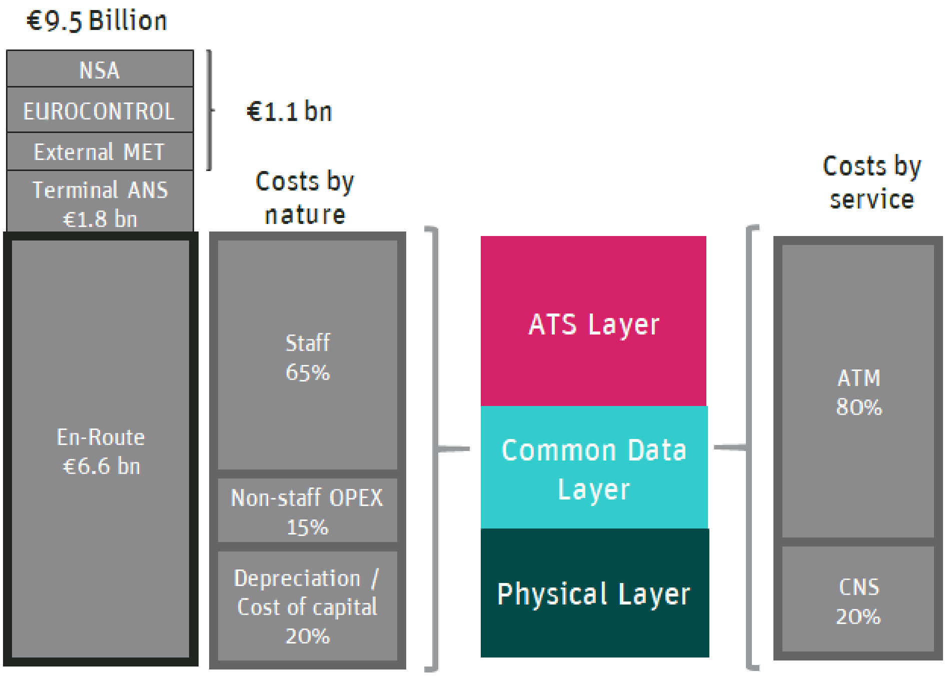


FIGURE 5: TOTAL ANS COSTS IN 2018[16]

For this analysis we are concentrating solely on the costs of en-route ANS as depicted excluding, AIS, MET and Exceptional costs[17]. The rationale for the exclusion of AIS and MET is provided in the previous section. The costs incurred by exceptional items are also excluded from the study given their unusual nature of being non-recurring costs related to the provision of air navigation services such as exceptional contributions to a pension fund or losses on the disposal of obsolete assets. To this extent, the costs incurred by ANSPs in the en-route segment amounted to €6 635 billion in 2018. However, for the 30 States covered by the SES Performance Scheme in RP2 that we consider in this study the costs amounted to nearly € 6 billion.

The following sections analyse the cost categories available to us: costs by nature (from the PRC) and costs by service (PRB). Understanding what costs make each cost category is essential to understand which layer to allocate the costs to in the future architecture.

[16] The split of cost by service categories are an approximation as not all countries has available RP2 data.

3.2 Costs by service

When submitting the Performance Plans, Member States include the costs by the main services[18]. Whilst the physical layer costs are reported separately as CNS costs in the Performance Plans, in accordance with the current architecture ATM costs cover both the ATS Layer and Common Data Layer. The aggregated cost per service is shown in Table 7. Our approach to estimating the split is described in the next section.

Cost type	Description [61]	Current	Allocation
Air Traffic Management (ATM)	Costs incurred from the system that enables aircraft operators to meet their planned times of departure and arrival and adhere to their preferred flight profiles with minimum constraints, without compromising safety.	€ 4.8 bn	Split between ATS Layer and Common Data Layer (see next section)
Communication (COM)	Costs related to aeronautical fixed and mobile services required to enable ground-to-ground, air-to-ground and air-to-air communications for ATC purposes.	€ 480 m	
Navigation (NAV)	Costs derived from the facilities and services that provide aircraft with positioning and timing information. The main navaids that are included in this cost are VHF Omnidirectional Range (VOR), Non-Directional Beacon (NDB) and Distance Measuring Equipment (DME).	€ 300 m	100% is allocated to Physical Layer, leading to an initial estimate of € 1.2 bn
Surveillance (SUR)	Cost derived from the facilities and services used to determine the respective positions of aircraft to allow safe separation. The main sensors in this service are primary and secondary radars.	€ 420 m	
Total Value		€ 6 bn	

TABLE 7: COST BY SERVICE

[18] The split of cost by service categories are an approximation as not all countries has available RP2 data.

3.3 Costs by nature

In the reporting tables that are required for the submission of Performance Plans, ANSP costs are provided for the following categories: staff costs, non-staff operating costs, depreciation cost, cost of capital and exceptional costs. In 2018, operating costs (including staff costs, non-staff operating costs and exceptional cost items) accounted for some 82% of total ATM/CNS provision costs, and capital-related costs (depreciation and cost of capital) represented some 18%.

The OPEX (operating expenditure) related costs is made of the working force (staff costs ~65%) and other operating costs such as systems or rents (~15%) whilst the CAPEX (capital expenditure) of a market (~20%) is composed by the capital-related costs (depreciation of assets owned and the costs of capital). We do not consider exceptional costs in our analysis.

As illustrated in Figure 6. the variation in cost types between ANSPs is significant, with staff cost ranging from 45% to 85%.

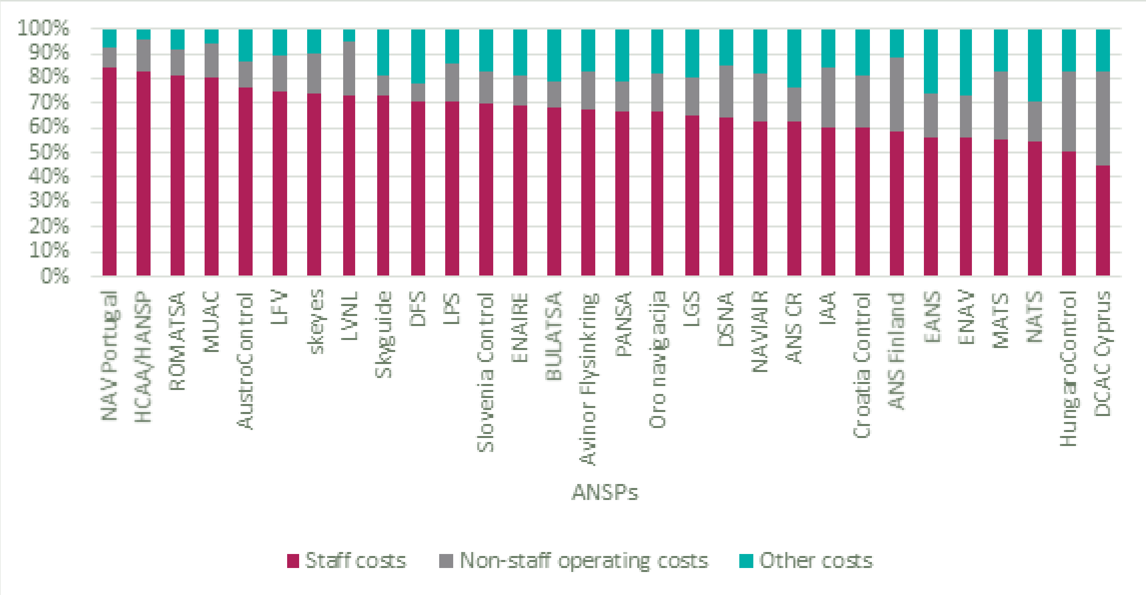


FIGURE 6: COSTS BY NATURE PER ANSP [30]

3.3.1 Staff costs

In 2018, staff costs made 65% of the ATM/CNS provision costs in Europe. These costs only refer to staff treated as an operating cost rather than capitalised cost and typically include gross wages and salaries, State social security scheme contributions, pension contributions and other benefits. Staff costs are defined according to the categories in Table 8which illustrates our assumptions for allocating staff costs to the three layers:

- ATS Layer:
  - Includes all the ATCOs and other staff in ops.
  - Contains a share of technical and admin support staff.
- Common Data Layer: Requires technical and admin support staff.
- Physical Layer: Half of the technical staff work in this layer and one third of administrative support.

Staff type	Description	Current	ATSL	CDL	PL
ATCOs	This category includes the staff costs originated from the ATCOs on operational duty, the support staff which cover ATCOs on other duties, trainees and ATC assistants and non-ATCO staff in operations.	50% - € 1,990 bn	100%	0%	0%
Technical	This category includes the staff costs derived from employing engineers and Air Traffic Safety Electronic Personnel (ATSEPs) delivering technical tasks for maintenance, planning, and development of the aeronautical systems.	25% - € 1 bn	25%	25%	50%
Administrative	Employment costs for staff on administrative duties for the correct running of the entities. This includes other staff that are not fit in the above categories.	25% - € 1 bn	33%	33%	33%
Total value		€ 3,990 bn	€ 2,573 bn	€ 583 m	€ 833 m

TABLE 8: STAFF COSTS

3.3.2 NON-STAFF OPERATING COSTS

Other operating costs besides staff employment are covered under this category and should include:

- costs incurred through the purchase of goods and services directly used to provide ANS;
- external outsourced services such as communications, IT, and external staff with short term assignment;
- materials, energy, utilities, rental costs, equipment, facilities & maintenance, travel costs;
- increases in provisions for bad debts;
- costs arising from exchange rate fluctuations; or
- insurance costs relating to the provision of ANS services.

These costs can be affected by the outsourced activities and the enhancement of the cooperation with other ANSPs to achieve synergies (sharing training of ATCOs, joint maintenance, and other matters). In 2018, these costs constituted nearly 15% of the en-route costs incurred by ANSPs. It is assumed that the cost will be split similarly across the three layers.

	Current SES Area	ATS	CDL	PL
Non-staff operating costs	€ 900 m	33%	33%	33%
Total Value	€ 900 m	€ 300 m	€ 300 m	€ 300 m

TABLE 9: NON-STAFF OPERATING COSTS

3.3.3 Other costs

Other costs include depreciation costs and costs of capital.

- The depreciation costs are related to the total fixed assets in operation for air navigation services purposes. These costs are in essence, the cost of owning capital and is in essence the amount ANSPs need to collect from the airspace user to offset the cost of the depreciation of the assets.
- The economic cost of capital is the amount that ANSPs are allowed to recover from the assets employed according to the Charging Scheme Regulation [32].
- Both of these costs make up the Regulatory Asset Base (RAB) as shown in Figure 7 and are part of the building block approach implemented by some National Supervisory Authorities to control prices. Under this approach, capital expenditure (CAPEX) that has been acquired within the year is not added directly to the costs, but is added to the RAB which as explained is the weighted average cost of capital plus depreciation. The weighted average cost of capital (profit that an ANSP is allowed to make or the allowance they have to borrow money) can include for example, interest rates paid on loans to finance capital. The operating expenditure (OPEX) is finally also summed to the first building blocks to give the total revenue requirement and therefore the determined costs.

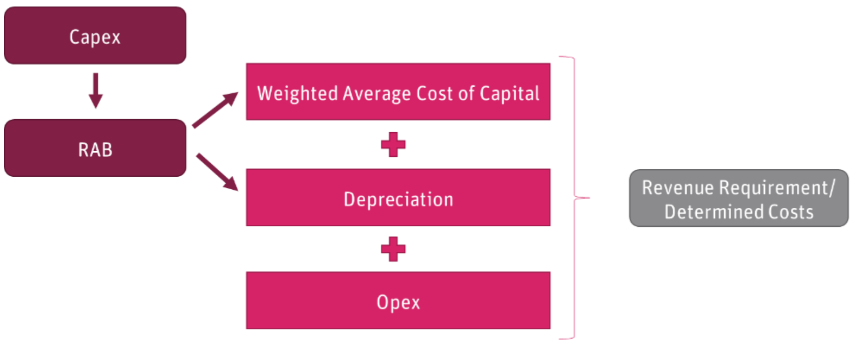


FIGURE 7: BUILDING BLOCK APPROACH USING RAB

The RAB is a system of long-term tariff design aimed at encouraging investment in the expansion and modernisation of the systems. In this study we are going to allocate the RAB into all the layers.

- In the ATS layer, the assets include the main centre of operations and the Controller Working Positions which are assumed to be approximately a quarter of the total RAB..
- In the Common Data Layer, the assets include the FDP, SDP, ground-to-ground communications and IT systems and equipment which are assumed to be approximately a quarter of the total RAB..
- In the Physical Layer, the RAB are all the CNS systems and navaids which are assumed to be approximately half of the total RAB.

	Current SES Area	ATS	CDL	PL
Other operating costs	€ 1,105 bn	25%	25%	50%
Total Value	€ 1,105 bn	€ 276 m	€ 276 m	€ 553 m

TABLE 10: OTHER COSTS

3.4 Estimated market sizes

Table 11 provides our initial estimates for the market size in each of the three layers along with the assumptions described in the previous sections.

Layer	Size	OPEX/CAPEX	Assumption on OPEX	Assumption on CAPEX
Air Traffic Services	€ 3,15 bn	91%/ 9%	• All the ATCOs and other staff in ops. • Share of technical and admin support staff.	• Secure buildings. • Controller Workstations are the main assets. • Resilient and cybersecure infrastructure.
Common Data	€ 1,15 bn	76% / 24%	• Technical and admin support staff.	• FDP, SDP, and systems that enable integration and security services are the main assets.
Physical	€ 1,7 bn	67% / 33%	• Half of the technical staff work in this layer and one third of administrative support.	• Remote sites. • High depreciation and capital costs
Total	€ 6 bn	82% /18%		

TABLE 11: ESTIMATED MARKET SIZES

However, as the national ANSP will retain overall responsibility for ANS within a State, they will therefore collect revenues to cover the costs in all three layers and pay fees or subscriptions for any outsourced services.

As illustrated in Figure 8, if all Common Data Layer and Physical Layer services were outsourced by the national ANSP, then CAPEX of the remaining business (i.e. Air Traffic Services) would be reduced from 20% to 5% whilst the overall cost base and risk[19] would remain largely unchanged. Given the current Performance Scheme [32] uses the RAB and weighted cost of capital to determine return in investment this would act as a barrier to virtualisation as it incentivises retention of capital assets.

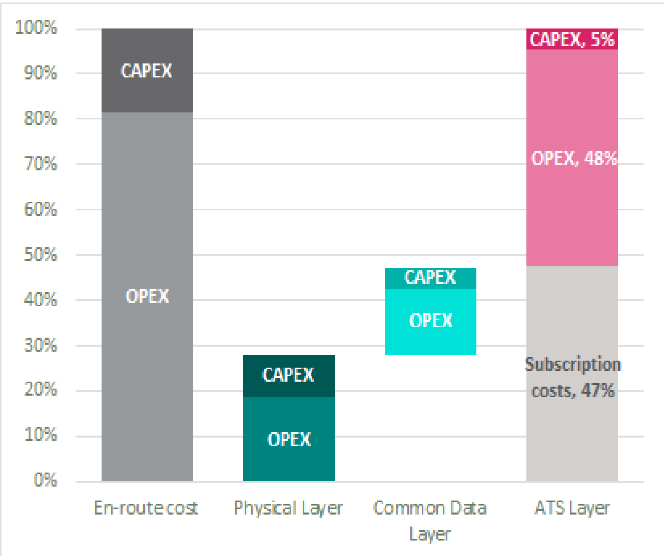


FIGURE 8: EXPENDITURE AND SUBSCRIPTION COSTS

[19] The extent to which traffic risk can be shared with ADSPs needs for research.

Part B

Benefit Mechanisms

4 Identification of benefits

4.1 Proposed transition path

Virtualisation of ATM is not simple and will not be achieved overnight. It is important therefore that a transition path exists with early benefits being realised whilst enabling the next steps and allowing different areas of Europe to move at different paces according to need and benefits. The transition proposed in the AAS is illustrated in Figure 9.

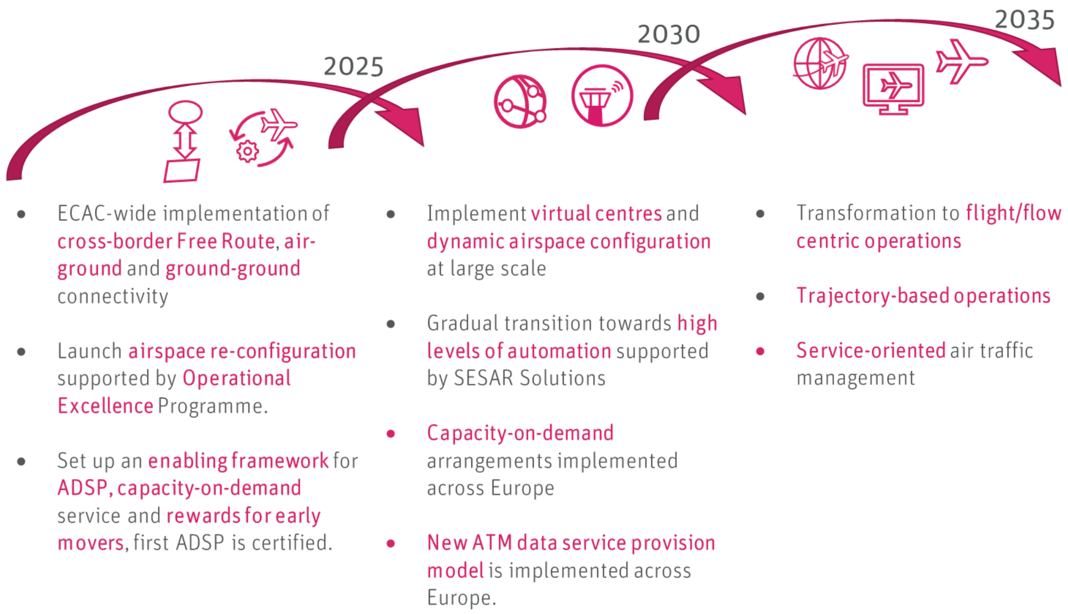


FIGURE 9: AAS TRANSISION (ADAPTED FROM [33])

During our research, we have elaborated on the AAS proposals (see Figure 10) to identify short term **rationalisation** benefits based largely on current technology, leading to additional benefits from greater **harmonisation** and eventually leading to **optimisation** including higher levels of automation. The following section considers the potential benefits of each step in the three layers.

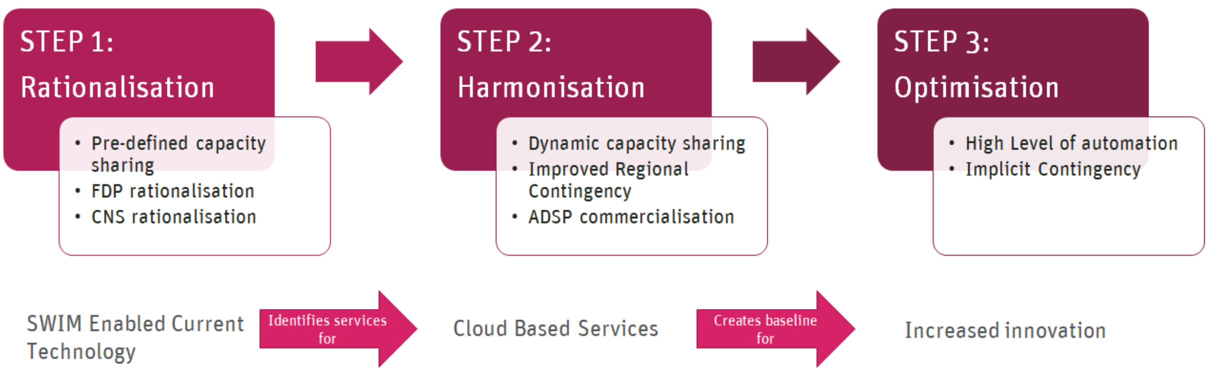


FIGURE 10: SIMPLIFIED TRANSITION PATH

4.2 Step 1: Rationalisation

The focus of step 1 is to use the principles of virtualisation and digitalisation to deliver benefits from the current generation of technology. This includes fully embracing SWIM for all operation data exchanges and developing a robust infrastructure for ground-ground communications as envisaged by NewPENS [18] and the SES Digital Backbone [34].

In terms of benefits within the ATS layer we include increasing ATCO productivity through the Operational Excellence Plan being developed by the Network Manager [67], which aims to identify and implement best in class operations to address local and network needs by facilitating seamless cross-border operations and effectively supporting harmonised/standardised implementation.

We also include initial steps towards capacity sharing between ACCs. At this stage two forms of capacity sharing are possible:

a) Between ACCs operated by the same ANSP;
b) Between ACCs operated by ANSPs within an alliance where controllers maintain additional validations for sectors normally controlled by another ANSP.

In the Common Data Layer, we explore the potential for rationalisation of ATM systems within the current paradigm and ability to rationalise CNS assets in the physical layer.

We note that these benefits can be achieved using current practices and therefore do not require digitalisation. We include them because the ANSP decision making process and subsequent organisational changes and motivation to achieve virtualisation also provides an improved framework for optimisation of ANS more generally.

Indeed, an important consideration is that virtualisation may be a catalyst for benefits that could be achieved in a different manner. This is the induced effect of digitalisation rather than the direct technical benefits of digitisation.

So, all of these benefits, summarised in Table 12 and explained further in the following sections, form the early steps towards virtualisation. Specific local steps such as the national Virtual Centre programme being followed by skyguide and the ATM Data as a Service project between MUAC and Slovenia are important elements of this step as they help validate the operational, technical, and financial feasibility of the following steps.

Layer	Benefit	Mechanism
ATS Layer	Operational Excellence	Increasing productivity to be best in class (within the collaboration). Note this is also a transition step to long term capacity sharing).
	Initial Capacity Sharing	Sharing capacity in limited pre-defined circumstances.
CDL	Data Systems Rationalisation	Consolidation of current ATM data systems and infrastructure (short term).
Physical Layer	CNS Rationalisation	CNS rationalisation infrastructure by removing CNS assets, in terms of VOR and NDB.

TABLE 12: BENEFITS OF STEP 1

4.3 Step 2: Harmonisation

The focus of step 2 is further harmonisation of operational concepts to allow dynamic sharing of capacity, but also includes the transition to ATM Data Services as a set of harmonised cloud services.

This step includes dynamic capacity sharing between control centres. This is enabled by a shift from the current sector-based validation to validation in the use of the system so that ATCOs could operate any sector.

Another benefit that has caught our interest, is reducing the cost of contingency arrangements. We all appear to live on top of each other in Europe, and the knock-on effects of losing airspace capacity can ripple around the network with disastrous effects. With flexible capacity sharing, ACCs with spare capacity can take on the traffic of an ACC experiencing problems and save airlines lengthy delays without the need for diversions as used the during the Summer of 2019.

In this second step we also expect the Common Data Layer to become a set of cloud-based services – reducing cost of both service provision and system upgrades.

Finally, we also consider the rationalisation of additional CNS assets due to an ability to plan coverage at a wider geographic scope.

These benefits are summarised in Table 13 and detailed in the following sections.

Layer	Benefit	Mechanism
ATS Layer	Dynamic Capacity Sharing	Re-sectorisation along common design principles and harmonised operational concept supporting “any sector, any airspace”[20].
	Contingency	Managing contingency at Virtual Centre level eases need for all Member States to have a national contingency arrangement.
Common Data Layer	ATM Data Service Harmonisation	Transition to commercial hardware supporting cloud services supported by appropriate cyber security measures.
Physical Layer	CNS Rationalisation	Improvements due to CNS planning at a wider geographic scope.

TABLE 13: BENEFITS OF STEP 2

[20] https://www.sesarju.eu/news/any-controller-any-airspace

4.4 Step 3: Optimisation

In the third step the focus is on using the infrastructure established in step 2 to enable optimisation of services through deployment of new ATM functionalities encompassing high levels of automation and new forms of CNS.

Figure 11 represents a potential future concept where for a given gate to gate flight, all ACCs and Digital Towers are able to access the same flight data and propose resolutions to downstream conflicts early in the flight to avoid costly path stretching late in the flight such as holding patterns. This is perhaps the ultimate realisation of TBO.

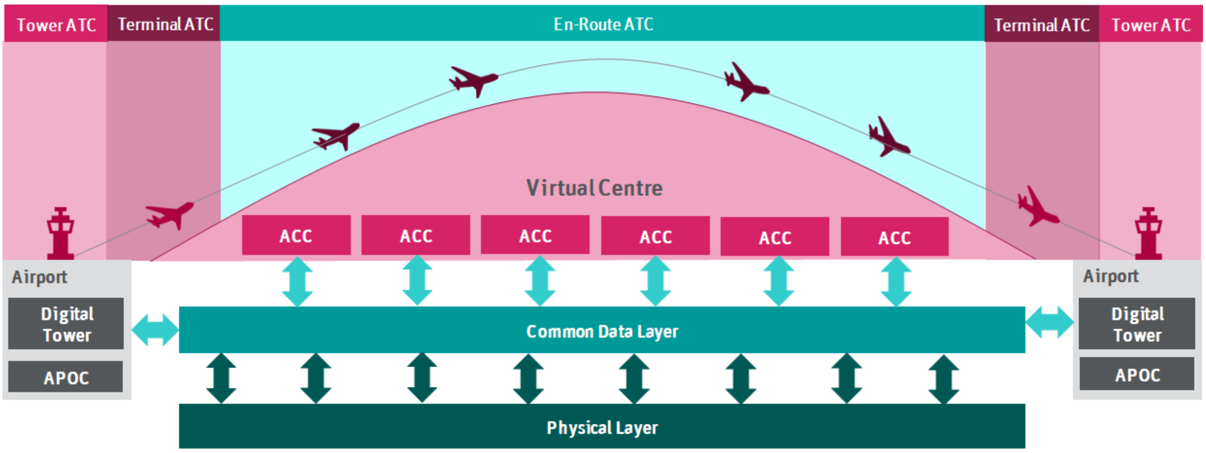


FIGURE 11: POTENTIAL FUTURE CONCEPT

The benefits in step 3 are twofold:

a) Increased productivity and efficiency due to new SESAR solutions; and
b) Reduced costs of deploying those new functionalities compared to the current architecture.

These benefits exist at all three layers (although the ATCO productivity benefit is only realised in the ATS Layer) and are summarised in Table 14 and detailed in the following sections.

Layer	Benefit	Mechanism
ATS Layer	Increased automation	Increased ATCO Productivity from automation. Reduced cost of deploying new or changes to ATS services.
Common Data Layer	Additional data services	Reduced costs of deploying new ATM data services.
Physical Layer	CNS Deployment	Reduced costs of deploying new CNS assets required to enable future concepts including realisation of the iCNS concept.

TABLE 14: BENEFITS OF STEP 3

4.5 Realising benefits

In the following sections we describe a framework for establishing the potential benefits of virtualisation so that we can assess how national ANSPs could be incentivised appropriately whilst maintaining their freedom to operate. In order to do so, we calculate benefits at three different geographical scopes:

Scope	Definition	ATS layer	Common Data Layer	Physical Layer
National	The transition occurs within the national boundaries where the benefit can be quite limited.	ANSPs maintain ATSUs under current arrangements but with the possibility to have VC concept between ATSUs.	ANSPs maintain their ATM data services and operate it nationally.	ANSPs maintain national auxiliary services.
Regional	ANSPs within a region create a Joint Venture to deliver increased benefits.	ANSPs maintain ATSUs but operate as a regional Virtual Centre.	Each region has a set of ADSPs collaborating as a virtual data centre.	Within a region, ANSPs share the provide the services collaboratively.
Pan-European	Pan-European collaboration to maximise benefits of virtualisation.	ANSPs maintain ATSUs but operate as a pan European Virtual Centre.	A set of ADSPs collaborating as a virtual data centre for the whole of Europe.	Pan-European collaboration for each auxiliary service.

TABLE 15: SUMMARY GEOGRAPHICAL SCOPES

For the regional alliances, we have developed 2 variations, one based on existing FABs and one based on main traffic flows (see section 8.1).

Table 16 summarises the identified benefits by layer, the following sections describe our approaches to estimating these benefits. All benefits represent the maximum possible cost savings since the assume a uniform application of virtualisation across the geographical scope they are applied to and transition costs are excluded. The benefits are calculated yearly so they can be added up.

Layer	Form of Benefit	Description	Estimation	Step	Section
ATS Layer	Operational Excellence	Increasing productivity to be best in class (Note this is also a transition step to long term capacity sharing).	Reduced ATCO related costs as controller productivity increases to be best in class.	Step 1	5.2
	Initial Capacity Sharing	Sharing capacity in limited pre-defined circumstances.	Ability to reduce delay within current sectorisation.	Step 1	5.3
	Dynamic Capacity Sharing	Re-sectorisation along common design principles and harmonised operational concept supporting "any sector, anywhere".	Ability to handle the same amount of traffic with lower "buffer".	Step 2	5.4
	Contingency	Managing contingency at Virtual Centre level eases need for all Member States to have a national contingency arrangement.	Reduced cost of contingency arrangements.	Step 2	5.5
	Increased automation	Adoption of a range of advanced SESAR Solutions.	Not quantified due to lack of appropriate data.	Step 3	5.6
Common Data Layer	Data System Rationalisation	Consolidation of current ATM data systems and infrastructure (short term).	Reduction of FDPs (assumes infrastructure can be scaled up to regional requirements).	Step 1	6.2
	ATM Data Service Harmonisation	Deployment of "cloud based" services (medium term).	Cost of "commercial" cloud services.	Step 2	6.3
	Additional ATM data services	Synchronised deployment of new data services and enhanced innovation.	Cost of deploying new ATM Data Services.	Step 3	6.4
Physical Layer	CNS Rationalisation	CNS rationalisation infrastructure by removing CNS assets, in terms of VOR and NDB.	Historical estimate from PRC.	Step 1	7.2
	CNS Consolidation	Planning of CNS assets on a wider geographical scale to reduce the numbers of certain assets – optimised SSR coverage.	Historical estimate from SJU.	Step 2	7.3
	CNS Deployment	A fast and simplified deployment of new CNS systems is supported.	Not quantified due to lack of appropriate data.	Step 3	7.4

TABLE 16: SUMMARY OF IDENTIFIED BENEFITS

5 Benefits in the ATS layer

5.1 Purpose

This section describes our approaches to estimating the potential maximum benefits within the ATS layer in terms of cost reduction and efficiencies gains. We explore:

- Increased capacity through Operational Excellence
- Initial Capacity Sharing
- Dynamic Capacity Sharing
- Contingency
- Increased Automation

5.2 Operational excellence

5.2.1 Problem

In the current system there are noticeable differences in performance between ANSPs. These arise from different operational concepts, deployed technology and levels and complexity of traffic. ATCO productivity (flight hours per hour) reflects how the different ANSPs work to operate the traffic demand safely and currently there is huge variability as shown in Figure 12 and Figure 13.

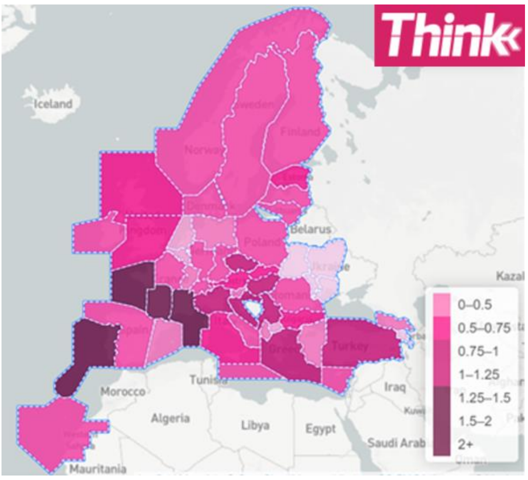


FIGURE 12: ATCO-PRODUCTIVITY PER FIR [30]

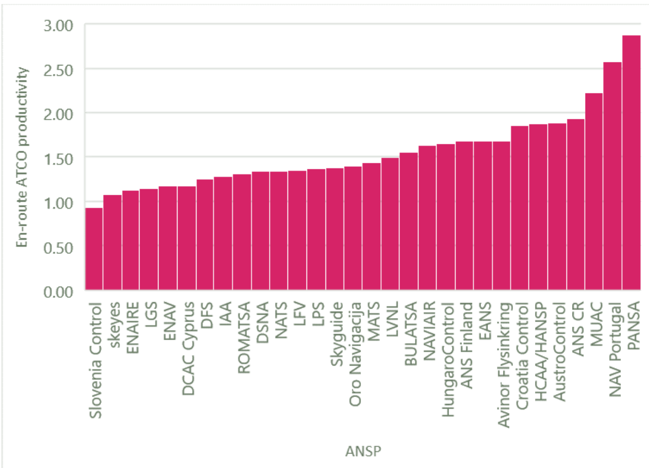


FIGURE 13: ATCO-PRODUCTIVITY PER ANSP [30]

The relation between the number of ATCOs in OPS per sectors open at maximum configuration in 2018 is expressed in Figure 14 and shows a correlation with some outliers that indicated that some ACCs might not have an appropriate number of ATCOs to deal with their sectorisation.

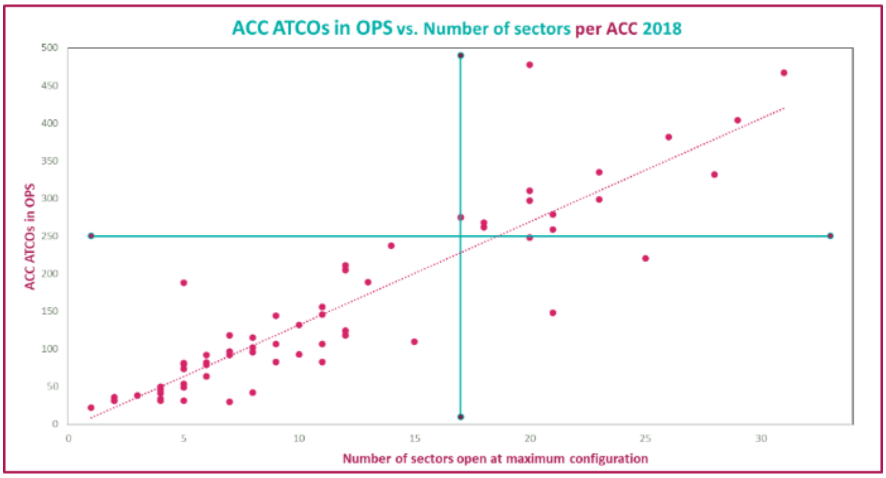


FIGURE 14: ATCOS PER NUMBER OF SECTORS IN ACC [30]

5.2.2 Solution

The harmonisation process led by the establishment of Virtual Centres reduces the operational and technical variations between ACCs, ensuring that all the units within a Virtual Centre operate seamlessly. If the same operational concepts are applied in all ACCs, systems and procedures are identical in each centre ensuring interoperability then all ACCs within a Virtual Centre can operate as best in class evening out the differences across the region.

The main benefit of harmonisation is enabling ATCO rostering at a Virtual Centre level. This means that ATCO hours within the workplace will be reduced whilst their utilisation will be increased and so will be the efficiency when dealing with peak traffic leading to an increase in flight-hours handled. Even if this is not measured directly, it has an effect on ATCO productivity which can be increased until productivity is the maximum in a given geographical area .

$$ATCO - hour\ productivity\ = \frac{flight - hour}{ATCO\ in\ OPS\ hours\ on\ duty}$$

As shown in Figure 15, if ATCO productivity had been increased to the maximum then ATCO hours on duty would have decreased and therefore the cost per ATCO hours would be reduced leading to less overall costs.

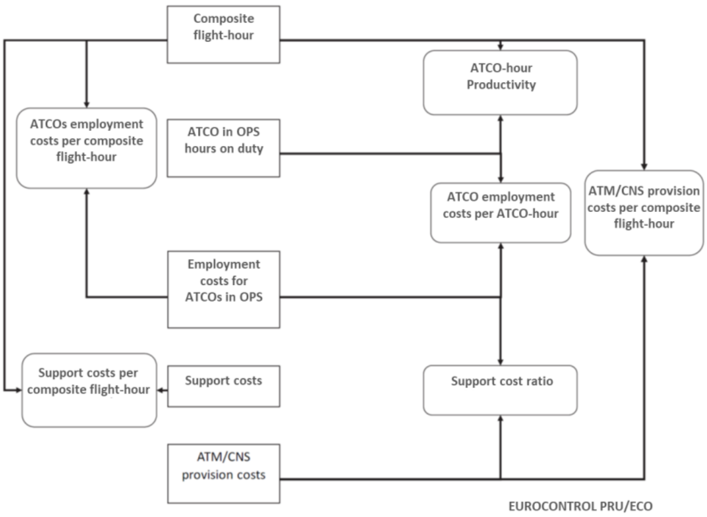


FIGURE 15: ATM COST-EFFICIENCY [27]

It must be reminded that these cost reductions are the maximum and only take into consideration the changes in the systems and infrastructure. This study recognises the weight of other factors such as culture differences in achieving the maximum performance or best-in-class productivity and understands this may limit the benefit obtained.

5.2.3 Calculation

The following steps summarise the assumptions and calculations used to find out the range of cost savings that operational excellence benefit allows:

1. The ANSPs improve their 2018 ATCO productivity to the maximum ATCO productivity (best in class) that exists in the region where they collaborate (regional scope) or in the whole of Europe (pan-EU scope) – depending on the geographical scope applied. The increase they experience is the lost productivity (productivity gain they could have had in 2018 but they did not because the AAS was not in place). For the purposes of this study, only en-route ATCO-hour productivity from 2018 has been considered.
2. The ATCO hours on duty are recalculated with the new productivity by dividing the flight hours that ANSP controlled in 2018 (which is a constant) by the new productivity. This allows us to identify how many ATCO hours on duty would have been with the new productivity, which are less than the ones used.
3. As the ATCO cost per ATCO hour is a known variable, the new ATCO costs can be calculated by multiplying the new ATCO hours by the ATCO cost per ATCO hour.
4. The costs that could have been saved in 2018 is the difference between the ATCO costs in 2018 and the new ATCO costs calculated from the increase in productivity.

5.3 Initial capacity sharing

5.3.1 Problem

Traffic variability (and volatility) and the limited flexibility to adjust the capacity in the short term is one of the causes of capacity and demand mismatch leading to poor service quality or an underutilisation of resources [35]. The ATS layer mitigates the effects of traffic variability by providing a better response to flexible use of resources on a shorter timeframe and over a wider area.

Figure 16 illustrates capacity utilisation of an airspace based on one week of traffic during summer 2017. It indicates that half of the time, sectors' utilisation is less than 60%, just below average sector load of 62%. If the spare capacity is used to support where there is insufficient capacity, then delay costs and capacity provision costs for airspace users are reduced.

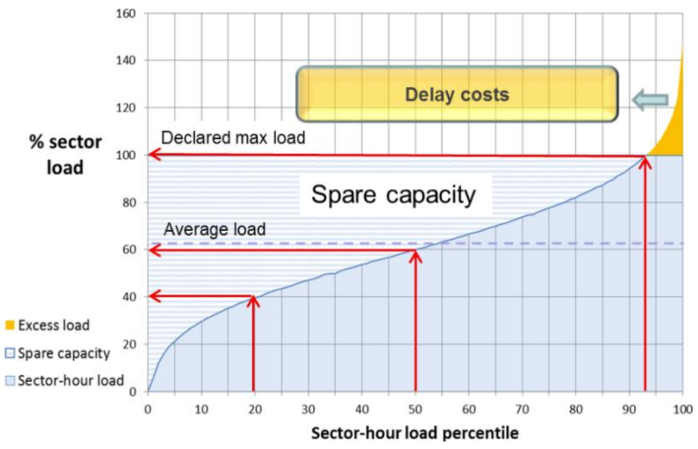


FIGURE 16: AIRSPACE CAPACITY UTILISATION [36]

ANSPs plan their schedules and resources well in advanced considering long-term traffic variability and short-term traffic unpredictability. Despite this, adjusting capacity to demand on short notice is limited and costly [37]. Airspace users take last-hours decisions on the route they are going to fly based on up-to-date data which saves a few hundred euros per flight [38][39][40] for themselves but on the contrary deteriorates the network performance [41] as a whole and reduces predictability and increases costs for ANSPs and the Network Manager.

In addition, the current route charging system does not incentivise a reduction of the mismatch between capacity provision and demand. The financial penalties for exceeding delay targets are insufficient to ensure ANSPs increase capacity leading to environmentally inefficient AU decisions to fly longer routes [60].

5.3.2 Solution

The solution would be the Capacity-on-Demand service which allows sectors to be temporarily operated by an alternative provider with spare capacity. When it comes to the capacity, two areas must be considered. On the one hand there is the system flexibility and structural changes across the airspace, and on the other hand the scalability and resilience of the system, involving a dynamic capacity management.

The study looks on how applying the Virtual Centre concept to achieve a flexible use of airspace can lead to benefits. In the short term, capacity can be shared in pre-defined situations enabled by a harmonised infrastructure as defined in Step 1 of the transition and using the current airspace structure. En-route delays could be reduced if additional sectors could have been opened and this can be enabled by the Virtual Centre concept allowing ACCs with spare capacity to operate opened sectors in overloaded areas.

In 2018 and in the second Reference Period (RP2) most of the delay in the network was generated by a limited number of ACCs operated by an even more limited number of ANSPs. The top 5 en-route delay locations generated 41,8% of the total ATFM (network) delay [42]. The most delay generating ACCs in 2018 were Karlsruhe (21.3%), Marseille (15.2%), Maastricht UAC (7.8%), Reims (6.7%), Brest (5.4%), Vienna (4.3%) and Barcelona (3.8%). Karlsruhe UAC and Marseille ACC together generated more than one third (36.5%) of all en-route ATFM delays in 2018 [35]. Figure 17 shows the minutes of delays per FIRs registered in 2018 across Europe and how they are concentrated towards the centre of Europe (France, Germany, and Belgium).

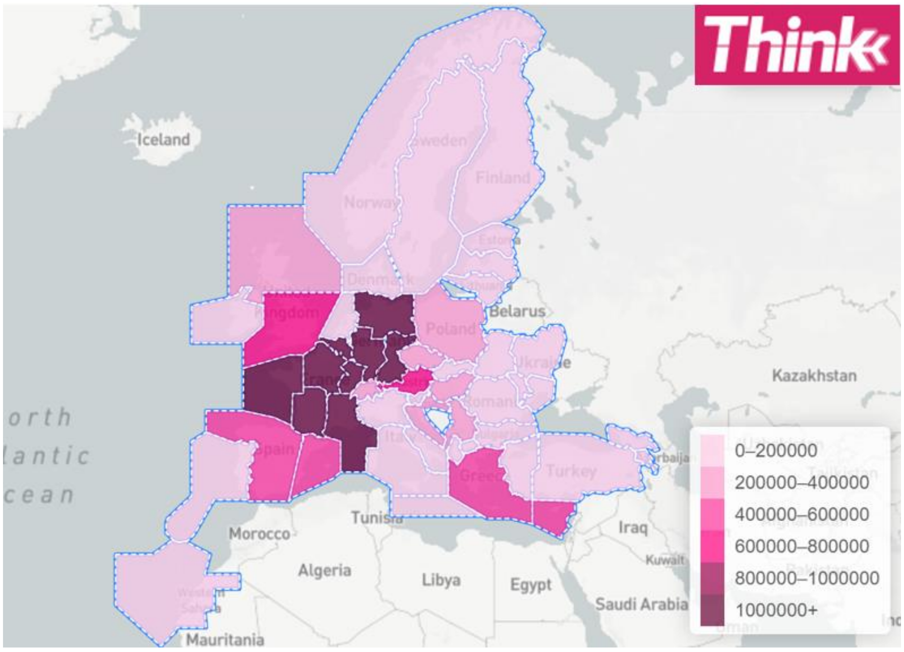


FIGURE 17: MINUTES OF DELAYS PER FIRS IN 2018 [30]

Figure 18 shows a typical day in 2018 where some sectors are both highly overloaded (shown in blue) and others had spare capacity (shown in pink) which could have been used to support the overloaded sectors.

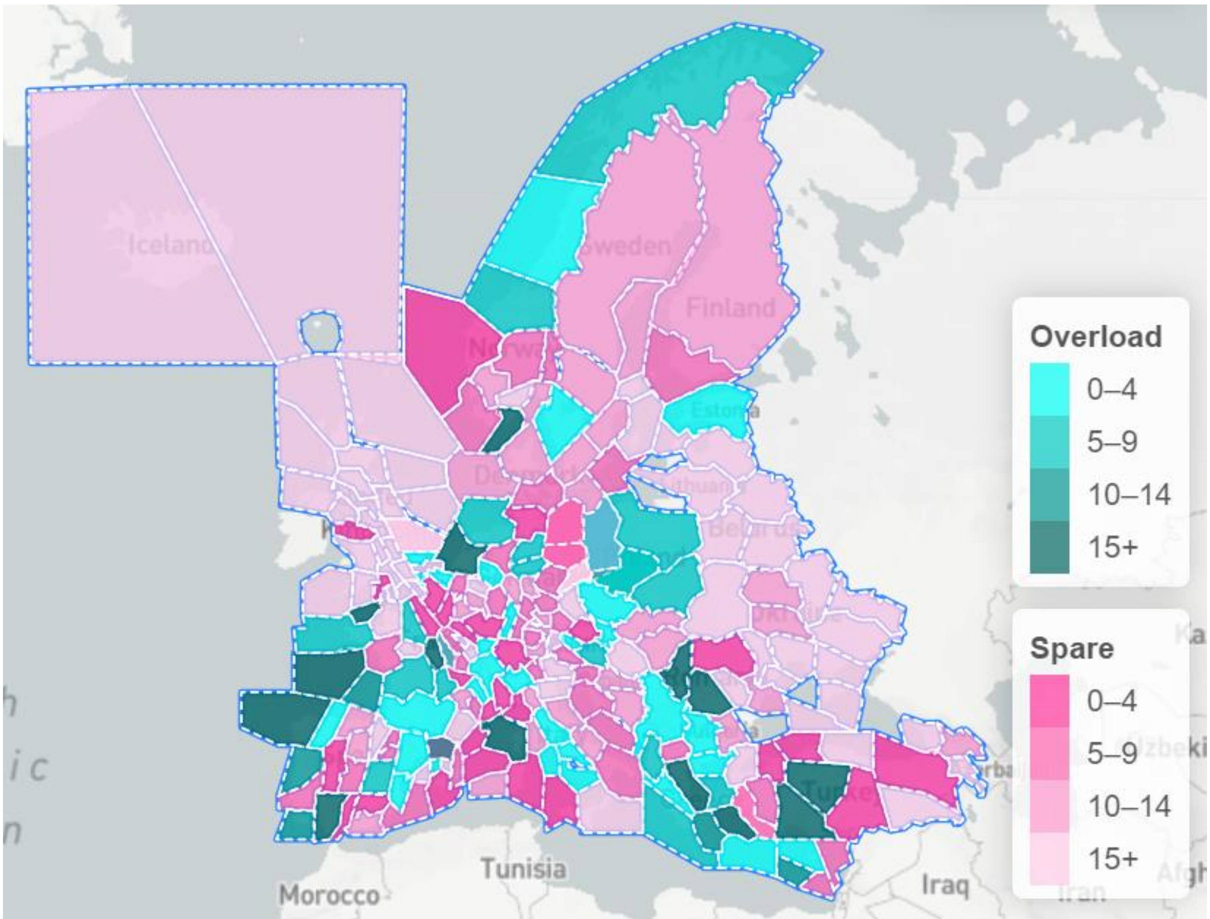


FIGURE 18: SECTOR UTILISATION[21] DURING A DAY IN 2018 [42][30][35]

However, the issue goes beyond restricting movements to prevent overloaded sectors since many of the congested areas had extra available sectors that were closed and could have been opened and therefore opening more sectors could have alleviated the problem on the those that were opened. The inability to open more sectors at maximum configuration so that they could deliver enough capacity to match the demand and hence avoid delay is mainly due to ATCO staff shortage. Europe has spare capacity and therefore staff, but it is not in the right place.

There are various examples of this in the centre of Europe. For example, as stated in NOP 2019 Germany is a clear example [43]. Karlsruhe ACC generated an average en-route delay of 2.17 minutes in 2018 mainly due to ATC staffing shortages which limited the number of sectors available to be opened. According to the 2019 NOP the ACC counted with 43 sectors that could have been potentially available but solely 27 could have been really opened at the maximum configuration.

Using the Virtual Centre concept and without re-designing airspace, in limited pre-defined circumstances the ACCs could collaboratively operate sectors where required regardless of the location until the peak number of sectors (which is currently never reached). An arrangement between two ACCs would require to temporarily transfer a sector and each ACC would need to be suitably harmonised and have validated ATCOs for the concerned sectors.

[21] A sector is overloaded when the capacity utilised is bigger than the declared capacity for that sector and inversely for the spare sectors. The capacity is referred as the number of flight entries per hour.

In the short term this could reduce the costs of delays, in 2018 it was estimated that there were 17 million minutes of en-route ATFM delay, out of which 11,7 million minutes were capacity related delays:

- 7,5 million minutes – ATC Capacity delay
- 4,2 million minutes – ATC Staffing delay

However, this is the benefit to the Airspace Users and it actually increases the ANSPs costs that come with increasing the capacity where required.

Furthermore, this benefit grows with traffic and while it is true that as a result of the current pandemic traffic is not expected to reach 2018 levels unless until 2024, capacity delays could also emerge as a result of unpredicted demand (e.g. States lift restrictions to restore tourism).

5.3.3 Calculation

The following steps summarise the assumptions and calculations used to find out the maximum benefit for AUs:

1. If capacity can be shared in pre-determined situations the delay that has been caused by capacity related issues could be significantly reduced. The maximum cost benefit would be the removal of the cost of capacity delays.
2. The delays related to capacity related issues in 2018 is the sum of the delays created by the regulation causes of ATC Capacity and ATC Staffing which are codes C and S in the NM Regulation Codes [44].
3. Given that the cost per minute of en-route delay is €75[22] as established in the Standard Inputs for EUROCONTROL CBAs [45], the total cost of the capacity related delays and hence the cost that could have been saved by Airspace Users if limited capacity sharing was enabled is the total minutes of delays multiplied by €75.

5.4 Dynamic capacity sharing

5.4.1 Problem

In the long term, the issue presented in 5.3 and the solution proposed of flexible use of airspace and capacity-demand balancing could be generalised at a wider scope and in every-day situations by allocating sector to ACCs to suit traffic and staff levels on day of operation.

5.4.2 Solution

To enable the "any sector, anywhere" concept, a high level of harmonisation (Step 1) and a complete airspace redesign (Step 2) is required to ensure common design principles, airspace optimisation and a harmonised operational concept that any ATCO can be validated on. This would provide ACCs the ability to handle additional traffic with a lower capacity buffer. Currently, the trade-off between the predictability for ANSPs and the flexibility for AUs results in a "reserve" of approximately 5-10% of an ANSP's capacity to take care of all predictability and nonadherence issues arising in pre-tactical and tactical stages [46]. Potential cost savings arising from a more predictable system (including improvements from earlier sharing of flight plans enabled by the common data layer)) are estimated to 45 million EUR per annum for that ANSP [47].

[22] We have taken the average value of airborne Tactical Delay Cost with network effect per minute (€) on short delays since we understand these delays (capacity and staffing) tend to occur due to short term changes rather than strategic. Whilst is a good working assumption for the scope of the project, future research could correctly assess these cost savings as a function of true duration, rather than the average.

5.4.3 Calculation

The following steps summarise the assumptions and calculations used to find out the ranges of cost savings for dynamic capacity sharing:

1. The maximum that the cost saving can be is the maximum reserve which is 10% of the ATS layer cost and adds on top of the limited capacity benefit (which is reducing delay without reducing the buffer).
2. Therefore, for whatever scope except national, the total cost of the ATS layer for the whole of Europe is multiplied by 0.1 to reveal the total cost savings that this benefit means.

5.5 Contingency arrangements

5.5.1 Problem

In Europe, given the interdependence of adjacent airspaces, the knock-on effects of untimely loss of airspace capacity ripples around the network with disastrous effects. In case of an unexpected failure or disruptions, moving capacity into remote contingency centres (replicas of current ACC) can provide the required ATS services to support operations – but is a very expensive option especially if applied nationally.

Whilst national ANSPs are required to have a contingency plan (for example see [48]) the level of service required following a major outage is left to national policy. Some countries have contingency sites in case of disruptions of operations, for example, Ireland has a contingency centre at Ballygirreen [49] to cover en-route operations and that can provide full service. The cost of these centres is difficult to know but given that they provide a full service it should be close to the total costs of an en-route centre.

5.5.2 Solution

Virtualisation, particularly once dynamic capacity sharing is established enables a different way of planning system outages as the ATSUs within the Virtual Centre will provide a natural level of redundancy to support contingency arrangements at short notice ensuring a smooth, safe, and quicker continuity of air traffic.

Estimating benefits of improved contingency can be done in two ways:

- Delay avoidance – In 2018 there were 1,3 million minutes attributed to strikes and unplanned system outages at a cost of 101 million euros to airspace users [30]. Ideally, this cost could have been avoided if effective contingency arrangements were in place. However, we recognise it is the maximum saving but not the most likely one as strikes may find a way to still cause delay.
- Cost Reduction – Contingency becomes part of the overall cost of the virtual centre rather than being a standalone cost of infrastructure that no-one wants to use.

5.5.3 Calculation

Under these benefits two types of cost savings can be calculated (one for AUs and other for ANSPs):

- Delay avoidance: Same approach as the one used in the initial capacity sharing benefit (See Section 5.3.3) but with the minutes of delays being those generated by the regulation causes of ATC Industrial Actions (code I) and ATC Equipment (code T) [44].
- Cost reduction:
    1. As the cost of contingency centres is not available, we assume that the maximum a contingency centre can cost is the cost of an ACC.

2. The cost of an ACC is calculated per ANSP as the total ATS layer costs excluding the staff costs leading (CAPEX cost in ATS layer) which is then divided by the number of ACCs that an ANSP has under its control.
3. To calculate the maximum savings by improved contingency we have calculated that the costs of all contingency centres (one per ANSP as calculated in the previous step) are saved except for the contingency centres that would still be required in the different geographical scopes to operate safely:
    - two top-end (corresponds to the maximum ANSP costs in the region) contingency centres per region;
    - one top-end (corresponds to the maximum ANSP costs in the FAB) contingency centre per FAB with less than four ANSPs;
    - two top-end (corresponds to the maximum ANSP costs in the FAB) contingency centres per FAB with four or more ANSPs; or
    - three top-end(corresponds to the maximum ANSP costs in Europe) contingency centres in the case of the whole Europe.

5.6 Increased automation

5.6.1 Problem

Within the existing architecture, it is currently difficult and expensive to deploy new ATM functionalities. One of the key benefits of virtualisation is that the development of a new ATM data (or ATS) service can be achieved in a much simpler manner as a consequence of common interfaces, procedures, and services of the common data layer.

In particular SESAR Phase D , the final phase of the implementation of the Digital European Sky with a fully scalable system, envisages "Fully scalable services supported by a digital ecosystem minimising the environmental footprint of aviation" [6] with a high level of automation.

5.6.2 Solution

The AAS [1] considered the potential benefits of automation in Run 2 of their simulation campaign concluding that widespread deployment of SESAR Phase D would lead to at least 50% increase in ATCO productivity.

- Lower cost of capacity – significant increases in ATCO productivity could potentially support reduced ATCO costs - but more importantly enable additional traffic to be handled without increasing ATCO costs.
- Lower implementation costs – the costs of upgrading ATS layer systems to support high levels of automation may be lower (including reduction in training costs), but the real cost reduction is in the common data layer (see Section 6.4).

5.6.3 Calculation

On top of the productivity increase obtained in the Operational Excellence benefit (See Section 5.2.3), the AAS study [1] estimated that current SESAR automation concepts would increase ATCO productivity by 50%.

The new productivity allows two calculations:

1. Reduced ATCO costs: To reduce ATCO costs, first the change in ATCO hours has to be calculated. New ATCO hours are calculated by dividing the flight hours handled in 2018 by the new productivity. This is then multiplied by the ATCO costs per ATCO hour to have the new ATCO costs. The difference between the 2018 and new ATCO costs is the cost saving. This benefit is on top of the operational excellence benefit and therefore such cost savings have to deducted when adding the benefits.

2. Increased extra traffic: To handle extra flight hours in the same ATCO hours as in 2018. The number of flight hours that can be handled under this new productivity is obtained from multiplying the new productivity and the ATCO hours.

5.1 Summary of Benefits

The overall benefit of the Step 1 and 2 in the ATS Layer ranges from €1.4 billion to €1.8 billion per annum (approximately 60% of the overall cost) depending on geographical scope as summarised in Table 17.

Benefit	FABs	Regional	European
Step 1: Operational Excellence	€ 550 m	€ 670 m	€ 980 m
Step 1: Initial Capacity Sharing	€ 0 m	€ 0 m	€ 0 m
Step 2: Dynamic Capacity Sharing	€ 315 m	€ 315 m	€ 315 m
Step 2: Contingency	€ 80 m	€ 70 m	€ 190 m
Step 3: Increased automation[23]	€ 480 m	€ 440 m	€ 340 m
	€ 1,425 m	€ 1,495 m	€ 1,825 m

TABLE 17: ATS LAYER ESTIMATED COST SAVINGS PER GEOGRAPHICAL SCOPE

[23] Note the benefits of increased automation are lower if the benefit was already achieved in the operational excellence step.

6 Benefits of the common data layer

6.1 Purpose

The benefits of the common data layer are twofold. Firstly, as an enabler of the benefits in the ATS layer and to some extent the Physical Layer, and secondly as a way of lowering the costs of providing ATM data services. In this section we consider the latter in the three steps introduced in Section 4, namely:

- Rationalisation – Using the ATM Data as a Service concept to rationalise the number of ATM Data Systems (Mostly FDP and RDP) in Europe.
- Harmonisation – Deployment of a common set of ATM Data Services ("in the cloud") to support a harmonised operation concept and dynamic airspace sharing.
- Optimisation – Deployment of advanced ATM data services to support high level of automation in the ATS layer.

6.2 ATM system rationalisation

6.2.1 Problem

With the current architecture, each ACC has its own ATM system specially designed for the area of responsibility and operational concept.

6.2.2 Solution

In the new architecture, rather than relying on the conventional data service at an ANSP level, ADSPs will offer the possibility of sharing the equipment and therefore the cost will be minimised.

In step 1 the focus is on sharing ATM system functions (e.g. FDP and or SDP infrastructure) between ANSPs as considered in projects such as ATM Data as a Service [24].

The consolidation benefit that could be achieved by reorganising and reducing to the minimum required – to maintain safety and optimise efficiency - the number of ATM data systems that have an average life of ten years depends on the geographical scope (as detailed in the following section).

6.2.3 Calculation

In the geographical scope of this study, we are considering 52 ACCs which have their own ATM data system and cost approximately € 876 million according to the calculations followed from the data [30] in Table 18.

Size of ANSP	Flight Hours	Total costs of ATM data systems
Small	<100,000	€ 10,306,250
Medium	100,000-230,000	€ 22,333,333
Large	>230,000	€ 36,320,000

TABLE 18: ATM SYSTEM COSTS PER ANSP SIZE [30]

Through common procurement alliances such as COOPANS and iTEC, there is a move to harmonised platforms for groups of ANSPs, but often with quite significant differences between installations. The lack of harmonisation therefore creates high costs for ATM systems. PRB analysis of CAPEX [31] suggests that the cost of the next generation of ATM system may be up to 10 times higher – although to some extent this is also due to the greater level of functionality.

The following steps summarise the assumptions and calculations used to find out the ranges of cost savings for the rationalisation of data systems:

1. Costs of ATM data systems were estimated by PRU in relation to the size of the ANSP which is linked to the flight-hours as shown in Table 18. Therefore, the flight-hours controlled by an ANSP is used to estimate the cost of data system for each ANSP and geographical area.
2. The bulk of cost savings from rationalisation is calculated by subtracting from the 2018 estimate of ATM data systems costs for a geographical area the costs of:
   - two top-end (corresponds to large in Table 18) ATM data systems packages per region;
   - one top-end (corresponds to large in Table 18) ATM data systems packages per FAB with less than four ANSPs;
   - two top-end (corresponds to large in Table 18) ATM data systems packages per FAB with four or more ANSPs; or
   - three top-end (corresponds to large in Table 18) ATM data systems packages in the case of the whole Europe.
3. Since it is assumed that ATM data systems (FDP/RDP) will have a life of 10 years on average, the yearly cost savings are the total cost savings (discussed in the point above) divided by 10.

6.3 ATM Data Service Harmonisation

6.3.1 Problem

The current generation of ATM systems is designed around the airspace and operational concept of the ANSP. As noted above this creates an heterogenous system with high development costs. The decoupling of the ATM data services from the ATS layer should allow for harmonisation – that is a common set of services provides to all ATSPs in a harmonised manner, such that the ATSP is able to build in specialisation for specific local issues through different combinations of services. In this way the ATSP only needs to subscribe to the services required for their level of complexity.

6.3.2 Solution

In step 2 rather than considering rationalisation of ATM systems we consider that ATM data services would be provided by specialist providers operating infrastructure similar to current web-based services. That the hardware is based on commercial products, but the software is ATM specific. Hence:

- ATSPs get access to next generation of FDP services with a focus on interoperable high-performance cloud services (for example Coflight Cloud Services[24]).
- ADSPs are operated by commercial IT providers and specialise in provision of data services with better quality and are cheaper. These providers could follow a business model similar to Amazon Web Services (AWS)[25].

6.3.3 Calculation

The following steps summarise the assumptions and calculations used to find out the ranges of cost savings for the commercialisation of data services:

1. According to AWS [50], implementing a cloud service could save up to 31% of infrastructure costs.

[24] https://coflight-cloud-services.com/
[25] https://aws.amazon.com/

2. We consider infrastructure costs to be the total Common Data Layer costs excluding staff costs.
3. To calculate the cost savings, nationally ANSPs could reduce 31% of the 2018 Common Data Layer infrastructure costs.
4. At other (non-national) geographical scopes the maximum cost savings are calculated as 31% of the infrastructure costs in each area, estimated to be the cost of:
    - two top-end (corresponds to the maximum ANSP infrastructure cost – most expensive ANSP - in the region) ADSPs per region;
    - one top-end (corresponds to the maximum ANSP infrastructure cost in the FAB) ATM data systems packages per FAB with less than four ANSPs;
    - two top-end (corresponds to the maximum ANSP infrastructure cost in the FAB)ATM data systems packages per FAB with four or more ANSPs; or
    - three top-end (corresponds to the maximum ANSP infrastructure cost in the Europe) ATM data systems packages in the case of the whole Europe.

6.4 Advanced ATM Data Services

6.4.1 Problem

Harmonised deployment has proved to be extremely difficult in ATM. If we look back to the EATCHIP programme of the 1990's [51], the first step was to harmonise both system and concepts before driving improvements; but this step has not yet been achieved. The reality is that there has never been sufficient motivation to align ANSP investments cycles. So, when a new ATM functionality is chosen for deployment, the national deployment plans have to consider the status of the ATM system, for some ANSPs the only way to implement the new ATM functionality may be to purchase a new ATM system – which could be 10 to 15 years away. Since the successes of Area Navigation (RNAV)[26] and Reduced Vertical Separation Minimum (RVSM)[27] in the late 1990s harmonised deployment has not really been achieved.

6.4.2 Solution

The solution offered by virtualisation is that new advanced ATM data services would be deployed in the Common Data Layer, with the ATSPs able to tailor how they use the new services to maximise benefits. This approach is anticipated to be much quicker and cheaper than requiring harmonised upgrades to 52 FDPs.

6.4.3 Calculation

Under the scope of this study, this benefit cannot be calculated numerically – however inspection of the ATM Master Plan [6] suggests that the frequency of adding new ATM functionalities will increase.

[26] RNAV is a method of navigation which permits the operation of an aircraft on any desired flight path; it allows its position to be continuously determined wherever it is rather than only along tracks between individual ground navigation aids.

[27] RVSM is defined as the reduction of vertical space between aircraft from 2,000 to 1,000 feet at flight levels from 29,000 feet up to 41,000 feet. RVSM was implemented as a means to increase airspace capacity and provide access to more fuel-efficient flight levels.

6.5 Summary of benefits

The overall benefit of the Step 1 and 2 in the Common Data Layer ranges from €180 million to €420 million per annum (approximately 20% of the overall cost) depending on geographical scope as summarised in Table 19.

Benefit	National	FABs	Regional	European
Step 1: ATM System Rationalisation	€ 0 m	€ 40 m	€ 50 m	€ 80 m
Step 2: ATM Data Service Harmonisation	€ 180 m	€ 175 m	€ 210 m	€ 340 m
Step 3: Additional ATM data services	Not Quantified			
Total	€ 180 m	€ 215 m	€ 260 m	€ 420 m

TABLE 19: COMMON DATA LAYER ESTIMATED COST SAVINGS PER GEOGRAPHICAL SCOPE

7 Benefits of the physical layer

7.1 Purpose

In this section we consider the potential benefits in the physical layer, in terms of:

- CNS Rationalisation - Removing CNS assets such as VOR and NDB with limited operational benefit.
- CNS Consolidation - Planning of CNS assets on a wider geographical scale to reduce the numbers of certain assets.
- New CNS Deployments - Fast and simplified deployment of new CNS systems are supported.

7.2 CNS Rationalisation

7.2.1 Problem

Over the years, the CNS infrastructure has been developed and optimised to meet the operational requirements. However, the auxiliary services were mostly implemented on a national basis and duplication of services may be found at national boundaries. The rationalisation of these services across the whole network is the first step and is the key to an efficient system.

Currently, each ACC operates its own physical layer that includes CNS and MET sensors. In the context of traffic growth and a fragmented infrastructure based more on a national basis, CNS showed over the years some inefficiencies, mostly related to an inappropriate distribution of equipment, saturated bands and overlapping operations of some technologies.

In the new airspace architecture, the common data layer enables auxiliary services to be operated independently from the ACCs enabling a more resilient and scalable system.

7.2.2 Solution

The aim for the physical layer is to be rationalised where possible, without losing coverage or spectrum use of any area, resulting in an increased operational efficiency and cost savings.

The recent CNS Advisory Group Report [52] expresses new data regarding the number of navaids expected to be decommissioned. Based on that, the assumptions on the avoided renewal and maintenance costs per equipment were gathered in Table 20.

Functionality	Equipment	Quantity in scope to decommission	Avoided renewal cost per equipment	Avoided maintenance cost per equipment
Navigation	NDB	725	€124k	€15k/yr
	VOR	313	€938k	€25k/yr

TABLE 20: OVERVIEW OF THE MONETISED BENEFITS [71]

7.2.3 Calculation

The range of benefits for CNS rationalisation in Table 20 represents the total savings for the CNS infrastructure and equipment but not the yearly savings. Therefore, we estimated that the yearly cost savings is a tenth reduction in the cost of capital of the physical layer or what is the same, a tenth of the total cost savings. We have assumed that 90% of the cost savings can be delivered for regions and 80% for FABs.

7.3 CNS Consolidation

7.3.1 Problem

The second set of benefits for CNS is related to consolidation of assets when deployment is planned at a wider geographic scope. Under current arrangements, CNS asset planning has been performed by national ANSPs who define requirements based on achieving the necessary operational requirements, e.g. voice, data coverage, surveillance performance to support 3NM or 5NM separation and navigation aids to support the required navigation performance (RNP) e.g. RNP-5 / RNP-1. Nominally, the ANSP demonstrates the sufficiency of the deployed CNS assets owned and operated by the ANSP supported by some data sharing with neighbouring ANSPs.

As virtualisation proceeds, and in particular operational harmonisation, then the CNS requirements will also be harmonised and the CNSP will use all assets they operate to demonstrate the required performance – hence allowing CNS planning at a wider geographic scope.

7.3.2 Solution

Replanning the CNS on a wider scale will allow harmonised operations across borders. Here a collaboration between ANSPs is required, the focus being on data sharing and exchanges, through which the number of certain assets will be reduced, and so will the costs. As illustrated in Table 21 a significant reduction in surveillance is still possible.

	Type of Surveillance Sensor				
	Mode A/C	Mode S	PSR	WAM	ADS-B
2006 [18]	237	63	203	-	-
Current [54]	100	205	130	856	109
Future [54]	0	150	110	1293	275

TABLE 21: REDUCTION ON SURVEILLANCE ASSETS

7.3.3 Calculation

The range of benefits for consolidation of radars is represented in Table 22 with the replacement of en-route radars which is the total capital savings but not the yearly savings. Therefore, we suppose that the yearly cost savings signify a tenth reduction in the cost of capital of the physical layer.

	All radars
Capital replacement costs	€380m
Annual operating costs	€5m

TABLE 22: SAVINGS DUE TO RATIONALISATION OF RADARS AT EUROPEAN LEVEL

7.4 CNS Deployment

7.4.1 Problem

The high levels of automation considered in Step 3 will require a refresh of the CNS infrastructure. The European ATM Master Plan [6] includes the integrated CNS (iCNS) concept including proposed deployments of:

- Next generation air-ground data links (LDATS and satcom)
- Integrated surveillance
- Additional navigation infrastructure.

7.4.2 Solution

A coordinated and simplified implementation of new systems will be enhanced, resulting in an increased system efficiency, high performance, and a significant reduction in costs.

With the ATM virtualisation, the CNS services could be harmonised at the European level or across regions, enhancing cooperation across the boundaries and a geographical distribution of the equipment.

The European ATM master plan include new technologies including satellite-based communications, datalink communications and providing opportunities to rationalise services and maximise the rationalisation benefit.

7.4.3 Calculation

Under the scope of these study, this benefit cannot be calculated numerically.

7.5 Summary of Benefits

The overall benefit of the Step 1 and 2 in the Physical Layer ranges from €45 million to €56 million per annum (approximately 3% of the overall costs) depending on geographical scope as summarised in Table 23.

Benefit	National	FABs	Regional	European
Step1: CNS Rationalisation	€ 0 m	€ 27 m	€ 31 m	€ 34 m
Step 2: CNS Consolidation	€ 0 m	€ 18 m	€ 20 m	€ 22 m
Step 3: CNS Deployment	Not Quantified			
Total	€ 0 m	€ 45 m	€ 51 m	m

TABLE 23: PHYSICAL LAYER ESTIMATED COST SAVINGS PER GEOGRAPHICAL SCOPE

Part C
Deployment Scenarios

8 Deployment scenarios

8.1 Organisational models

A deployment scenario is the combination of applying an organisational model to a geographical scope at each different layer. A key policy focus is maintaining market choice for the national ANSPs[28] who should have freedom to select the most appropriate business model for them in each layer.

The organisational models define the types of organisations that operate in each of the three layers and drive benefits, given that benefits are largely driven by rationalisation and consolidation. In the current arrangements we have a single organisation – the national ANSP – responsible for provision of all required services. In the future, to support different market mechanisms to the various layers, a variety of organisational models have been postulated (see [1] and [4]).

We have adopted a simpler approach, based on the choices that the national ANSP could make for each layer:

a) National Provision – the national ANSP maintains provision of the service.
b) Regional Alliance – a group of ANSP collaborate to deliver an optimised service.
c) Outsourcing within a contestable market (which we assume is pan-European in nature).

Currently, the main forms of regional alliances used in ATM are Functional Airspace Blocks (FABs) which were introduced by the SES legislation and Industrial Alliances such as the Borealis Alliance. However, there is potential to improve the current arrangements. We recognise that the best alliances should have:

a) Common Culture – Creating a common culture that cultivates collaborative behaviour and is based on a clear understanding of roles and responsibilities as well as direction.
b) Homogenous Operations – Having commonalities and leveraging the differences to create value in a way that enables harmonisation and deployment of technologies.

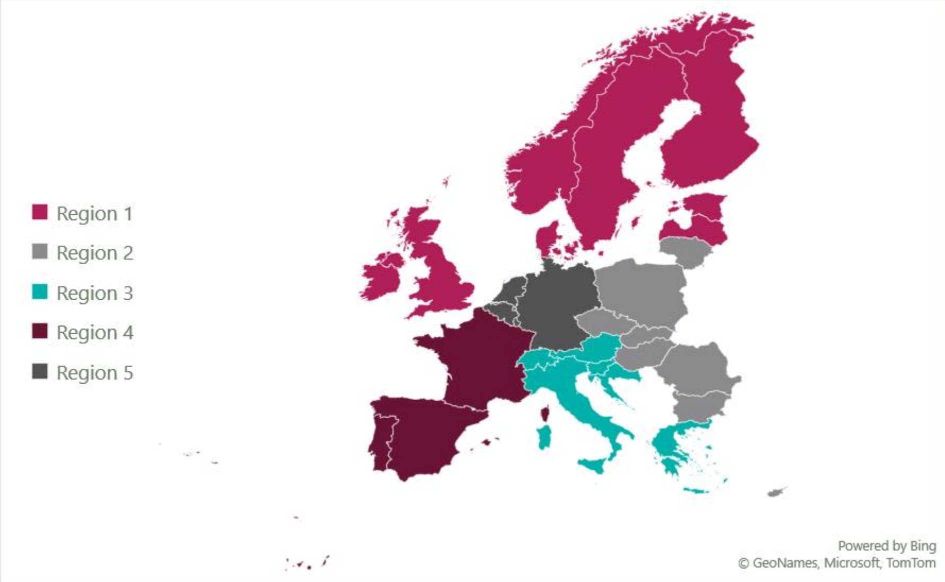
For our scenarios, we have developed two regional models (See Table 24) based on the existing configuration of FABs and five regional collaborations based around main traffic flows and adjusted to level traffic.

These configurations are merely illustrative. Detailed study on the optimum regional arrangements of the European network is key to maximise the benefits of regional collaborations.

[28] The national ANSP is the organisation that the MS delegates the responsibility for ATS provision.

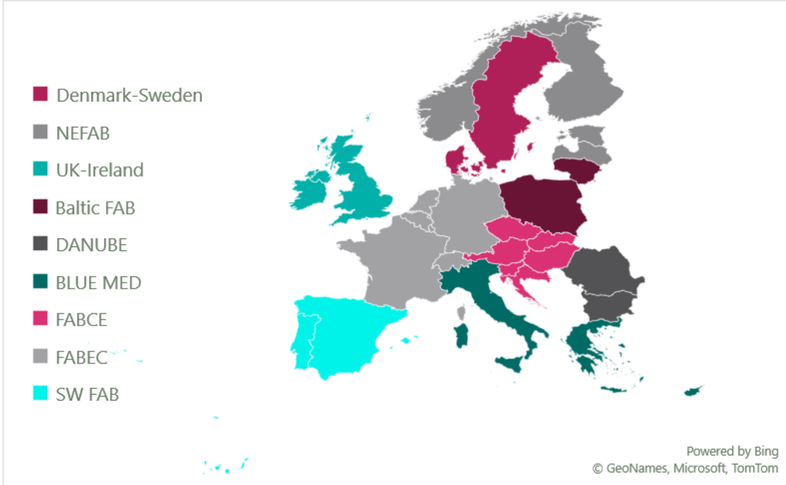
Regional	FABs

Regional



Region	Area	Countries	Flight-hours	Airspace km	Density (Flight hours/ airspace)	ACC
Region 1	North	Denmark, Finland, Ireland, Latvia, Norway, Sweden, UK, Estonia	6067007	3143200	1.9	14
Region 2	East	Lithuania, Poland, Bulgaria, Cyprus, Czech Republic, Hungary, Romania, Slovak Republic	5483984	1506400	3.6	8
Region 3	South-East	Italy, Austria, Croatia, Greece, Malta, Slovenia, Switzerland	6054095	1801300	3.4	11
Region 4	South-West	France, Portugal, Spain	5989351	3871000	1.5	12
Region 5	Central	Belgium, Germany, MUAC, Netherlands	6269560	742500	8.4	7

FABs



FAB	Countries	Flight-hours	Airspace km	Density (Flight hours/ airspace)	ACC
UK-Ireland	United Kingdom, Ireland	3149317	1337000	2.4	5
NEFAB	Estonia, Finland, Latvia, Norway	1381524	1314200	1.1	6
Denmark-Sweden	Denmark, Sweden	1465747	785000	1.9	3
Baltic FAB	Poland, Lithuania	1117906	408700	2.7	2
FABEC	France, Germany, Belgium, Netherlands, Luxembourg, Switzerland	10831270	1822100	5.9	14
FABCE	Czech Republic, Slovak Republic, Austria, Hungary, Croatia, Slovenia, Bosnia and Herzegovina (In this study Bosnia and Herzegovina are not considered.)	4472195	460400	9.7	6
DANUBE	Bulgaria, Romania	1609228	402000	4.0	2
BLUE MED	Italy, Malta, Greece, Cyprus	3105353	1674000	1.9	7
SW FAB	Portugal and Spain	2731457	2861000	1.0	7

TABLE 24: GEOGRAPHICAL SCOPES

8.2 Identified scenarios

A key consideration is that the national ANSPs should have a freedom to decide how to operate in each of the three layers. For this study, we assume:

a) The national ANSP will retain the ATSP role, but progressively work within an alliance with other ATSPs to deliver ATS services.
b) For the common data and physical layers, the national ANSPs will chose:
    a. Self-supply (including the possibility of supplying these services to other ATSPs)
    b. To form an alliance to supply services within a region; or
    c. To outsource with consolidation left to the market.

The national ANSP is expected to make different decision in each layer –even where they decide to form alliances, they may choose different combinations in different layers - for example smaller alliances for the ATS layer and larger alliances or outsourcings for the common data layer. However, if an active and contestable market is to be created for outsourced services, it is likely that this will need to be a common decision to ensure sufficient market size to support multiple providers. Table 25 defines scenarios we have chosen for further analysis.

#	Name	Description	ATS	Data	Physical
0	Baseline	Existing national regulated entities are maintained. This scenario is used as a reference against which the value of changes is measured.	National	National	National
1	FAB Alliances	ANSP form alliances within exiting FABs to optimise ANS provision, including consolidation of common data and physical layer services.	FAB	FAB	FAB
2	Regional Alliances	The same as Scenario 1 but based on larger regional alliances based on traffic flows and complexity.	Regional	Regional	Regional
3	Pan European Common Data Layer	National ANSPs form FAB level alliances to provide ATS, outsource common data layer services, and maintain physical layer services as a national asset.	FAB	European	National
4	Pan European Common Data and Physical Layers	The same as Scenario 3, but physical layer services are provided in a Pan-European market	FAB	European	European
5	Pan European Services	All three layers are provided by collaborations at the European level. The ATS layer is managed according to network needs, the other layers outsourced.	European	European	European

TABLE 25: IDENTIFIED SCENARIOS

The level benefits are discussed in the next section. It is important to note that at this stage we only consider how the scope of collaboration drives efficiency – whether competition or regulation would lead to better forms of collaboration is discussed in Part D.

9 Discussion of scenarios

9.1 Scenarios 1 and 2: Alliances

Scenarios 1 and 2 consider the benefits of alliances at two levels: FABs and regions as described in Table 24:

- Scenario 1 considers collaborative arrangements between ANSPs within the existing FABs to provide a fully combined service provision (Virtual Centre) acting as if they were a single entity.
- Scenario 2 considers the same collaborative arrangements but in five larger regions consisting of neighbouring countries with similar ATS complexity.

These Alliances enable benefits at each step:

- In Step 1, ANSPs rationalise their assets and systems in the data and auxiliary services and start working together to allow interconnection of the systems and procedures in the ATS layer driven by coordination to enable limited capacity sharing and contingency arrangements to happen within the Virtual Centre.
- In Step 2, the Alliance seeks an extra level of harmonisation which allows to set up full capacity sharing arrangements between the ACCs in the Virtual Centre and a considerable modernisation of the technology that supports the ATM data systems.
- In Step 3, automation and maturity of the systems enables a faster deployment of new technologies in any of the layers within the ACCs of a Virtual Centre.

Figure 19 illustrates how the benefits increase with the size of the alliances modelled.

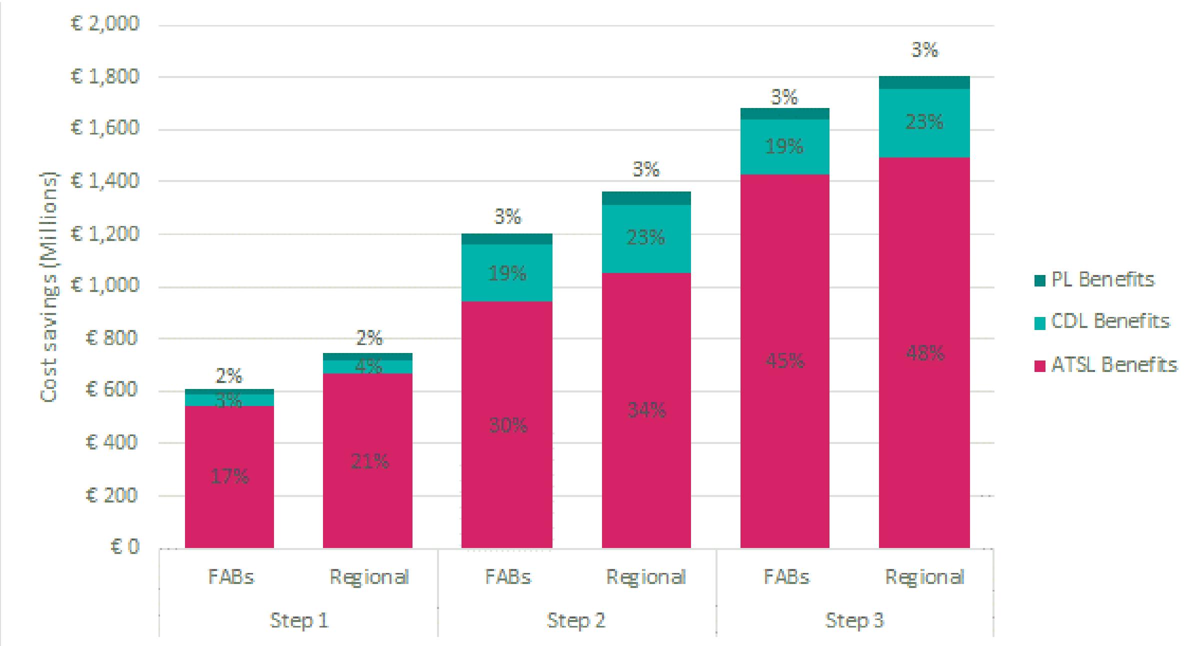


FIGURE 19: SCENARIOS 1 AND 2 LAYER BENEFITS

The ATS layer brings the biggest cost savings in both scenarios and steps. In step 1, the greatest cost saving is found in the ATS layer where a cost saving of 17% and 21% for scenarios 1 and 2 respectively as a result of the benefits of step 1 at the geographical scope that these scenarios consider (FABs and regions).

The Alliance organisational model allows the contingency arrangements to become a possibility in Step 1 resulting in the significant cost savings in this step. In Step 2 the ATS layer benefits from 30% and 34% of cost savings in scenarios 1 and 2 respectively as a consequence of enabling full capacity sharing in the virtual centres. In Step 3, increased automation allows savings of 45% and 48%.

The common data layer and the physical layer both have a low cost saving of less than 5% in step 1 - only 2% in the physical layer. However, in step 2 the common data layer sees a significant increase in the cost savings from less than 5% in step 1 to nearly 25% in step 2 given the introduction of modernised ATM data systems. The physical layer experiences slightly further cost savings in step 2 and 3 with a 1% increase. In step 3, the benefits of the common data layer are maintained.

9.2 Scenarios 3 and 4: Pan-European Common Data and Physical Layers

As benefits tend to increase with the geographical scope the next two scenarios consider collaboration at pan-European level:

- Scenario 3 considers extended collaboration in the common data layer whilst the physical layer is maintained as the current national regulated market.
- Scenario 4 considers extended collaboration in the common data layer and the physical layer.

Both scenarios contemplate the existence of FAB Alliances in the ATS layer. However, the benefits of the ATS layer will not be evaluated under these scenarios since they were already contemplated under Scenario 1.

In the common data layer, having three or more ADSPs at European level leads to a wider rationalisation of the ATM data systems in both Scenarios 3 and 4. In the physical layer, in Scenario 4 a wide rationalisation of the CNS assets leads to cost savings. In step 3, maturity of the systems enables a faster deployment of new technologies in all three layers (but are not quantified).

Figure 20 illustrates how the benefits increase as the collaborations are extended.

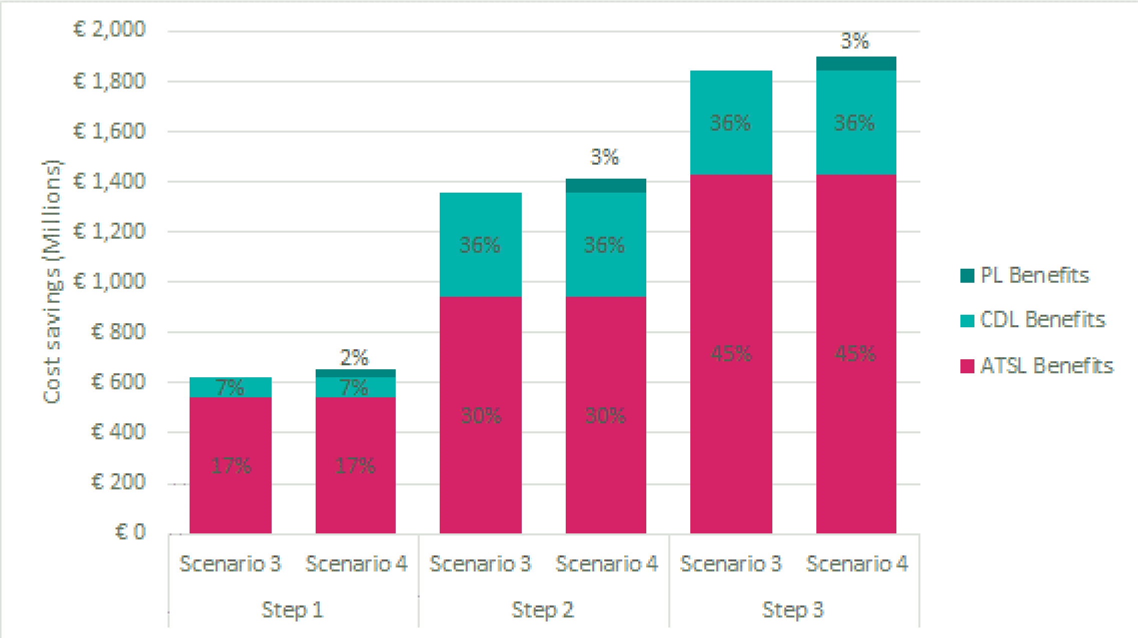


FIGURE 20: SCENARIOS 3 AND 4 LAYER BENEFITS

The benefits of a pan-European common data layer are more significant in step 2 than step 1. In step 1, the common data layer rationalisation is limited whereas in step 2 the cost savings increase up to 36% is due to the shift away from the current systems to cloud based services.

In Scenario 4, the benefits of pan European auxiliary services lead to cost savings of 2-3% in the layer. This results in an additional 1% of cost savings over the total identified benefits of Scenario 3.

9.3 Scenario 5: Pan-European Services

Scenario 5 considers the benefits of implementing pan-European services in all the layers now including the ATS layer leading to much greater cost savings.

In step 1, the ATS layer ensures systems are interoperable within all the European organisations enabling to achieve best in class operations to the maximum in Europe and pre-determined capacity sharing within the established European Virtual Centres.

In the ATS layer, step 2, and its increase in harmonisation of systems leads to dynamic capacity sharing and contingency shared within the European network.

In step 3, all the services experience lower deployment costs as upgrading systems becomes quicker and easier which in the ATS layer is enhanced by an increased automation of the systems and an increase in the flight hours that can be handled.

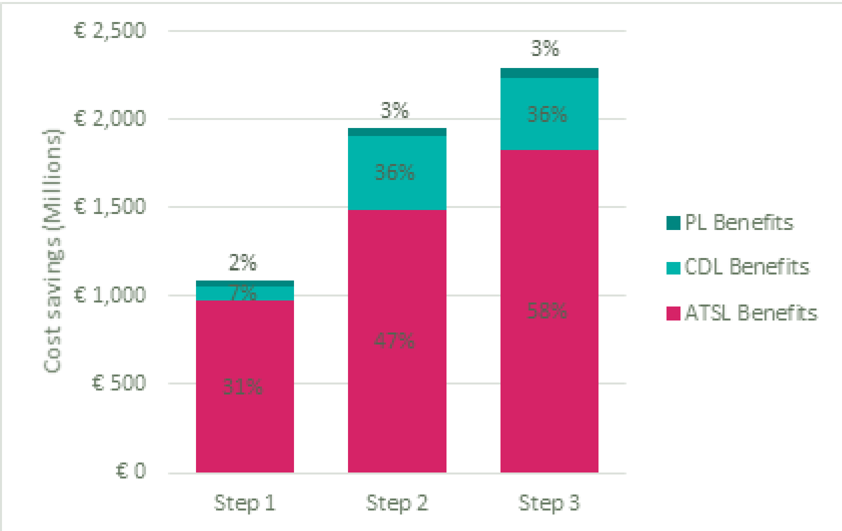


FIGURE 21: SCENARIO 5 LAYER BENEFITS

As Figure 21 shows, in Scenario 5 the benefits of having a European ATS layer introduce cost savings of 30% in Step 1 and they rise to nearly 60% in step 3. In step 1 the benefits of the common data layer and the physical layer are modest under 7% and it is not until step 2 is achieved that the common data layer benefits rise considerably up to 36%. However, the physical layer benefits are still low at 3%. The implication of such cost savings in the various layers and through the transition is that the total benefits increase from 18% in step 1 to 38% in Step 3.

9.4 What drives the benefits?

Figure 22 summaries the benefits to illustrate the main findings:

- The ATS layer has the largest potential benefits which are largely enabled by the existence of the common data layer.
- There are still significant benefits available from harmonisation of ATS provision in Europe, but this can be accelerated by the ability to collaborate effectively.
- The real benefit of virtualisation is potentially in Step 3 where the cost of capacity would be dramatically reduced by high levels of harmonisation and automation.

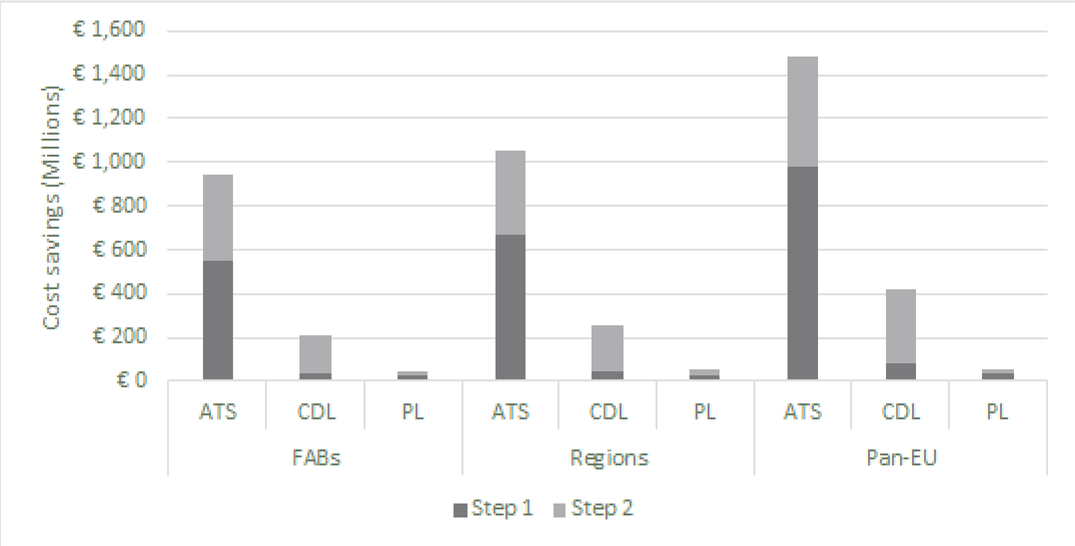


FIGURE 22: SUMMARY OF BENEFITS FOR STEPS 1 AND 2

Part D

Incentivisation

10 Market analysis

10.1 Market mechanisms

10.1.1 Context

In this part of the report, we consider how to incentivise virtualisation. In this section we consider each of the three layers as separate markets, discuss their size, costs, potential benefits and their ability of competition and collaboration to generate benefits. In the next section we consider how the future role of national ANSPs may change given virtualisation and finally in Section 12 we summarise our main findings and consider how future research could refine the concepts and arguments discussed on this report.

In previous parts, we have defined three markets and calculated the potential benefits of collaboration within each layer. If virtualisation had been adopted before 2018 across Europe – ATM costs could have been 30% cheaper and en-route ATFM delay targets would have been met with only unremovable delay would have remained e.g. caused by weather. The potential net benefit to Airspace Users would have been in the order of €3.5 bn per annum [35]. If virtualisation had been adopted by FABs, costs could have been 20% lower. These benefits are the maximum possible as a uniform application of virtualisation across the geographical scope is assumed and transition costs are excluded.

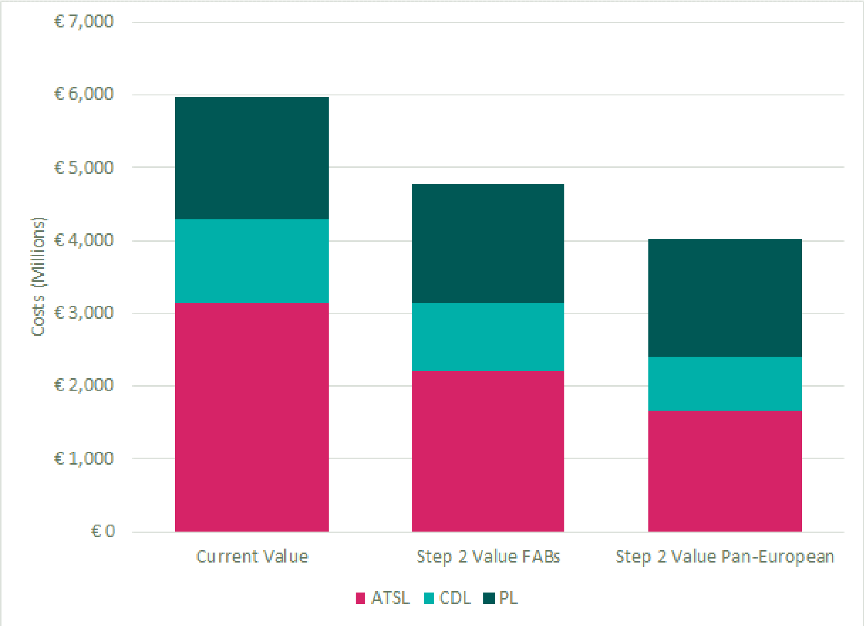


FIGURE 23: FUTURE COSTS OF ATM UNDER VIRTUALISATION

The real benefit of virtualisation is the reduction on the cost of capacity in Step 3 across all three layers. Without significant increase in costs, Step 3 would enable up to 3 times the traffic whilst meeting en-route ATFM delay targets [1].

Aviation has been severely curtailed by the pandemic and the long-term impacts on propensity to travel are not yet known [53]. The latest EUROCONTROL 5-year forecast [54] suggests that traffic will not return to 2018 levels before 2024 or even 2029 if vaccinations are not successful globally.

The quandary for the ATM industry is how to invest in modernisation when traffic (and therefore revenues) is lower. Justification is required to invest now in new infrastructure that increases flexibility and scalability to enable both increased capacity, as required by airspace users, and greater resilience to deal with future crises.

10.1.2 Managing the transition

The transition represents a technical challenge with new forms of standards and interoperability required. However, to achieve a successful technological change the real issue is in the organisational and regulatory sphere. This organisational transition cannot happen overnight and will need to go through different stages to get to its optimum form, but we know from other industries such as telecommunications or banking that it is possible.

Each step of the transition comes with investment and set-up costs that will lead to the benefits that each step enables, including:

- New Assets – new assets required to support virtual services.
- Stranded Assets – decommissioned assets with a residual book value.
- Exceptional Costs – one-off cost associated with organisational change, e.g. creating joint ventures.

However, the initial decision a national ANSP faces is not the investment but the organisational model or the form of collaboration with neighbouring ANSPs in each of the three operational layers. Which in turn leads to the questions of how best to incentivise forms of collaboration that yield larger benefits.

Under the Single European Sky, ANSPs operate under a form of economic regulation defined by the Performance Scheme and Common Charging Regulation [32]. The regulation fixes unit prices for a reference period with return on investment tied to the regulated asset base. Traffic and Risk sharing schemes are applied to reduce the risk to the service provider. ANSPs that operate under a contestable market are not subject to price control[29].

This form of economic regulation does not appear to incentivise the correct behaviours that are required to transition service delivery to the virtualisation model (e.g. [55]). ANSPs returns are based on capital employed (e.g. physical assets or infrastructure) which promotes ANSPs to increase planned capital expenditure (to increase allowed profitability) and to some degree to delay that expenditure (to increase actual profitability). An ANSP buying ATM data and CNS services will have lower CAPEX and higher OPEX (e.g. subscriptions to the underlying services) suggesting that switching to a TOTEX (total expenditure) approach [56] may be more beneficial than the current approach to successfully tackle the capex bias challenge by providing greater scope for making efficient CAPEX-OPEX trade-offs. This approach to price control has already been successfully applied in markets with similar characteristics such as the utilities industry in Italy and the UK.

Introducing competition in the ATM market should incentivise greater performance as entities strive to sustain and grow market power/share, resulting in downward pressure on prices and increased productivity. Competition tends to create a more cost-efficient and better-quality service, as entities are encouraged to shift to a more customer-centric approach in order to attain a better reputation than their competitors. So far competition has been limited to the Terminal ANS market [57]. With virtualisation it is possible to envisage competition in all three layers. However, to successfully introduce competition between firms we need to consider the notion of contestability. A contestable market has low barriers to entry and limited sunk costs allowing new entities to easily exit.

Each of the three AAS layers could be established as a contestable market – although careful consideration is required to ensure that the duplication of infrastructure and oversupply of assets to enable competition is not

[29] Currently this is limited to TANS market in specific MS including the UK.

greater than the benefits of competition. So, in analysing the individual markets for each layer we consider three issues:

- The size of the market and the level of benefits available.
- The forms of collaboration that realise those benefits and types of costs involved; and
- Whether a contestable market could exist to drive accrual of benefits.

10.2 ATS Layer as a market

10.2.1 Market size and benefits

The ATS layer is the largest market and has the greatest scope for improvement with the potential to reduce current costs of about €3 bn by up to 60%.

Existing costs	Rational transformation of costs	Revised costs (Europe wide)
Market size: € 3,150 m OPEX: 90% CAPEX: 10%	Reduction in costs as a result of: • Increased ATCO productivity enabled by Operational Excellence and increased automation. • The reduced capacity buffer that the dynamic capacity sharing enables.	Market size: € 1,660 m Reduction: -50%

TABLE 26: ATS LAYER MARKET SUMMARY

10.2.2 Collaboration in the ATS Layer

Three forms of collaboration could exist in the ATS layer:

- Intra-ANSP Virtual Centre (where more than one ACC is currently operated)
- Inter-ANSP Virtual Centre;
- Inter-ANSP Capacity Sharing.

These forms of collaboration all require investment in infrastructure renewal including modifications to the controller HMI to support remote access to ATM data services. Further the existing ATM system may need to be considered as a stranded asset if it is no longer used.

10.2.3 Contestability in the ATS Layer

The COMPAIR study [3] modelled the use of auctions as a means of introducing competition of en-route ATM services – however, based on the current architecture rather than virtual centres. The results suggest that competition could drive value for money in the market, but the "rules of the game" modelled in COMPAIR allowed ANSPs to lose competitions and either consolidate with other ANSPs or even go out of business.

From RoMiAD's perspective the identified benefits rely on collaboration to maximise the use of available capacity rather that organisational consolidation and therefore we do not feel that competition would encourage the correct collaborations. Further the high cost of entry (building an ATSU) would suggest that there are high barriers to creating a contestable market. However, in step 2 the "capacity on demand" style services could include competition when an ANSP decides to open an additional sector. This would happen if several ATSPs decided to operate under a model with a body running competitions to tackle demand and capacity balancing across regions/the network as explained in Sections 11.3 and 11.4 .

10.3 Common Data Layer as a market

10.3.1 Market size and benefits

The market size is in the order of €1 bn per annum, potentially reduced by 35% if the infrastructure is sufficiently harmonised. The flexibility provided to the ATS layer has three times the benefits available from rationalisation within the Common Data Layer itself.

Existing Costs	Rational transformation of costs	Revised Costs (Europe wide)
Market Size: € 1,150 m OPEX: 75% CAPEX: 25%	• Initial saving from rationalisation of infrastructure and systems. • Further saving from "commercialisation" of ATM data centres.	Market size: € 740 m Reduction: -35%

TABLE 27: COMMON DATA LAYER MARKET SUMMARY

10.3.2 Collaboration in the Common Data Layer

In order to provide a genuine common data layer (in which all authorised ATM actors can access all relevant information) is likely to be achieved by a collaboration of ADSPs - potentially specialising in different types of ATM data service (for example a specialist provision of VOIP for air-ground voice).

In the early stages, it has to be considered that ADSPs will actually be national ANSPs working collaboratively with other national ANSP under their existing SES certifications.

However, if we consider the longer term, then new entrants such as Joint Ventures between national ANSPs and system suppliers may create advantage by combining operational and system knowledge.

10.3.3 Contestability in the Common Data Layer

Contestability in the common data layer is a policy objective of the European Commission [4]. This is supported by our findings in that the Step 2 benefits (cloud services) far outweigh the rationalisation benefits in Step 1 and are a better enabler for Step 3.

As the cost of entry to the market may be initially high for new entrants as a result of the increasing ATM data system costs (described in Section 6.2), Early steps to create a contestable market would support new entrants and hence more likely to lead to commercialisation.

Two potential models have emerged during our consultation with stakeholders.

- Groups of ANSPs purchase an ANSP system for their entire area of responsibility. This model enables ATM Data Services to be provided by the organisation currently authorised to provide them.
- ANSPs subscribe to an ANSP system owned and operated by the system manufacturer. This model reduces the needs for ANSPs to maintain the ATM system but requires a new model for authorisation of the ADSPs.

Both models are viable, with the ANSP needing to decide how best to provide the overall service. Models that incentives the use commercial cloud computing solutions will lead to greater decreases in hardware costs.

10.4 Physical Layer as a market

10.4.1 Market size and benefits

The physical layer is different to the other two markets due to the range of services involved in addition to the CNS considered in this report, there is also AIS and MET. We see limited benefits within in the traditional CNS markets but much high potential when considering the transition of iCNS and deployment of new technologies.

Existing Costs	Rationale transformation of costs	Revised Costs (Europe wide)
Market Size: € 1,680 m OPEX: 65% CAPEX: 35%	• The limited benefits in the physical layer come from CNS rationalisation for legacy issues and of doing so at a pan-EU level. • Increased benefits when considering deployment of new technology.	Market size: € 1,620 m Reduction: -3%

TABLE 28: PHYSICAL LAYER MARKET SUMMARY

10.4.2 Collaboration in the physical layer

Collaboration in the physical layer has two potential benefits:

- Improved CNS planning due to horizontal collaborations.
- Reduced maintenance costs due to specialisation of service providers.

However, there is limited scope for benefits with the current infrastructure. The benefits are really as enabler of greater data sharing and simpler deployment of new assets.

10.4.3 Contestability in the physical layer

Establishing a contestable market in the provision of auxiliary services has been long in the plans of the European Commission. Mobile phone companies have demonstrated the benefits of competition that may apply to the physical layer in ATM - but it has also proved that regulation is required to incentivise the right behaviour and avoid high charges.

Given the high cost of assets, the entry barriers would be high, but a contestable market could be created by outsourcing operations and maintenance but not CNS planning and asset ownership which would be kept under the ANSP/State responsibility and therefore limit the horizontal collaboration benefit.

Moving beyond the traditional CNS market to new entrants, and in particular space-based CNS such as space-based ADS-B from Aireon[30] and datalink from Inmarsat[31] offers a different perspective for CNS where national ANSPs rely on different combinations of in-house traditional CNS (capable of enabling a minimum service) and outsourced external systems.

Pan-European procurement of commonly agreed new services by the Network Manager or another European body should be investigated as a way on minimising costs.

[30] https://aireon.com/

[31] https://www.inmarsat.com/en/solutions-services/aviation/focus-on/iris.html

11 Future role of the national ANSP

11.1 Role and responsibility

Nominally, a national ANSP has responsibility to the State for the provision of Air Traffic Services. The large number of States in Europe leads to a natural level of fragmentation that hinders cost-efficient service provision. For example, Table 29 summarises the latest FAA/Europe comparison [58].

Year 2016/17	U.S.	Europe	U.S. vs. Europe
Geographic Area (million km^2)	10.4	11.5	≈-10%
No of civil en-route ANSPs	1	37	
No of ATCOs in Ops	12 170	17 794	≈-32%
Flight hours controlled (million)	23.8	16	≈+48%
No of en-route facilities	23	62	-42
Source	FAA/ATO	EUROCONTROL	

TABLE 29: U.S. – EUROPE KEY ATM SYSTEM FIGURES AT A GLANCE (2017)

Prior to the AAS [1], the implied approach to reduce the cost of fragmentation was consolidation of area control centres and ANSPs using the MUAC model. This approach was not popular with States who retain sovereignty over airspace and wish to retain the ability to control their own airspace at least in times of crisis.

Virtualisation provides a different path – one that allows States to retain national ANSPs and infrastructure – but to collaborate in optimised service delivery including ATS delegation without regard to national boundaries.

In this section we consider the future role and responsibility of national ANSPs. We assume that national ANSPs retain the responsibility for ensuring ATS provision such that they:

- Can collaborate on service provision to reduce cost and increase network performance;
- Have freedom to decide how to collaborate; and
- Retain the ability to control all national airspace.

This leads ANSPs to make various decisions:

- How do I achieve the best outcome for my clients?
- Who do I want to collaborate with?
    - What services should I provide?
    - What services could be provided by others?
    - Do I want to provide services to other ANSPs?

In order to explore these decisions, we consider three future visions – an ANSP centric and Network Manager centric and hybrid solution.

11.2 ANSP Centric

In the ANSP centric model (Figure 24) the national ANSP retains the responsibility for ANS within the state and does so utilising the services of an external ADSP and a mixture of in-house and specialist auxiliary service providers.

The national ANSP collects revenues from the Airspace Users and establishes contracts and pays subscriptions as necessary for the Common Data and Physical Layers. The ANSP would remain a monopoly provider of ATS and be subject to economic regulation. Services purchased from a contestable market would not be subject to a price cap.

The national ANSP would need to ensure that ATM Data and auxiliary services are sufficient (in terms of coverage of quality of services) to provide an efficient and safe service in the ATS layer.

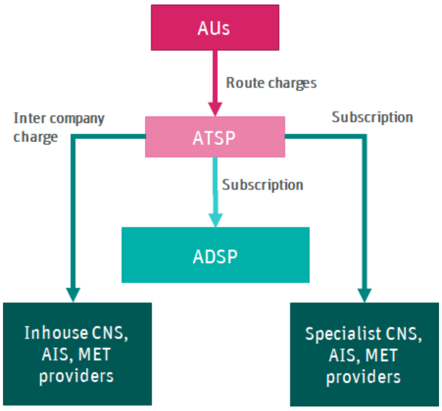


FIGURE 24: ANSP CENTRIC VIEW

The ANSP could operate separately in this model (Figure 25) or in the ATS layer the national ANSP could form an alliance with neighbouring ANSPs to form a cross-border Virtual Centre (Figure 26) in which fully dynamic capacity sharing is enabled through an alliance agreement that includes redistribution of revenues according to traffic handled.

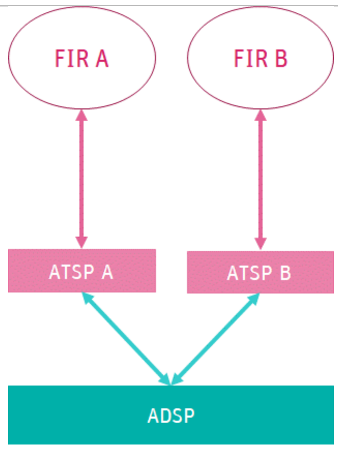


FIGURE 25: NATIONAL ANSP MODEL

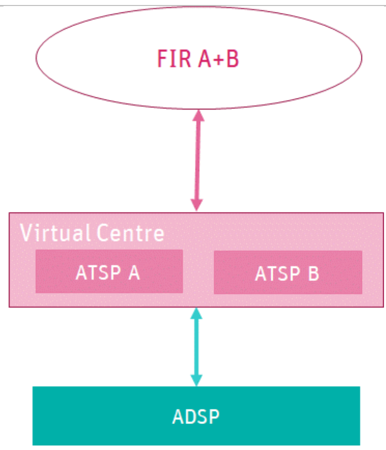


FIGURE 26: REGIONAL MODEL

In this case, ANSPs in the alliance would need to demonstrate that the common data and physical layers cover the combined area of responsibility of the virtual centre. This would be aided by the joint certification and designation of the virtual centre alliance (e.g. mutual recognition of the alliance by all National Supervisory Authorities).

This model is supported by a contestable market for ADSPs.

11.3 Network Centric Version

In the Network Centric version (see Figure 27) the Network Manager takes overall responsibility for ATS provision collecting Route Charges from Airspace Users and facilitating contracts with national ATSPs as well as ADSPs and auxiliary service providers. In this model, the Network Manager takes responsibility for ensuring the adequacy of the common data layer and physical layer.

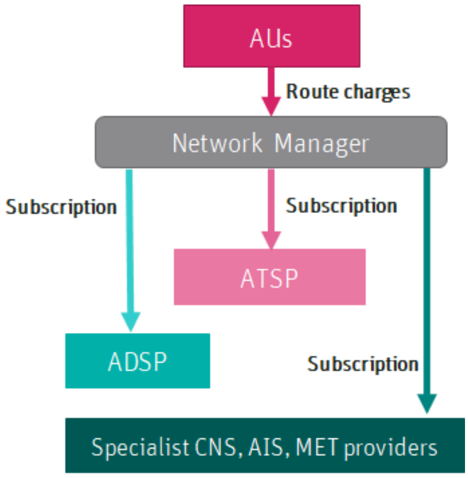


FIGURE 27: NETWORK CENTRIC MODEL

In the ATS layer, the national ATSPs retain the ability to manage State airspace, including asset ownership for a minimum service level, but the Network Manager could arrange for each ATSP to "open" additional sectors on behalf of other ANSPs to minimise ATFM delay (Figure 28) using a concept such as capacity on demand.

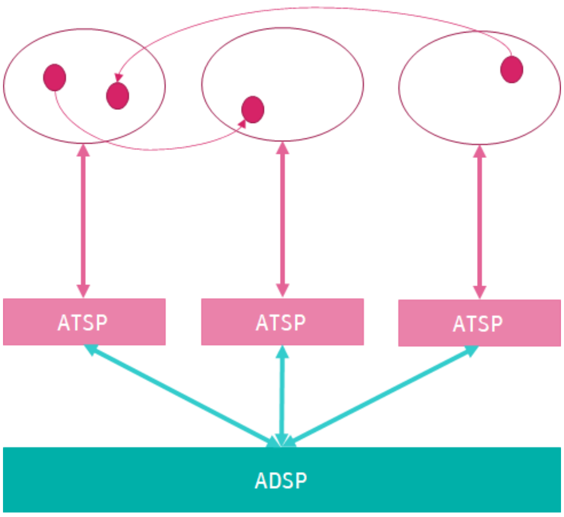


FIGURE 28: DYNAMIC AIRPSACE SHARING

In this model, it is assumed that the Network Manager would run competitions for the provision of common data layer and physical layer services using a harmonised procurement model enabling a more contestable market that if ANSPs chose different procurement models.

This model is more beneficial in Step 3 once the issues with dynamic cross-border service provision are resolved.

11.4 A hybrid model

The ANSP Centric model is most likely in the short term, with some form of Network Centric model being possible in the longer term. However, even in the short term the Network Manager should have a role in the provision of pan-European services of general good for the ATM community. This would include the transversal services such as ground-ground comms, SWIM registry and network cyber security as well as pan-European deployments of new CNS infrastructure -particularly air-ground comms (See Figure 29).

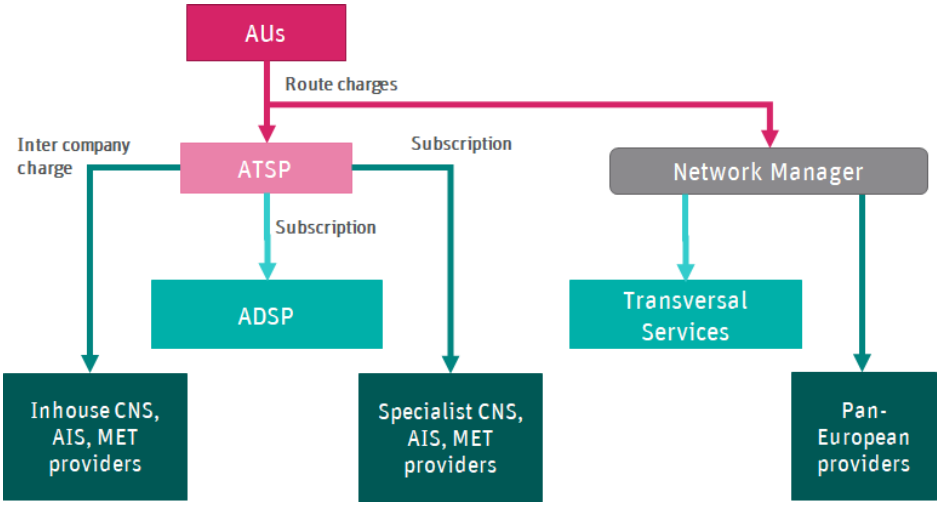


FIGURE 29: HYBRID DEPLOYMENT MODEL

We would also expect to see hybrid arrangements for airspace sharing where the predominant form of ATS delegation is within Virtual Centres, but the Network Manger has the ability to request limited forms of ATS delegation between Virtual Centres to maintain traffic flow due to unforeseen circumstances – such as volcanic eruptions (see Figure 30).

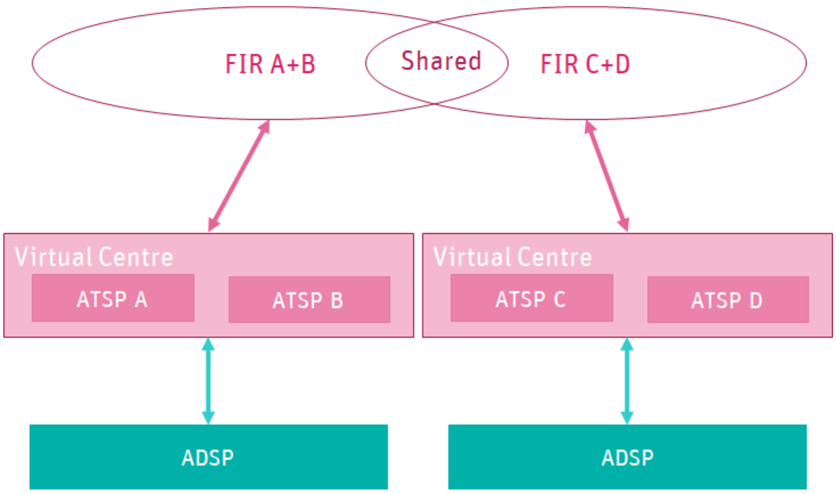


FIGURE 30: HYBRID ARRANGEMENT FOR ATS DELAGATIONS

12 Conclusions

12.1 Main findings

During the course of Project RoMiAD, it has become clear that virtualisation offers an opportunity to modernise ATM in Europe by enabling collaboration between national ANSPs in a way not currently achieved using the current technology within FABs. The virtual centre concept enables alliances of ANSPs to gain flexibility and scalability benefits previously only considered possible by consolidation of area control centre and even ANSPs.

It has also become clear that a greater understanding of the objectives of virtualisation is required to ensure that the technical solutions developed are capable of realising the benefits. Our analysis demonstrates that the real benefits (75% of the total) are through improvements in the ATS layer and are best enabled by the flexibility that the common data layer provides. The focus needs to be on building alliances and collaborations within the ATS layer to ensure that the common data layer is able to support those collaborations.

Although we have tried to stay clear of the technical issues in this study, it is worth considering the expectations on ADSPs. Currently ANSPs tend to specify ATM systems based on their operational concept. In order to join a common procurement programme for an ATM system, the ANSP has to agree (to some extent) on a common operational concept – hence each vendors' ATM system provides different functionality and at least initially (e.g. Step 1) it is likely that ADSPs will implement these variations. It makes sense that ANSPs collaborating in a virtual centre agree to use a single ADSP implementing the agreed variations. In the longer term, we may find that best value is driven by:

- Harmonisation so that there is no variation between the services offered by ADSPs; or
- Innovation driven by competition between ADSP leading to greater specialisation of ATM Data services.

In either case, the driver should be enabling ATS benefits rather than just cost reduction in the common data layer. Optimisation of each layer requires national ANSPs to make decisions to change organisational structures to enable the more beneficial forms of collaborations.

12.1.1 Optimising the ATS Layer

Within the ATS layer, the key issue is to understand the necessary geographical scope of collaborations, for example is it possible to:

- Create cross-border Virtual Centres based on key flows and choke points; and
- Inter Virtual Centre collaboration to support contingency and crisis management.

12.1.2 Optimising the Common Data Layer

Within the Common Data Layer, it is still necessary to consider the scope of services (as discussed in Section 2.2) and the potential benefits to airspace users and airports. It may well be that ATM data services include:

- Local/Regional services for specific areas of responsibility that include local specialisations that are procured by the Virtual Centre alliance; and
- Pan-European services procured by the Network Manager that are of general interest to all ATM Stakeholders.

Both types of service could form part of a contestable ADSP market in the future, but we should not exclude core ATM data services being provided by ANSP alliances, particularly in the short term.

12.1.3 Optimising the Physical Layer

The physical layer is not homogenous – in contains a range of services with very different operating characteristics, of which three groups seem to emerge:

- Local services based on assets deemed to be nationally important (particularly from a defence perspective) that will be owned by the national ANSP (but possibly operated under contract by specialists);
- Regional services that a group of ANSPs outsource collectively for cost efficiency gains; and
- Pan-European CNS provision (e.g. IRIS and AIREON) that could be optimally secured by the Network Manager.

Realisation of benefits can only be achieved if we understand the best scope for the provision of individual services but use performance-based CNS concepts to understand the best mix of services for a given operational context.

12.1.4 Getting incentivisation right

Virtualisation implies significant change for national ANSPs. It is a change that has already started, in terms of FAB based collaborations, regional alliance like Borealis and FDP procurement initiatives. In the age of SES and SESAR, European ANSPs talk to each other more and make more collective decisions than ever before.

These collaborations need to be deeper, particularly in terms of operational concepts and ATS delegations. The distributed architecture being discussed since the publication of the AAS [1] provides the platform for such collaborations. Their incentivisation includes:

- Supporting the validation and initial deployment of the proposed architecture (e.g. through the SESAR programme);
- Changing the performance scheme to ensure Return on Investment related to overall costs and not just CAPEX; and
- Ensuring restructuring costs are not penalised when setting price caps.

12.2 Future research

Project RoMiAD is deliberately wide in scope and relies on high level estimates to drive the arguments. We did not set out to solve all the problems but rather to explore the context to unearth where detailed research would be beneficial. In addition to the three areas discussed below there is clearly significant and necessary technical R&D underway in SESAR on how virtualisation will work, but that research must be informed by organisational concerns.

12.2.1 Refining the benefits

The key issue to unlocking the benefits of virtualisation is to understand the depth of collaboration required in the ATS layer. Throughout the report we have considered different forms of capacity sharing based on temporary ATS delegations. We have estimated the coarse benefits by considering a harmonised approach. With detailed information on actual sector usages (and pan-European simulation such as EUROCONTROL's NEST[32]) it would be possible to refine our scenarios to establish the optimum alliances and inter-alliance arrangements to minimise ATFM delay.

We also feel it would be beneficial to widen the benefits argument to the network effects of airlines and airports having access to common data layer services.

[32] https://www.eurocontrol.int/model/network-strategic-modelling-tool

We also recognise that our estimates would be improved by both a better understanding of the real costs of ATM systems and their trends as well as detailed information on current and planned CNS assets but feel that this is not a priority.

12.2.2 Refining the regulations

We have not had time in Project RoMiAD to reflect properly on the SES regulations and indeed the Commission's proposals for a recast of SES2 [59]. We recognise that a regulatory reform is necessary to enable and incentivise virtualisation, including:

- Approval and oversight of ADSPs.
- Certification and/or approval of distributed architectures and in particular cloud-based services.
- Form of economic regulation and definition of contestable markets for each layer.
- Setting performance targets and financial penalties to incentives inter-ANSP measures to reduce ATFM delay.
- Charging, revenue distribution and risk management within a virtual centre.
- Financial support for early adopters.

12.2.3 Driving airline behaviours

A final area that we have not considered at all, but which we believe needs careful consideration is the potential environmental benefits achievable from virtualisation if its incentivises the correct airline behaviours – that is ensuring the least fuel consuming route is nominally the most economic from an overall cost perspective. Current legislation provides various potential mechanisms that have been found to be non-ideal for the current service provision arrangements (e.g. [60]).

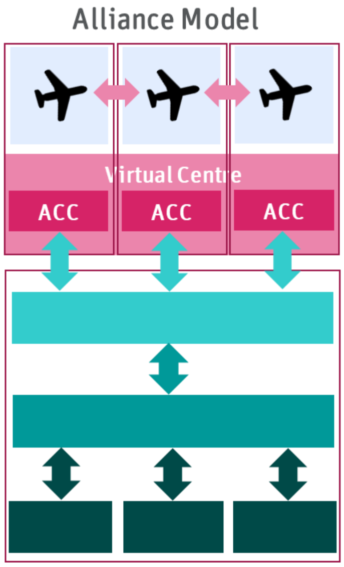
Virtualisation should offer greater incentives for ANSPs to minimise ATFM delays and share revenues and traffic risk, leading to a different applicability for mechanisms such as:

- Common Charging;
- Congestion Charging; and
- Price Modulation for Equipage.

We therefore feel that a detailed study of en-route charging should be performed for this new context.

Annexes

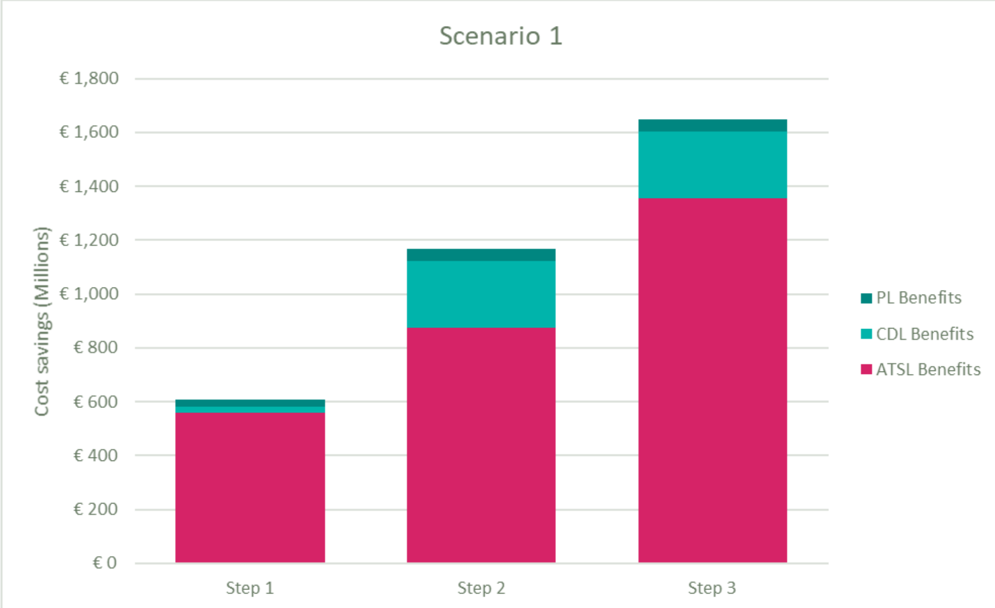
Annex A: Scenario descriptions

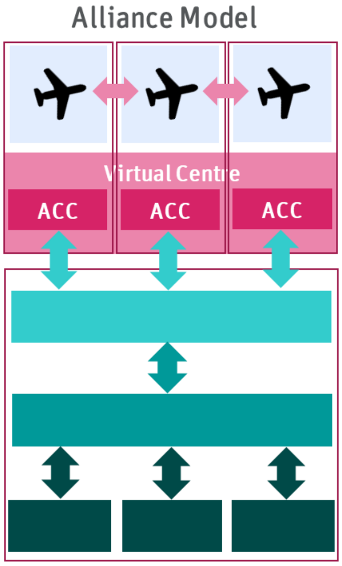
Name	Scenario 1: Alliance Model at FAB level
Overall Description	 The Alliance Model is fundamentally a joint venture constructed by a group of countries which bring cost savings from collaborating within a given FAB in all the layers. It is essentially a group of ANSPs operating common data layer and physical layer services. In this model, regional collaboration through a joint venture delivers cost-efficiency. The ATSPs collaborating in the virtual centre would also collaborate in the provision of ATM data services and physical data services. This collaboration would initially be regulated in the same way as the ATSP – but with potentially reduced regulatory burden if the operational efficiencies are commensurate with potential benefits of competition. This model is perhaps not new in that such collaborations have always been possible and in the cases of COOPANS and Borealis delivered specific benefits. The difference is that AAS deployment offers an easier opportunity to create a deeper collaboration on service provision.
Layers	• The ATS Layer is a regional collaboration in FABs, where national ATSP operate an ACC collaborating in a virtual centre. • The Common Data Layer Physical Layer are also regional collaborations where the Alliance creates a "Services Company" to provide all other services. The Alliance buys or maintains two high-end ATM data systems (FDP and RDP) and decommissions the other in the Common Data Layer and ANSPs transfer all the national CNS assets to be used by the Alliance in the Physical Layer.
Benefit scope	In this model, the benefits are enabled in three steps: • In Step 1, ANSPs rationalise their assets and systems in the data and auxiliary services and start working together to allow interconnection of the systems and procedures in the ATS layer driven by coordination to enable enables limited capacity sharing and contingency arrangements to happen within the Virtual Centre. • In Step 2, the Alliance seeks an extra level of harmonisation which allows to set up full capacity sharing arrangements between the ACCs in the Virtual Centre and a considerable modernisation of the technology that supports the ATM data systems. • In Step 3, automation and maturity of the systems enables a faster deployment of new technologies in any of the layers within the ACCs of a Virtual Centre.

Cost savings

Step	ATSL Benefits	% ATSL	CDL Benefits	% CDL	PL Benefits	% PL	Total Benefits	% Total
Step 1	€ 560 m	18%	€20 m	2%	€ 27 m	2%	€ 610 m	10%
Step 2	€ 870 m	28%	€ 250 m	21%	€ 45 m	3%	€ 1,170 m	19%
Step 3	€ 1,360 m	48%	€ 250 m	21%	€ 45 m	3%	€ 1,850 m	28%

Benefits of different steps



<table>
<tr><th>Name</th><th>Scenario 2: Alliance Model at Regional level</th></tr>
<tr><td>Overall description</td><td>

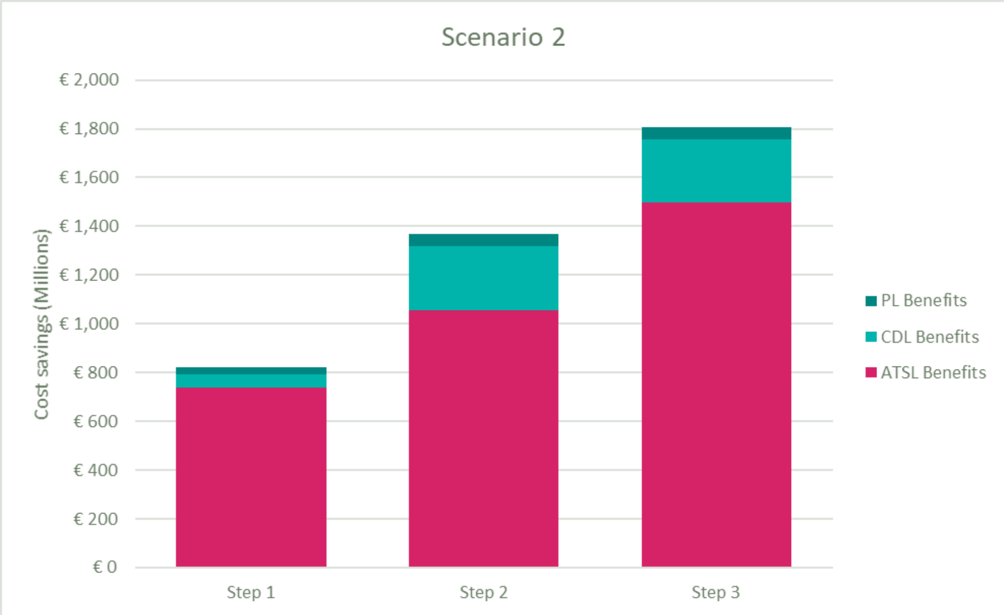
The Alliance Model is fundamentally a joint venture constructed by a group of countries which bring cost savings from collaborating within a given region in all the layers. It is essentially a group of ANSPs operating common data layer and physical layer services.
In this model, regional collaboration through a joint venture delivers cost-efficiency. The ATSPs collaborating in the virtual centre would also collaborate in the provision of ATM data services and physical data services. This collaboration would initially be regulated in the same way as the ATSP – but with potentially reduced regulatory burden if the operational efficiencies are commensurate with potential benefits of competition.
This model is perhaps not new in that such collaborations have always been possible and in the cases of COOPANS and Borealis delivered specific benefits. The difference is that AAS deployment offers an easier opportunity to create a deeper collaboration on service provision. </td></tr>
<tr><td>Layers</td><td> The ATS Layer is a regional collaboration, where national ATSP operate an ACC collaborating in a virtual centre.
The Common Data Layer and Physical Layer are also regional collaborations where the Alliance creates a “Services Company” to provide all other services. The Alliance buys or maintains two high-end ATM data systems (FDP and RDP) and decommissions the other in the Common Data Layer and ANSPs transfer all the national CNS assets to be used by the Alliance in the Physical Layer. </td></tr>
<tr><td>Benefit scope</td><td> In this model, the benefits are enabled in three steps:

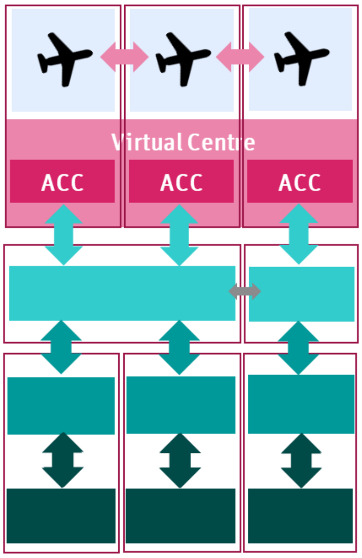
In Step 1, ANSPs rationalise their assets and systems in the data and auxiliary services and start working together to allow interconnection of the systems and procedures in the ATS layer driven by coordination to enable enables limited capacity sharing and contingency arrangements to happen within the Virtual Centre.
In Step 2, the Alliance seeks an extra level of harmonisation which allows to set up full capacity sharing arrangements between the ACCs in the Virtual Centre and a considerable modernisation of the technology that supports the ATM data systems.
In Step 3, automation and maturity of the systems enables a faster deployment of new technologies in any of the layers within the ACCs of a Virtual Centre.
</td></tr>
</table>

Cost savings

Step	ATSL Benefits	% ATSL	CDL Benefits	% CDL	PL Benefits	% PL	Total Benefits	% Total
Step 1	€ 740 m	24%	€ 50 m	4%	€ 30 m	3%	€ 820 m	14%
Step 2	€ 1,050 m	34%	€ 260 m	23%	€ 50 m	3%	€ 1,370 m	23%
Step 3	€ 1,500 m	48%	€ 260 m	23%	€ 50 m	3%	€ 1,800 m	30%

Benefits of different steps

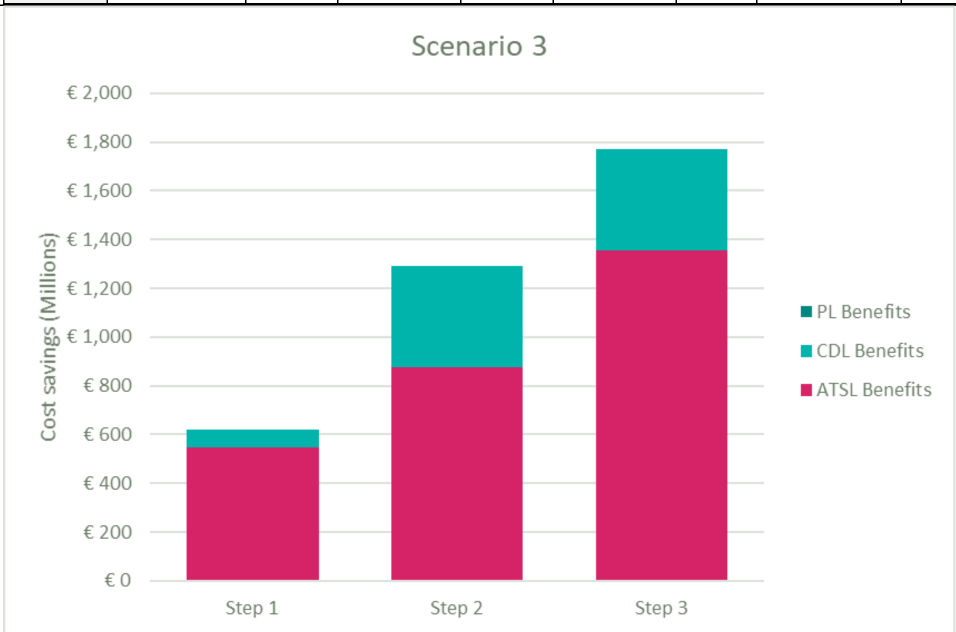


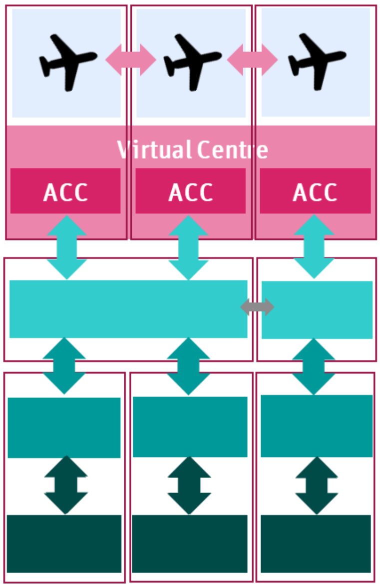
Name	Scenario 3: Pan European Common Data Layer
Overall Description	 Within this scenario we consider of a pan European common data layer via a new breed of service provider – the ADSP or ATM Data Service Provider. Legislation needs to ensure that there is at least one ADSP that every ATSP can subscribe to. It also requires establishing a common service definition including appropriate standards and rules covering fair access to data. We consider for this scenario there would be at least 3 ADSPs in Europe. Moving from the bespoke hardware of previous FDPs to a largely software defined product running "in the cloud" may lead to significantly reduced CAPEX and the possibility of real competition between ADSPs. In the interim, however, it may be necessary to ensure collaboration between ADSPs. In this scenario we consider that physical layer services would continue to be provided largely by the national ATSPs from their regulated business with economic regulation used to incentivise collaboration to reduce costs regionally. Whilst this may not be the most efficient way of organising the layer it does allow for national control of assets that can have a dual civil/military role.
Layers	In the ATS layer one or more ANSPs decide to operate a Virtual Centre within a FAB with an external ADSP and they invest in controller working positions and communication upgrades. However, as the FDP is managed and rationalised by a ADSP the ANSP divests in ATM data services. In the physical layer, they maintain ownership of CNS assets entering an agreement with the ADSP to ensure that data is well-managed.
Benefit scope	In this model, the benefits are enabled in the first three steps of the transition: • Step 1: To start with, the systems and procedures in the ATS layer are harmonised. However, no contingency arrangements can be done within the FAB since the data services are outsourced. The competitive ADSPs at European level leads to a wider rationalisation of the ATM data systems. However, CNS assets are still managed as they were by individual ANSPs nationally leading to no benefit in this layer. • Step 2: Once the step 1 benefits are achieved and arrangements are well established with the ATSPs capacity sharing can fully happen between the ACCs in the FAB and commercialisation of the data systems occur at a European level. • Step 3: In the ATS layer automation and maturity of the systems enables a faster deployment of new technologies in any of the layers within the ACCs of a Virtual Centre in FABs. In the Common Data layer, the benefit is deploying new advanced ATM data services throughout Europe that would be tailored to the ATSPs needs as well as quicker to synchronise across centres and cheaper. However, under the scope of this study the Common Data layer benefits in Step 3 are not quantified.

Cost savings

Step	ATSL Benefits	% ATSL	CDL Benefits	% CDL	PL Benefits	% PL	Total Benefits	% Total
Step 1	€ 550 m	17%	€ 80 m	7%	€ 0 m	0%	€ 620 m	10%
Step 2	€ 870 m	28%	€ 420 m	36%	€ 0 m	0%	€ 1,290 m	22%
Step 3	€ 1,360 m	43%	€ 420 m	36%	€ 0 m	0%	€ 1,770 m	30%

Benefits of different steps



<table>
<tr><th>Name</th><th>Scenario 4: Pan European Common Data Layer and Physical Layer</th></tr>
<tr><td>Overall Description</td><td>


In this scenario we will consider the benefits of pan-European market to the physical layer whilst having a pan-European ATM data service market and FAB alliances in the ATS layer. We note that there are already commercial entities providing these services – ARINC and SITA in communications, ESSP in navigation and AIREON in surveillance. None of these entities provide a complete service – and a key role of an ANSP is to combine in-house and commercial services to deliver the overall service requirements. To some extent this role may shift to the ADSPs.

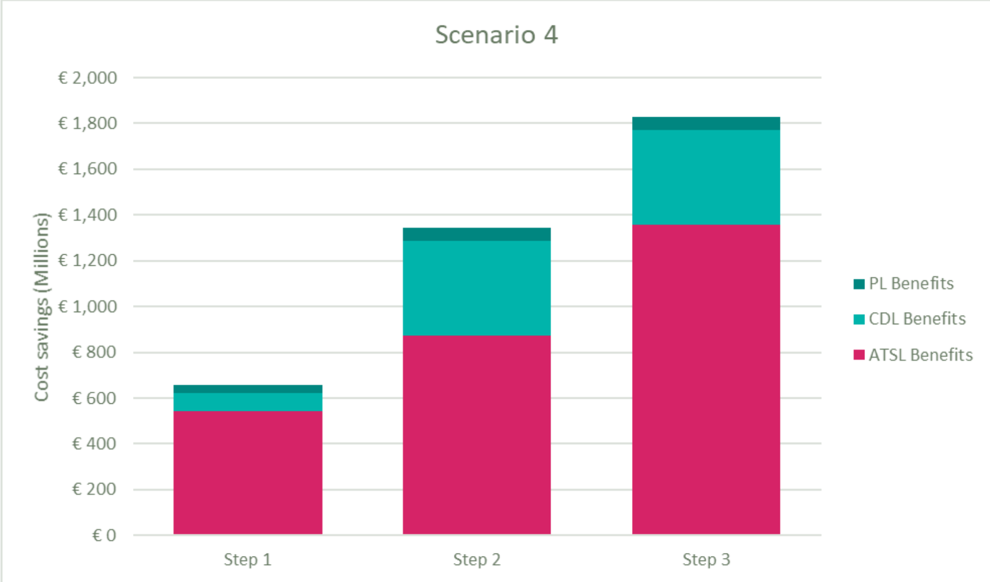
The other consideration in the physical layer is asset ownership. If the benefits come from reducing the number of assets, then it does not make sense to create competition by duplicating the assets. This may mean that competition is “for the market” – where the service provider is selected for several years in advance and may be leased the required assets rather than the more usual “in the market” competition where the consumer of the service chooses the provider when accessing the service - rand based on operating nationally owned assets.
</td></tr>
<tr><td>Layers</td><td>In the ATS layer one or more ANSPs decide to operate a Virtual Centre with an external ADSP, and they invest in controller working positions and communication upgrades. However, as the FDP is managed and rationalised by a ADSP the ANSP divests in ATM data services. In the physical layer, they transfer the ownership of CNS assets to a third party which will competitively manage the data through an agreement with the ADSP.</td></tr>
<tr><td>Benefit scope</td><td>
In this model, the benefits are enabled in the first three steps of the transition:

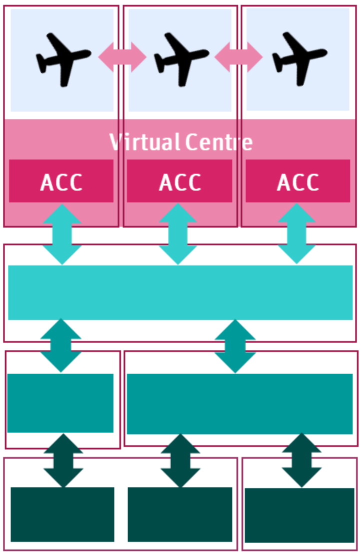
- Step 1: To start with, the systems and procedures in the ATS layer are harmonised. However, no contingency arrangements can be done within the FAB since the data services are outsourced. The competitive ADSPs at European level leads to a wider rationalisation of the ATM data systems. In the physical layer, CNS assets are rationalised at a European level.
- Step 2: Once the step 1 benefits are achieved and arrangements are well established with the ATSPs capacity sharing can fully happen between the ACCs in the FAB and commercialisation of the data systems occur at a European level. The auxiliary services are consolidated at a European level.
- Step 3: In the ATS layer automation and maturity of the systems enables a faster deployment of new technologies in any of the layers within the ACCs of a Virtual Centre in FABs. In the Common Data layer, the benefit is deploying new advanced ATM data services Europe wide and for the auxiliary services new automated systems experience a European coordinated and simplified coordination. However, under the scope of this study the Common Data layer and physical layer benefits in Step 3 are not quantified.
</td></tr>
</table>

Cost savings

Step	ATSL Benefits	% ATSL	CDL Benefits	% CDL	PL Benefits	% PL	Total Benefits	% Total
Step 1	€ 550 m	17%	€ 80 m	7%	€ 30 m	2%	€ 660 m	11%
Step 2	€ 870 m	28%	€ 420 m	36%	€ 60 m	3%	€ 1,350 m	23%
Step 3	€ 1,360 m	43%	€ 420 m	36%	€ 60 m	3%	€ 1,830 m	31%

Benefits of different steps



<table>
<tr><th>Name</th><th>Scenario 5: Pan EU Services</th></tr>
<tr><td>Overall Description</td><td>


Managing ATM services in a sustainable and efficient manner at a European level can be achieved through the application of two main economic mechanisms: competition or collaboration. Both mechanisms are foreseen to drive cost-efficiency in all the layers at a European level and is based around the capacity broker model already proposed by previous studies.

This final scenario is drawn from the COCTA [2] study and recommendations of the Wise Persons Group report. It foresees a new role for the Network Manager as Capacity Broker with the responsibility for ensuring that all three layers are properly defined and have optimised infrastructure operated in an efficient manner. One way of achieving the latter could be to organise competitions for services in each of the layers.

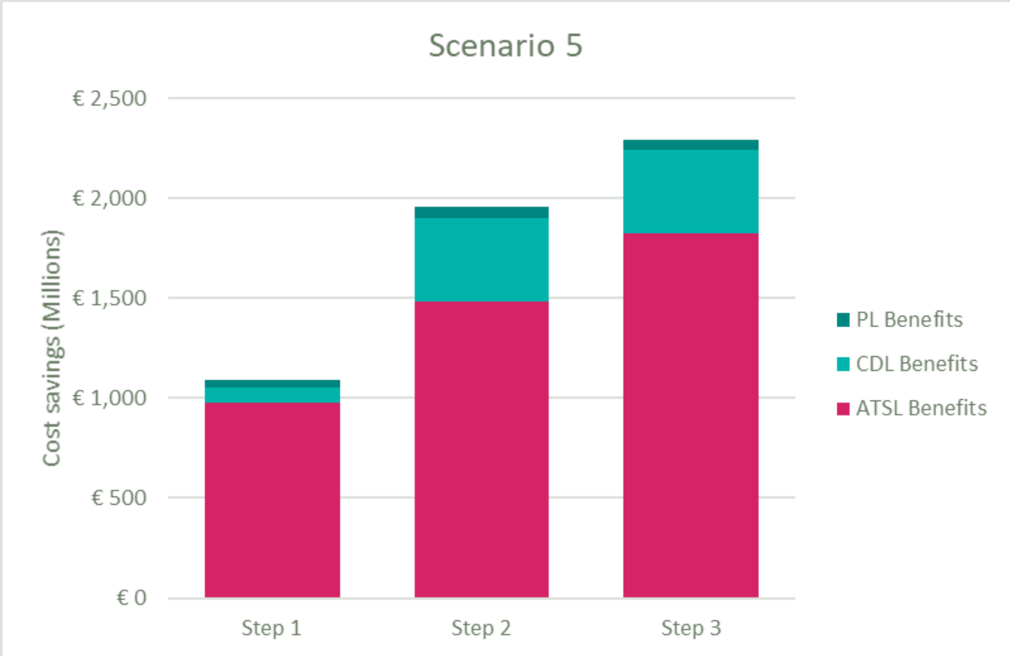
Regulation could be used to ensure that the Common Data Layer provides an efficient service and the certainty that this creates can incentivise contestability in the ATS and Physical Layer. This supports well having one single pan-European ADSP and enhances pan-European consolidation of the other two layers. In this case, the Network Manager could be the moderator that owns and operates the Common Data Layer whilst acting as a broker for the other two layers.
</td></tr>
<tr><td>Layers</td><td>In this model, ATSPs operate ACCs as an element of a network at virtual level by providing ATS. These services are purchased by an organisation that is in charge of the network capacity-demand balancing. In the common data layer, there are multiple ADSPs, at least three to allow competition, and regulation is in place to ensure coverage of service levels and interoperability. In the physical layer, there is a market for pan-European providers of the auxiliary services</td></tr>
<tr><td>Benefit scope</td><td>
Escalating the benefits into a wider European scope in the three layers allows fully optimised systems and operations bringing maximum cost reduction in all the steps:

- Step 1: The ATS layer ensures systems are interoperable within all the European organisations enabling to achieve best in class operations to the maximum in Europe and pre-determined capacity sharing within the established European Virtual Centres. The common data layer and the physical layer see some rationalisation of their infrastructure.
- Step 2: Cloud services are commercialised at a European level and further consolidation of the physical layer to avoid redundant coverage is achieved. In the ATS layer, step 2, and its increase in harmonisation of systems leads to dynamic capacity sharing and contingency shared within the European network.
- Step 3: All the services experience lower deployment costs as upgrading systems becomes quicker and easier which in the ATS layer is enhanced by an increased automation of the systems and an increase in the flight hours that can be handled. However, under the scope of this study the Common Data layer and physical layer benefits in Step 3 are not quantified.
</td></tr>
</table>

Cost savings

Step	ATSL Benefits	% ATSL	CDL Benefits	% CDL	PL Benefits	% PL	Total Benefits	% Total
Step 1	€ 980 m	31%	€ 80 m	7%	€ 34 m	2%	€ 1,090 m	18%
Step 2	€ 1,490 m	47%	€ 420 m	36%	€ 56 m	3%	€ 2,000 m	33%
Step 3	€ 1,820 m	58%	€ 420 m	36%	€ 56 m	3%	€ 2,300 m	38%

Benefits of different steps



Annex B: Acronyms

Acronym	Definition
ATM	Air Traffic Management
AAS	Airspace Architecture Study
ACC	Area Control Centre
ACE	ATM Cost Efficiency
ADF	Automatic Direction Finder
ADS-B	Automatic Dependent Surveillance-Broadcast
ADSP	ATM Data Service Provider
AIS	Aeronautical Information Service
AISP	AIS Provider
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATFM	Air Traffic Flow Management
ATS	Air Traffic Services
ATSL	Air Traffic Services Layer
ATSEP	Air Traffic Safety Electronics Personnel
ATSP	Air Traffic Service Provider
ATSU	Air Traffic Service Unit
AU	Airspace Users
AWS	Amazon Web Services
BA	Business Aviation
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CDL	Common Data Layer
CNS	Communications, Navigation and Surveillance
CNSP	CNS Provider
COM	Communication
COTS	Commercial Off-The-Shelfs

CWP	Controller Working Position
DME	Distance Measuring Equipment
EU	European Union
EUIR	European Upper Information Region
FAB	Functional Airspace Block
FDP	Flight Data Processing system
FIR	Flight Information Region
GA	General Aviation
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organization
IP	Internet Protocol
IT	Information and Technology
JV	Joint Venture
KTN	Knowledge Transfer Network
LoA	Letters of Agreement
MET	Meteorological Services
METP	MET Provider
MLAT	Multilateration
NAV	Navigation
NAVAIDS	Navigation Aid
NDB	Non-Directional Beacon
NM	Network Manager
NSA	National Supervisory Authority
OPEX	Operating Expenditure
OPS	Operations Support
PENS	Pan European Network Service
PL	Physical Layer
PRB	Performance Review Body
PRC	Performance Review Commission
PRR	Performance Review Report
PRU	Performance Review Unit
QoS	Quality of Service
RAB	Regulatory Asset Base

RDP	Radar Data Processing system
RNAV	Area Navigation
RNP	Radio Navigation Performance
RP	Reference Period
RVSM	Reduced Vertical Separation Minima
SATCOM	Satellite Communication
SDP	Surveillance Data Processing system
SES	Single European Sky
SESAR	Single European Sky ATM Research (Programme)
SJU	SESAR Joint Undertaking
SSR	Secondary Surveillance Radar
SUR	Surveillance
SWIM	System-Wide Information Management
TBO	Trajectory-Based Operations
TC	Terminal Control
TEN-T	Trans-European Transport Network
TOTEX	Total Expenditure
UAC	Upper Area Centre
VC	Virtual Centre
VCCS	Voice Communication (and) Control System
VDL	VHF Data Link
VHF	Very High Frequency
VOR	VHF Omnidirectional Range
WAM	Wide Area Multilateration
WAN	Wide Area Network

Annex C: References

[1] A proposal for the future architecture of the European airspace, SESAR Joint Undertaking, 2019. Available at: https://www.sesarju.eu/node/3253

[2] Coordinated Capacity Ordering and Trajectory Pricing for Better-Performance ATM – COCTA, SESAR Joint Undertaking, 2018. Available at: https://www.sesarju.eu/projects/cocta

[3] Competition for Air Traffic Management (COMPAIR), SESAR Joint Undertaking. Available at: https://www.compair-project.eu/

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