SESAR Engage KTN – catalyst fund project final technical report

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1. Abstract and executive summary

1.1 Abstract

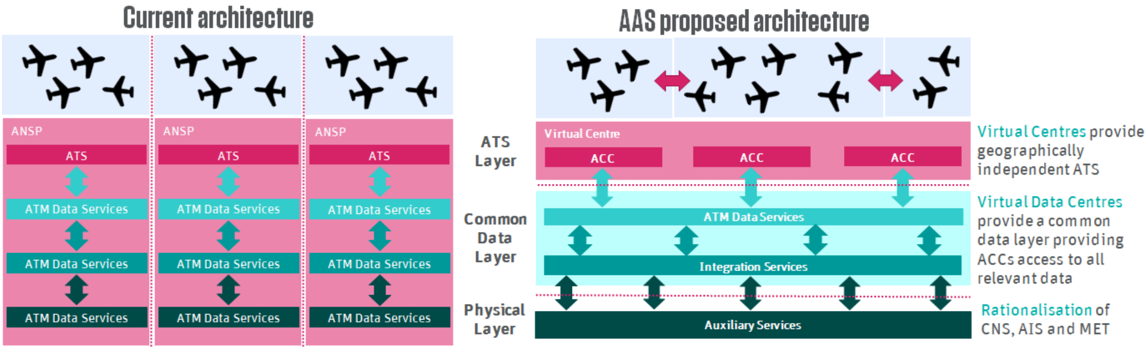
Virtualisation provides a path for air navigation service providers (ANSPs) to address the implementation of the open architecture proposed by the Airspace Architecture Study (AAS). Project RoMiAD has developed an understanding of the high-level benefits of deploying the distributed architecture proposed by the AAS and potential mechanisms to incentivise the organisational reengineering necessary to achieve a Digital European Sky whilst ensuring national sovereignty over airspace.

During the course of Project RoMiAD, it has become clear that if virtualisation had been adopted before 2018 across Europe – ATM costs could have been 30% cheaper and there would have been no significant en-route delay – only unremovable delay would have remained e.g. caused by weather. 75% of the benefits come from improvements in the air traffic services (ATS) layer - increasing Air Traffic Controller Officer (ATCO) productivity and capacity sharing - and are best enabled by the flexibility that the common data layer provides. The focus to achieve the benefits needs to be on building alliances and collaborations within the ATS layer to ensure that the common data layer can support those collaborations.

1.2 Executive summary

Objective

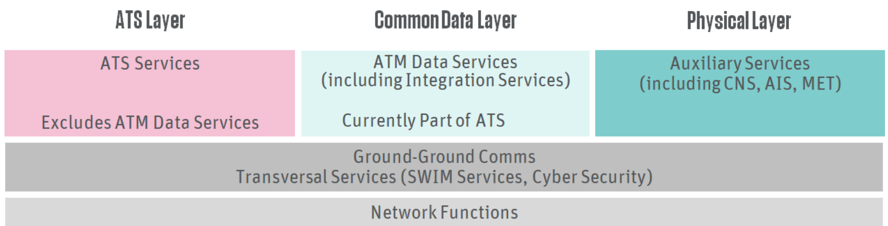
The European ATM system is in need of modernisation – in particular to increase performance, resilience and sustainability. The current system is a patchwork of national ANSPs operating vertically integrated systems. A single organisation therefore typically provides all the necessary services – from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



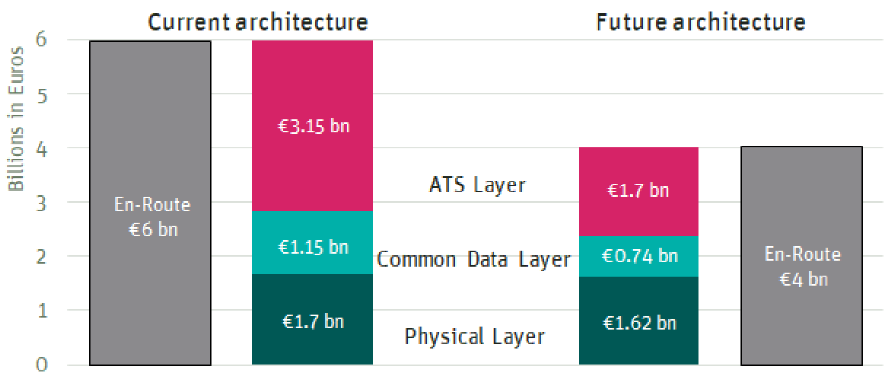
The future system proposed by the Airspace Architecture Study (AAS) breaks down the current vertically integrated systems to enable a more efficient set of services to be integrated horizontally. The architecture is based on three layers: air traffic services (ATS) layer, common data layer and physical 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 on the evolution of the ATS, Common Data and Physical Layer for en-route ATM.



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 €3.15 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%

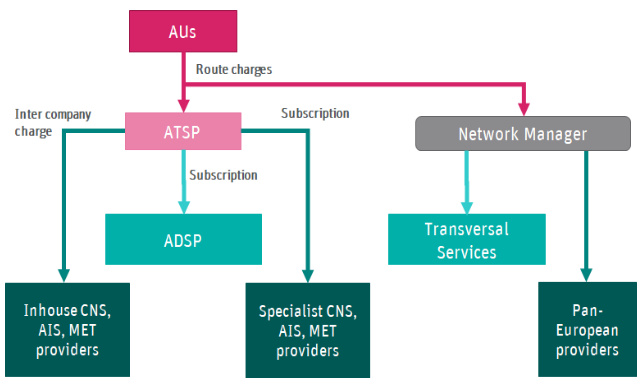
Physical Layer: The physical layer is different to the other two markets due to the range of services involved in addition to the CNS considered in this report, there is also AIS and MET. We see limited benefits within in the traditional CNS markets but much high potential when considering the transition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

Existing costs	Rational 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.



2. Overview of catalyst project

2.1 Operational/technical context

Currently, the air traffic management (ATM) 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[1] to air traffic services. Airspace is predominantly organised by national boundaries. Flight data is held locally in the ATM System (or Flight Data Processor (FDP)) with limited sharing of data between neighbouring centres leading to restricted interoperability between Area Control Centres (ACC).

The technical limitations of the current architecture, limit overall capacity as well as flexibility, scalability, resilience and coordinated deployment of new ATM functionalities. As a result, prior to the COVID-19 pandemic, the airspace was so congested that airspace users experienced high delays and low flight efficiency. The pressure to embrace modernisation and digitalisation to address those challenges in a cost-efficient and sustainable manner remains – albeit with the urgency more on environmental performance rather than very short-term capacity.

The future system 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 architecture 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.

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 at network level. 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 ACCs and have airspace allocated, provide geographically independent ATS and support Capacity on Demand 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 Virtual Data Centres operated by ATM Data Service Providers, provides ATSUs (and other stakeholders) access to all the relevant up-to-date data 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 air navigation services (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. An evolution of network management services is to be expected as part of the process of virtualisation.

[1] Auxiliary services are defined by the AAS as services with a geographical dependency such as Communications, Navigation, Surveillance, AIS and MET.

Project RoMiAD is looking into the potential economic benefits enabled by implementing the future architecture proposed by the AAS [1] and how to incentivise it. RoMiAD is doing so by considering:

- Market Size – how much does it currently cost to provide the services in each layer?
- Benefits – how does horizontal integration lead to benefits in each layer? How much would it reduce the costs in each layer?
- Deployment Scenarios – how do geographical scopes applied to each of the layers affect the overall benefit?
- Incentivisation – what sort of organisations would operate the new services and how would they be best incentivised to achieve the identified benefits?

2.2 Project scope and objectives

In Project RoMiAD, we considered the architecture proposed by the AAS [1] to analyse how cost efficiency 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 on economics, resource allocation and cost-efficiency. It is the all-rounder setting up the work of the specialists.

The aim was to establish a framework for identifying benefits of virtualisation and how different market mechanisms may incentivise the transition in the different layers. Our analysis focusses on the following questions:

- What does virtualisation 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 project focuses only on en-route ATM and uses 2018 as the baseline to estimate the benefits of virtualisation but it excludes AIS, MET and exceptional items.

2.3 Research carried out

Prior to delving into core of the study, a literature review of existing work was carried out on three main topics:

- Technical in ATM- research that supports the implementation of Virtual Centres;
- Organisational/Economic in ATM – research that investigates other organisational structures that may support virtualisation in ATM; and
- Economic in other industries – explored the success and failure of other industries that have introduced different economic approaches to maximise their cost-efficiency.[2]

To investigate the deployment of the AAS, its benefits in each layer and how to incentivise the transition towards it, the study has followed the approach detailed in Table 1 and Figure 1.

[2] For example, the UK Water industry and their regulation with price-controlled periods [18] or the UK & Italy Utilities industry using a total expenditure (TOTEX) approach.

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) [29][32] and Performance Review Body (PRB) [30] 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	What sort of organisations would operate the new services and what cost savings would they deliver?	• 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: ROMIAD APPROACH

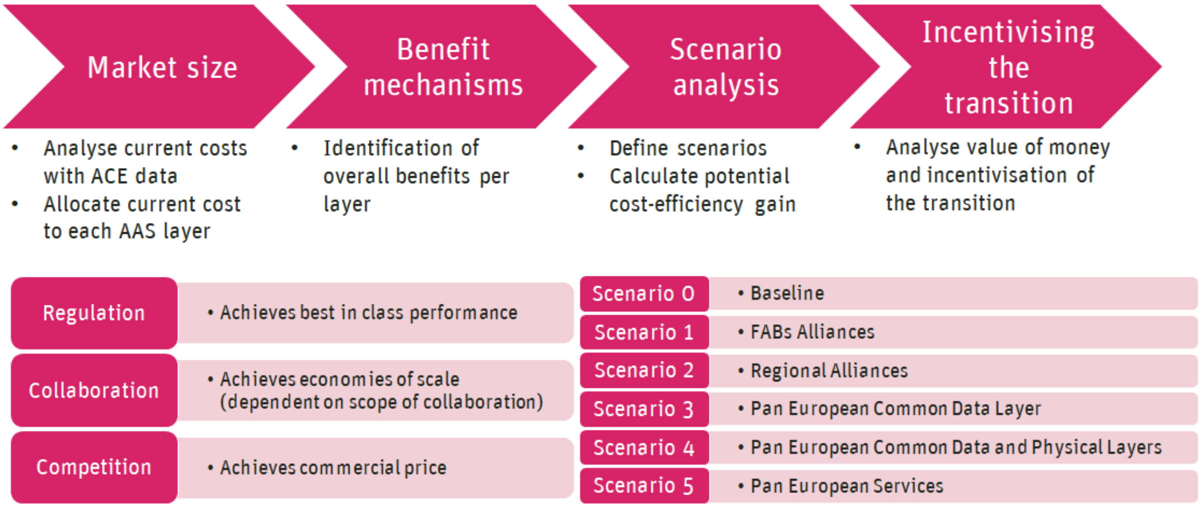


FIGURE 1: ROMIAD APPROACH

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) [37] 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 [31]: 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.

2.4 Results

As a result of the literature research we reached various reasonings:

- SESAR research on Virtual Centres enables us to assume that virtualisation is technically feasible, although we recognise that a number of technical issues need to be resolved.
- In ATM previous studies on economic/organisational changes either look at the vertical integrated concepts or more recently focus on the ADSP. RoMiAD looks at the applicability given the new infrastructure in a comprehensive approach. There is further research required in this topic.
- Other industries – especially in the public domain- proof to benefit from:
    - a distributed architecture;
    - moving to a TOTEX approach;
    - introducing contestability.

Part A: Market sizes

In 2018 the 38 ANSPs that provide data to the EUROCONTROL Performance Review Commission (PRC) had a full cost for ANS provision of approximately €9.5 bn in 2018 [32], this included en-route and terminal ATS as well as NSA, EUROCONTROL and External MET costs. However, we are concentrating solely on en-route ANS excluding, AIS, MET and Exceptional costs (non-recurring costs). Under this scope, the costs incurred by the 38 ANSPs in the en-route segment amounted to €6 635 bn in 2018. For the 30 European ANSPs we consider in this study, these costs add up to nearly € 6 bn out of which 20% is capital expenditure and 80% operational.

Current costs were allocated to the three layers proposed in the AAS through a series of assumptions, using the cost categories (staff, non-staff operating costs, capital costs and depreciation) that ANSPs report against in the Performance Plans. The assumptions as shown in Table 2, were validated through an expert User Group leading to the initial estimates for the market size of each layer.

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 2: 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. Such that 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 would remain largely unchanged. Given the current Performance Scheme uses the Return on Asset Base (RAB) and weighted cost of capital to determine return in investment this would act as a barrier to virtualisation as it lacks incentives to engage with the process.

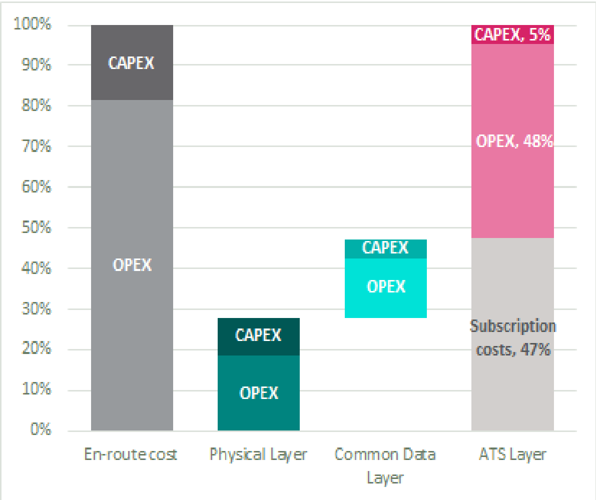


FIGURE 2: EXPENDITURE AND SUBSCRIPTION COSTS

Part B: Benefit Mechanisms

The virtualisation process that the AAS proposes to get from standalone systems to the three layers 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 move at different paces according to need and benefits.

During our research, we have elaborated on the AAS transition proposals (see Figure 3) 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 consider the potential benefits of each step in the three layers.

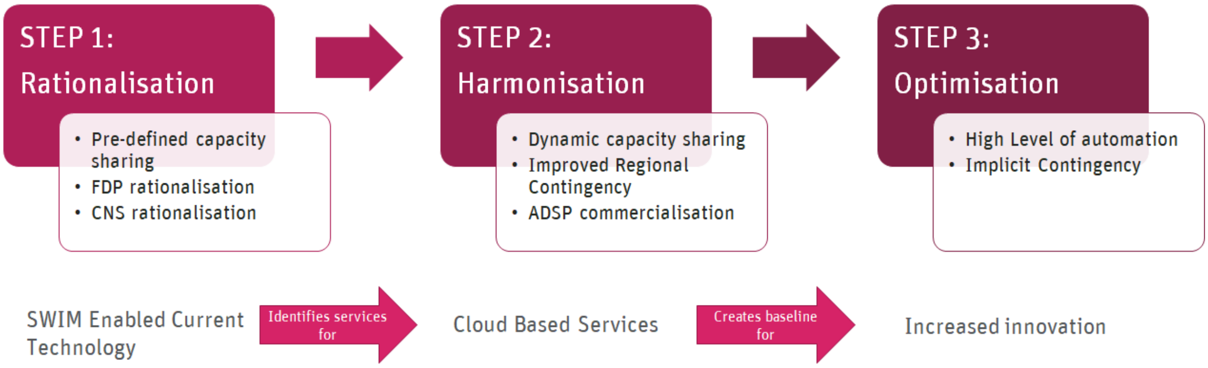


FIGURE 3: SIMPLIFIED TRANSITION PATH

The different steps of the transition enable benefits in each layer which are summarised in Table 3.

The various benefits are calculated at three different geographical scopes to understand how ANSP choices may affect the level of cost savings:

- National - The transition occurs within the national boundaries where the benefit can be quite limited.
- Regional - ANSPs within a region create a Joint Venture to deliver increased benefits. We have considered two variations of regions: one based on existing FABs and one on main traffic flows.
- Pan-European - Pan-European collaboration to maximise benefits virtualisation.

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
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
	Initial Capacity Sharing	Sharing capacity in limited pre-defined circumstances.	Ability to reduce delay within current sectorisation.	Step 1
	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
	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
	Increased automation	Adoption of a range of advanced SESAR solutions.	Not quantified.	Step 3
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
	ATM Data Service Harmonisation	Deployment of "cloud based" services (medium term).	Cost of "commercial" cloud services.	Step 2
	Additional ATM data services	Synchronised deployment of new data services and enhanced innovation.	Cost of deploying new ATM Data Services.	Step 3
Physical Layer	**CNS Rationalisation**	CNS rationalisation infrastructure by removing CNS assets, in terms of VOR and NDB.	Historical estimate from PRC.	Step 1
	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
	CNS Deployment	A fast and simplified deployment of new CNS systems is supported.	Not quantified.	Step 3

TABLE 3: SUMMARY OF IDENTIFIED BENEFITS

Table 4 shows the order of benefits for each step in each layer, depending on the geographical scope. For Step 3 we do not have an estimate for the reduced costs of deploying new functionalities in the common data and physical layers using with the distributed architecture.

Step	ATS Layer	Common Data Layer	Physical Layer	Total
Step 1	Operational Excellence Initial Capacity Sharing	Data Systems Rationalisation	CNS Rationalisation	
	€ 550 m – 1 bn	€ 40 m – 80 m	€ 27 m – 34 m	**€ 1,1 bn**
Step 2	Dynamic Capacity Sharing Contingency	ATM Data Service Harmonisation	CNS Consolidation	
	€ 350 m – 500 m	€ 175 m – 350 m	€ 18 m – 22 m	**€ 850 m**
Step 3	Increased automation	Additional ATM data services	CNS Deployment	
	€ 350 m – 500 m	TBD	TBD	**At least € 500 m**
Total	**Up to € 1,9 bn (60%)**	**At least € 215 m (25%)**	**At least € 45 m (3%)**	**At least € 2 bn**

TABLE 4: ESTIMATED BENEFITS

In broad terms:

- The ATS layer has the largest potential benefits which are enabled by 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.

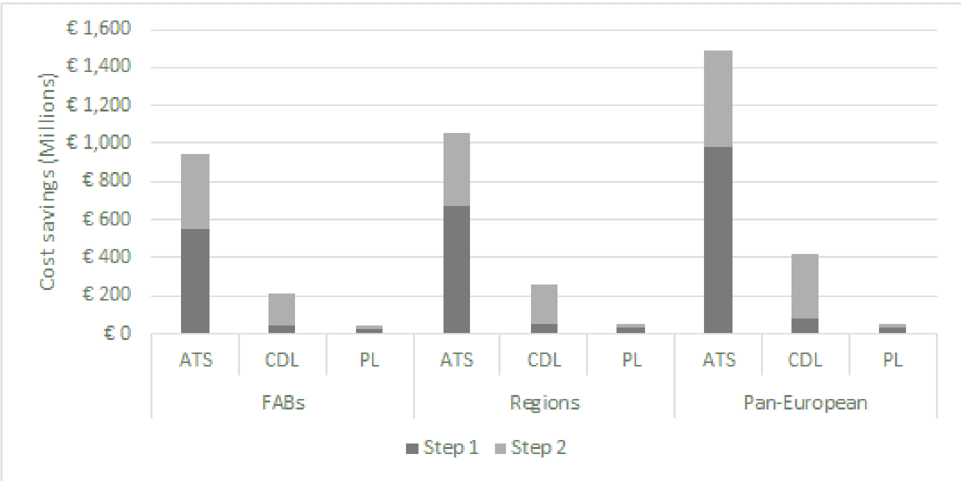


FIGURE 4: SUMMARY OF BENEFITS FOR STEPS 1 AND 2

Part C: Scenario Analysis

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 to have freedom to select the most appropriate business model for them in each layer. Our approach is 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).

For this study, we assume that the national ANSP will retain the ATSP role, but progressively work within an alliance with other ATSPs to deliver ATS services. However, in 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.

Table 5 defines scenarios chosen for further analysis.

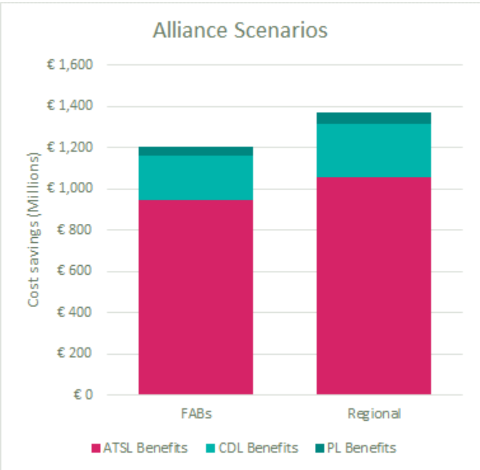
#	Name	Description	ATS	Data	Physical
0	Baseline	Existing national regulated entities are maintained. This scenario is used as a reference against which the value of changes is measured.	National	National	National
1	FAB Alliances	ANSP form alliances within exiting FABs to optimise ANS provision, including 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

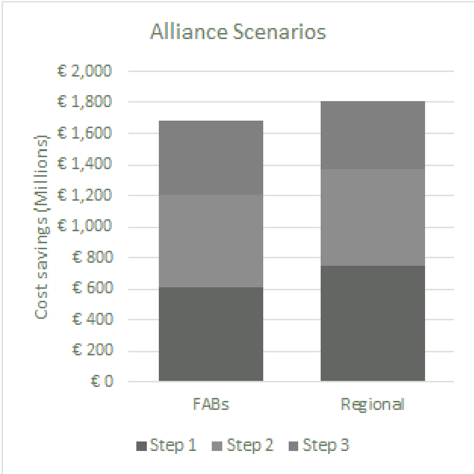
TABLE 5: DEPLOYMENT SCENARIOS

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.

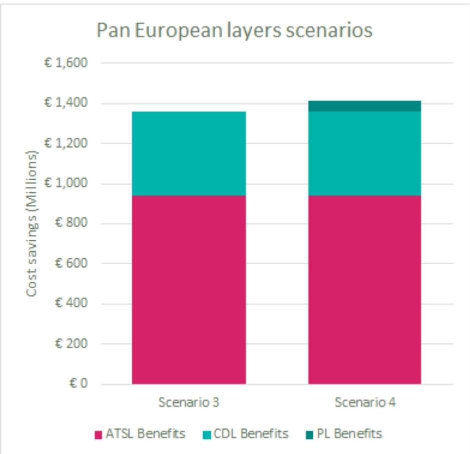
An analysis of the level benefits raised by each scenario allow us to understand where benefits are coming from:

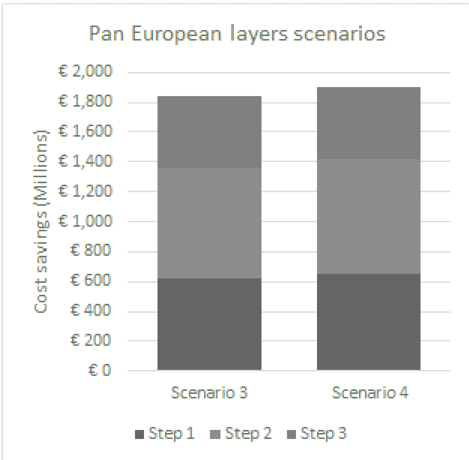
- In Alliances (Scenarios 1 and 2) a key driver is that bigger alliances lead to higher cost savings.



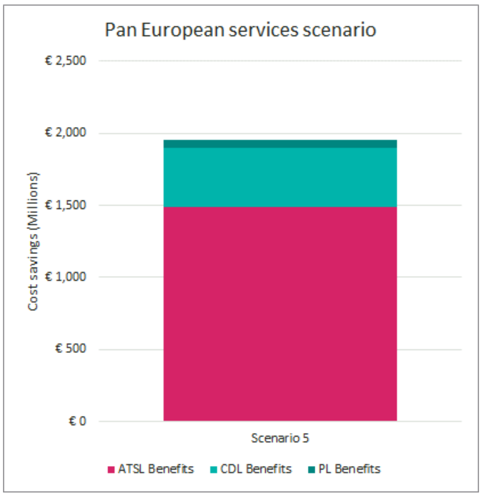


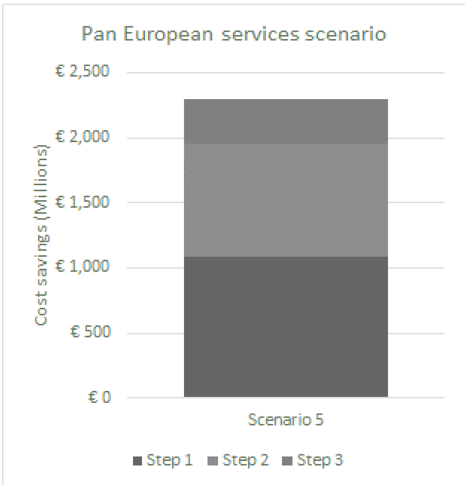
- The common data layer also benefits from widening collaborations, but the nature of the physical layer limits the benefits.





- Scenario 5 shows how optimising all the layers at a pan-EU level is a key driver for cost savings.





Part D: Incentivisation

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 "deeper" forms of collaboration. Current form of economic regulation defined by the Performance Scheme and Common Charging Regulation [34] does not incentivise the correct behaviours that are required to transition service delivery to the virtualisation model. A Total expenditure (TOTEX) model [58] is considered under this study to be more efficient than the current returns based on capital employed.

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. With virtualisation it is possible to envisage competition in all three layers. However, to successfully introduce competition between firms we need to create a contestable market with barriers to entry and limited sunk costs.

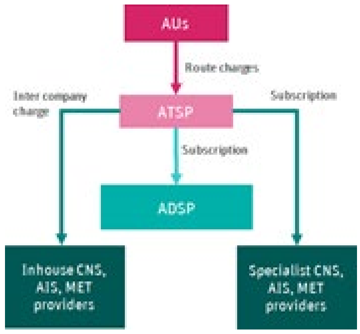
A qualitative analysis of the three markets is the result of considered weather competition or collaboration would better suit each of the layers as discussed in Table 6.

Layer	Collaboration	Contestability
Air Traffic Services	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. All require investment in infrastructure renewal including modifications to the controller HMI and CWP to support remote access to ATM data services. Further the existing ATM system may need to be considered as a stranded asset.	• COMPAIR study [2] suggests using auctions to introduce competition of en-route ATM services drive value for money in the market, but the “rules of the game” modelled allowed ANSPs to lose competitions and either consolidate with other ANSPs or even go out of business. Also, it was based on the current architecture rather than virtual centres. • From RoMiAD’s perspective the identified benefits rely on collaboration to maximise the use of available capacity rather than organisational consolidation and competition would encourage the correct collaborations. • High cost of entry (building an ATSU) suggests there are high barriers to creating a contestable market. • In step 2 the “capacity on demand” style services could include running competitions to tackle demand and capacity balancing when an ANSP requires an additional sector.
Common Data	• Collaborating ADSPs will potentially specialise in different types of ATM data service. • In the early stages, ADSPs will be national ANSPs working collaboratively with other national ANSP under existing SES certifications. • In the longer term, then new entrants (e.g., JVs ANSPs and system suppliers) may create advantage by combining operational and system knowledge.	• Our findings support contestability in the CDL - Step 2 benefits (cloud services) far outweigh the rationalisation benefits in Step 1 and are a better enabler for Step 3. • Contestable market will support new entrants and more likely to lead to commercialisation. • Cost of market entry may be initially high for new entrants (cost of assets is high), but if existing suppliers looking to move to a subscription model the cost could be low. • If future ADSPs use commercial cloud computing solutions then hardware costs will decrease, and the value will reside in the software products.
Physical	• Improved CNS planning due to horizontal collaborations. • Reduced maintenance costs due to specialisation of service providers. • Limited scope for benefits with the current infrastructure. The benefits are mostly as enabler of greater data sharing and simpler deployment of new assets.	• Mobile phone companies have demonstrated the benefits of competition applicable to ATM physical layer - but it proved regulation is required to incentivise right behaviours and avoid high charges. • Entry barriers would be high (high cost of assets) but a contestable market could be created by outsourcing operations and maintenance but not CNS planning and asset ownership which would limit the horizontal collaboration benefit. • New entrants (e.g. space-based) could offer 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-EU procurement of commonly agreed new services by the Network Manager or another European body could minimise costs.

TABLE 6: COLLABORATION AND CONTESTABILITY IN THE LAYERS

ANSP Centric

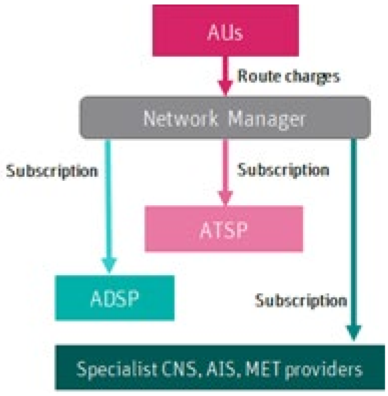
National ANSP retains the responsibility for ANS within the state and utilises the services of an external ADSP and a mixture of in-house and specialist auxiliary service providers.



- The ANSP collects revenues from users and establishes contracts and pays subscriptions as necessary for the Common Data and Physical Layers and ensures they are sufficient to provide efficient and safe ATS.
- ANSP remains a monopoly provider of ATS subject to economic regulation. Services purchased from a contestable market would not be subject to a price cap and the ANSP.
- The ANSP could operate separately in this model or in the ATS layer forming an alliance with neighbouring ANSPs (VC) with full dynamic capacity sharing. The alliance agreement would include redistribution of revenues according to traffic handled.

Network Centric Version

In this model, 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.

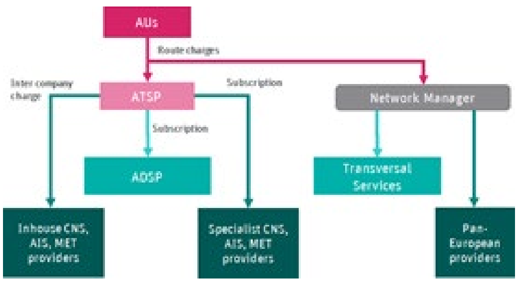


- The Network Manager ensures the adequacy of the common data layer and physical layer.
- The national ATSPs retains ability to manage State airspace, including asset ownership for a minimum service level, but the Network Manager arranges for each ATSP to "open" additional sectors on behalf of other ATSPs to minimise ATFM delay using a concept such as capacity on demand.
- Network Manager uses competition to select providers in common data layer and physical layer services using a harmonised procurement model enabling a contestable market.

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

A hybrid model

In this model the Network Manager would have a role in the provision of European services of general good for the ATM community. In the short term this could be transversal services such as ground-ground comms, SWIM registry and cyber security as well as pan-European deployments of new CNS infrastructure.



Hybrid arrangements may also exist for airspace sharing where the predominant form of ATS delegation is within Virtual Centres, but the Network Manger could request limited forms of ATS delegation between Virtual Centres to maintain traffic flow due to unforeseen circumstances – such as volcanic eruptions.

3. Conclusions, next steps and lessons learned

3.1 Conclusions

During 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 within FABs and whilst maintaining national ANSPs. 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 can realise the benefits. If virtualisation had been adopted before 2018 across Europe – ATM costs could have been 30% cheaper and there would have been no significant delay. The potential net benefit to Airspace Users would have been in the order of €3.5 bn per annum [37]. If virtualisation had been adopted by FABs, costs could have been 20% lower. These benefits assume a uniform application of virtualisation across Europe and exclude transition costs.

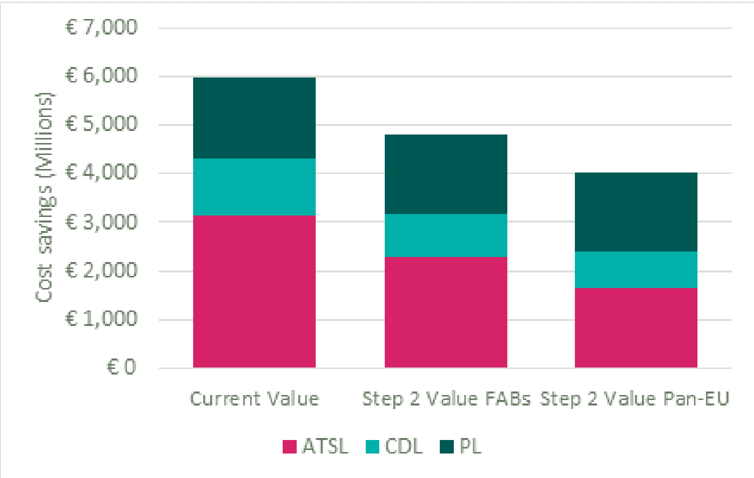


FIGURE 5: FUTURE COSTS OF ATM UNDER VIRTUALISATION

Our analysis demonstrates that the real benefits (75% of the total) are through improvements in the ATS layer - increasing ATCO productivity and capacity sharing – 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 can support those collaborations. However, 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 without significant delay [1].

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. 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.

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.
Optimising the Common Data Layer	Within the Common Data Layer, it is still necessary to consider the scope of services 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.
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.

TABLE 7: POTENTIAL OPTIMISATION OF THE LAYERS

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.

3.2 Next steps

Next outputs and events

The forth coming events and outputs are summarised in the following table.

Output name	Output type	Expected date
RoMiAD final technical report	Final technical report	May 2021
Final RoMiAD report	Final complete report	April 2021
RoMiAD Whitepaper	Whitepaper	April 2021
Virtualisation and ATS delegation	Poster	April 2021
The Benefits of virtualisation	Poster	April 2021
Virtualisation and the transition	Blog	April 2021
AAS Layers and their benefits	Blog	April 2021
The future of ATSPs	Blog	April 2021
Engage TC4 - RoMiAD workshop	Workshop	June 2021

TABLE 8: NEXT OUTPUTS AND EVENTS

There are additional outputs forthcoming but that are still not fully defined such as an article for the next SESAR Innovation Days with RoMiAD's results and an article for ATM magazine.

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.

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[3]) it would be possible to refine our scenarios to establish the optimum alliances and inter-alliance arrangements to minimise ATFM delay.

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

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.

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.

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 [61]. 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.

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 always 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. [62]). 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.

3.3 Lessons learned

The size of these Engage projects perfectly fits its purpose of early-stage research that explores the context to unearth where detailed research would be beneficial.

The catalyst funding approach has served this project well allowing it to diverge and adapt to the necessities that raise as the internal and external work evolved. Internally, the Virtual User Group helped define where the ATM community's interest and gaps in the research topic. Externally, the project took into consideration findings and gaps of projects running in parallel such as the ADSP study or SESAR PJ32 on Virtual Centres or initiatives such as SES 2+, EUROCAE WG 122 or CANSO STWG.

The project type also allowed to engage students at different European universities so that they could be involved in the literature review and analysis of various aspects of the project.

However, the flexibility format that catalyst funds offer also brought some drawbacks such as the potential never-ending changes in the scope and therefore using more resources than available under the funding. Furthermore, the limited availability of data and the restriction of its format had an impact on the project scope and led to unexpected changes and delays. This could have been palliated by an early review of the existing data prior to defining the scope or by ATM institutions sharing more detailed data for research purposes on ANS costs.

4. Dissemination

The main outputs of the projects, extant or forthcoming, will be part of a dedicated resources webpage under https://think.aero/resources/:

- Final technical report
- Final complete RoMiAD report
- Technical note - Economic aspects of the AAS
- Scenario and benefits model spreadsheet
- RoMiAD whitepaper
- RoMiAD video
- RoMiAD powerpoint
- Two posters: *Virtualisation and ATS delegation* and *The Benefits of virtualisation* (to be published)
- Blogs throughout the project:
    - Blog on *Introducing RoMiAD: Catalyst of ATM transformation.*
    - Blog on *Do we need to regulate virtualisation?*
    - Blog on *Benefits of ATM virtualisation*.
    - Blog on *Virtualisation and the transition.*
    - Blog on *AAS Layers and their benefits.*
    - Blog on *The future of ATSPs.*

There are additional outputs forthcoming but that are still not fully defined such as an article for the next SESAR Innovation Days with RoMiAD's results and an article for ATM magazine.

RoMiAD results have also been or are to be presented on the following events:

Event	Date	Output
First Virtual User Group	October 2020	Internal Presentation – RoMiAD VUG
Second Virtual User Group	December 2020	Internal Presentation – 2nd RoMiAD VUG
Third Virtual User Group	February 2021	Internal Presentation – 3rd RoMiAD VUG
Engage Summer School	September 2020	Video – Engage Summer School 2020 RoMiAD
ICAO Global Symposium	December 2020	Video – Considerations on the economic impact of virtualisation
EUROCAE WG-122	2020-2021	Presentation – Regulatory considerations for the deployment of virtual centres
CANSO STWG	2021	Presentation – Inputs on the deployment of virtual centres
Engage TC4 Workshop	June 2021	Presentation – RoMiAD workshop

TABLE 9: ROMIAD EVENTS

5. References

5.1 Project outputs

The project outputs are shown in Table 10**Error! Reference source not found.**:

Output name	Output type	Date	Available at
RoMiAD final technical report	Final technical report	May 2021	Engage KTN channels https://engagektn.com/cf-summaries/
RoMiAD presentation	Presentation	May 2021	Under https://think.aero/resources/ but TBD
RoMiAD video	Video	May 2021	https://www.youtube.com/channel/UC-Gzl0gJ9U57uBt9VpHtosg
Final RoMiAD report	Final complete report	May 2021	Under https://think.aero/resources/
Technical note - Economic aspects of the AAS	Technical note	September 2020	Internal
Scenario and benefits model	Spreadsheet	March 2021	Internal
How to incentivise innovation in ATM?	Whitepaper	May 2021	Under https://think.aero/resources/ but TBD
Virtualisation and ATS delegation	Poster	May 2021	Under https://think.aero/resources/ but TBD
The Benefits of virtualisation	Poster	May 2021	Under https://think.aero/resources/ but TBD
Introducing RoMiAD: Catalyst of ATM transformation.	Blog	August 2020	https://think.aero/views/romiad-catalyst-of-atm-transformation/
Do we need to regulate virtualisation?	Blog	October 2020	https://think.aero/views/do-we-need-to-regulate-virtualisation/
Benefits of ATM virtualisation.	Blog	March 2021	https://think.aero/views/initial-thoughts-on-the-benefits-of-virtualisation-in-atm/
Virtualisation and the transition.	Blog	May/June 2021	Under https://think.aero/views/ but TBD

Output name	Output type	Date	Available at
AAS Layers and their benefits.	Blog	May/June 2021	Under https://think.aero/views/ but TBD
The future of ATSPs.	Blog	May/June 2021	Under https://think.aero/views/ but TBD
RoMiAD VUG	Internal Presentation	October 2020	Internal
2nd RoMiAD VUG	Internal Presentation	December 2020	Internal
3rd RoMiAD VUG	Internal Presentation	February 2021	Internal
Engage Summer School 2020 RoMiAD	Video	September 2020	https://think.aero/videos/role-of-markets-in-aas-deployment/
ICAO Global Symposium 2020- Considerations on the economic impact of virtualisation	Video	December 2020	https://think.aero/videos/how-virtualisation-can-transform-the-atm-marketplace/
EUROCAE WG 122 - Regulatory considerations for the deployment of virtual centres	External Presentation	2020-2021	EUROCAE internal documents
CANSO STWG - Inputs on the deployment of virtual centres	External Presentation	2021	CANSO internal documents
Engage Workshop: Economic incentives for future ATM implementation	Presentation/Panel moderation	June 2021	https://www.sesarju.eu/node/3824

TABLE 10: ROMIAD OUTPUTS AVAILABILITY

There are additional outputs forthcoming but that are still not fully defined such as an article for the next SESAR Innovation Days with RoMiAD's results and an article for ATM magazine. Furthermore, RoMiAD has been submitted to the SESAR Digital European Sky Awards 2021.

5.2 Other

A full list of references is provided in the final report. The references used in this shortened version are listed below.

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Annex I: Acronyms

The following table contains the acronyms used throughout this document:

Term	**Definition**
ATM	Air Traffic Management
AAS	Airspace Architecture Study
ACC	Area Control Centre
ACE	ATM Cost Efficiency
ADSP	ATM Data Service Provider
AIS	Aeronautical Information Service
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATFM	Air Traffic Flow Management

Term	Definition
ATS	Air Traffic Services
ATSL	Air Traffic Services Layer
ATSP	Air Traffic Service Provider
ATSU	Air Traffic Service Unit
AU	Airspace Users
CAPEX	Capital Expenditure
CDL	Common Data Layer
CNS	Communications, Navigation and Surveillance
CNSP	CNS Provider
COM	Communication
CWP	Controller Working Position
EU	European Union
FAB	Functional Airspace Block
FDP	Flight Data Processing system
FIR	Flight Information Region
ICAO	International Civil Aviation Organization
IT	Information and Technology
JV	Joint Venture
KTN	Knowledge Transfer Network
MET	Meteorological Services
METP	MET Provider
NAV	Navigation
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
RP	Reference Period
SES	Single European Sky

Term	Definition
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
TOTEX	Total Expenditure
UAC	Upper Area Centre
VC	Virtual Centre

TABLE 11: ACRONYMS