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COMPAIR

COMPETITION FOR AIR TRAFFIC MANAGEMENT

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Abstract

The increasing air travel demand observed in the last two decades in the European airspace has challenged the Air Traffic Management (ATM) system to adapt and respond to the new capacity and congestion issues derived from this growth. The introduction of competition in the ATM sector has been proposed as a means to incentivise the adoption of new technology and more efficient strategies, and thus contribute to the achievement of the European high-level policy objectives for aviation.

This report expresses the project members' vision on the future for ATM sector in Europe from an institutional perspective. It describes potential pathways towards new institutional designs for the European ATM sector. These institutional elements will likely include more competitive dynamics that should lead to performance improvements on various ATM key performance areas. COMPAIR also investigated ways of implementation. This involves understanding distributional impacts and possibly the need for government oversight and enforcement for effectively implementing the proposed changes. This report also discusses potential drawbacks and ways of addressing perverse incentives in new institutional designs. This can include ways of overcoming potential market concentration of ATM service provision in the hands of just a few Air Navigation Service Providers (ANSPs).

The report starts with a concise executive summary which outlines the main idea of the project, the approach taken, the main results and policy recommendations that can derive from it.

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1 Executive Summary

Goals of the project

The overall goal of COMPAIR was to study various institutional and market design approaches for introducing competition for en-route ATM services, in order to assess their potential contribution to the European Single European Sky objectives. The project had the following objectives:

- Propose a set of new institutional market designs for the introduction of competition in the European ATM sector;
- Define a framework allowing a comprehensive assessment of the impact of different institutional market designs;
- Develop a variety of economic and network simulation models allowing the assessment of the proposed approaches;
- Assess the feasibility and acceptability of proposed institutional changes for various market actors;
- Propose a vision for the implementation of the most desirable institutional structures.

Possible options to increase competition

To achieve the overall objectives set above the project focused on four potential ways to introduce competitive elements in the ATM sector:

- Option 1 – Performance regulation with variations in ownership and governance models
- Option 2 – Unbundling
- Option 3 – Tender of licenses for en-route air traffic services
- Option 4 – Flight centric, sector-less operations

These options are based on the initial ideas at the outset of the project proposal, which have been further fine-tuned in [3] in a variety of ways: literature review and desk research, workshops with aviation stakeholders and the Advisory Board Members, face-to-face interviews with selected respondents and a survey that was sent out to a broader set of ATM actors.

Option 1 – Performance regulation with variations in ownership and governance models

The ownership form of ANSPs varies over countries, from government agencies to government owned corporations to semi-public, semi-private firms (for profit and not-for-profit). There is also variation in the consultation processes by ANSPs of ATM stakeholders before making strategic decisions. In some countries, extensive consultation procedures are in place, whereas in others formal processes are currently under development or do not exist. The composition of an ANSP governance board may be designed to reflect the presence of specific skills or different opinions of ATM stakeholders.

The project highlighted that there is a significant difference in the efficiency of European Air Navigation Service Providers [5]. Therefore, in theory there is room for serious improvement. Having more impact of various stakeholders on the ANSPs, could mean a drive for a more efficient operation.

As there are already examples for this approach, this option could be implemented in a shorter timeframe (<5 years from now).

Option 2 – Unbundling

Unbundling is the process by which a large company with several different lines of business retains one or more core businesses and sells off the remaining assets, products, services, etc.

The provision of Air Traffic Management can be subdivided in the following components:

- 1) Network management: currently EUROCONTROL is in charge and is supported by national ANSPs, Military, Airlines and Airports.
- 2) En-route air traffic service (ATS) provision
- 3) Terminal air traffic service (ATS) provision (incl. approach and tower control)

The unbundling of ATM services could start with the separation of terminal air traffic services. As a second step, a number of en-route air traffic supporting services could also be unbundled. These are mainly ATM support services such as Meteorological services (MET), Aeronautical information services/management (AIS/AIM), etc. Further outsourcing of ATM activities could involve more specialised ATM activities such as en route air traffic control (see option 3).

The project analysed the effects of unbundling of the terminal control in some Member States (mostly regional airports) and the analysis shows that efficiency increases such as cost reductions of 40% or more could be possible [5].

However, without a change in ownership form or the strengthening of the price cap approach, there is little interest in cost efficiency hence little interest in unbundling from the viewpoint of ANSPs.

COMPAIR considers this option might be executed in the medium term (by 2030).

Option 3 – Tender of licenses for en-route air traffic services

Option 3 concerns the tendering of a license to operate core en-route air traffic services, namely the provision of air traffic control, in a specific geographical area and for a certain period.

This time-based tendering process over time can also lead to consolidation among European ANSPs and to a less fragmented European airspace.

This option may also lead to lower charges than occurs today, in part due to the economies of scale achieved through defragmentation and in part due to the bidding process that creates a competitive environment [6][7].

There are however also some points to keep in mind:

- Results suggest that, for Europe as a whole, a maximum market share of 20% ensures sufficient competition.
- It is important to ensure that a sufficient number of competitors take part for the auction process to be successful over time.
- For-profit companies appear to be closer to achieving the Single European Sky objectives under competition than non-profit ones.

As there are already working examples of tendering of terminal operations in several European states, the same approach might be technically feasible even today, but due to the political and institutional boundaries, it is more likely to act as a middle-term solution (by 2030).

Option 4 – Flight centric, sector-less operations

This option may also increase the scope of competition in the ATM sector, with ATM providers competing on a per-flight basis or per-airline, rather than per geographical zone. The Sector-less scenario also acts in COMPAIR as an example of the effects of technology changes on the institutional structures.

The results of the simulation [7] suggest that, since the dominant ANSPs tend to increase their market share in each auctioning process, the maximum market share permitted is a necessary measure in order to avoid the emergence of a monopolistic ANSP serving the entire European market.

Option 4 would mean a fundamental change in the way air traffic control is done today and it requires a further technology development, so COMPAIR considers this approach as a long-term way to boost competition (after 2050).

Overall, the results of the different options with different models show that **introducing competition for the market**

- **May increase efficiency**
- **May lead to a reduction in charges by up to half of the current levels.**
- **May lead to a faster uptake of technologies than is happening nowadays**

Stakeholder feedback

In terms of the feedback of stakeholders, their opinion can be summarized as follows:

- Most of them consider some competition necessary to increase the efficiency of the European air navigation service environment.
- Nearly all of them highlight that the main obstacle is the lack of enough political will to execute the changes.
- Many consider the current auctioning process of terminal control is a good first step, which might pave the way for further steps.

Next steps

Before implementation, further benchmark studies should be completed. These should assess the same industry at other locations or to see how other industries with a monopolistic situation in Europe went through a similar route. An interesting example for the first case could be a more detailed (quantitative) assessment of NavCanada. For the second case, telecommunications and the airline industry show valuable reference points.

The most important implementation step is to maintain an institutional environment that can support competition. This environment is to be created both at European and at member states level. “Environment” does not only include the legal measures, but also the overall political, administrative, economic landscape that can support better efficiency and which is competition friendly in general.

The options mentioned in COMPAIR should be further assessed and should be updated if necessary. The models could be extended to include more countries and/or relax some conditions. In addition, other options might be considered if there are good examples for them. Detailed implementation steps and guidelines should be prepared for each option and they should be promoted in the European aviation community. It is important that these talks should not be at the level of air navigation service providers only, airlines, airports, passenger representatives and other aviation stakeholders should be duly involved.

Also, when preparing for the implementation, other factors should be taken into account like the emergence of new, disruptive technologies in general with special emphasis on the unmanned aircrafts (UAS) as a game changer for air navigation, the airport capacity shortage in Europe and the need for an update of the European ATM Master Plan.

The COMPAIR consortium believes that following the steps mentioned above can mean the **starting of a process to create a more competitive European air navigation service sector, which would help to make the overall European aviation industry more efficient and more profitable.**

2 Project Overview

This chapter provides the context, the project objectives and the work performed.

2.1 Operational/Technical Context

Air transport is facing many challenges such as increasing demand, larger airports, increased network congestion, etc. which also need to be reconciled with environmental issues. Hence there is a need for smarter solutions at service, operational and technical level. One of the important players within aviation is Air Traffic Management (ATM). Since 2004, the European Union gained competences in ATM. The main objective of the EU is to reform the European ATM system in order to cope with sustained air traffic growth under safe, cost-efficient and environmentally friendly conditions. The Single European Sky (SES) initiative aims to re-structure the European airspace as a function of air traffic flows, create additional capacity and increase the overall efficiency of the ATM system¹. The European Commission has set ambitious goals for the SES in 2012 to be reached by 2020², including a 3-fold increase in airspace capacity and a cost reduction of at least 50% for the provision of ATM services.

In order to gain full understanding of the current trends in air navigation service provision, it is worthwhile to look back into history and establish where the current state originates.

The International Civil Aviation Organisation (ICAO) defines the Air Traffic Control Service as a service provided for the purpose of preventing collisions between aircraft, and on the manoeuvring area between aircraft and obstructions and expediting and maintaining an orderly flow of air traffic. Although ICAO does give guidance on the type of organisational units air traffic control service should be provided from, the actual solutions and service levels provided are left to the discretion of the ICAO Member States. The obligation inherent in the ICAO provisions for each State to provide air traffic services (of which the air traffic control service is one) in the airspace under their jurisdiction has led to the establishment of air traffic control units in all but the smallest States. These units provide services at aerodromes, in the terminal areas and in en-route airspace. Particularly in Europe, having an air traffic control unit was seen as a sign of nationhood and the new nation States born for instance from the former Yugoslavia were quick to establish en-route centres, even when their airspace represented only a few minutes of flying time. The proliferation of air traffic control units, particularly for en-route traffic, has led to a very fragmented and in many ways inefficient air traffic management environment. Early efforts to prevent and eliminate fragmentation were not really successful as evidenced by the very limited transfer of en-route control responsibility evidenced to-day. The situation is well illustrated by the Functional Airspace Blocks (FAB), which, instead of reducing fragmentation, resulted in even higher level of fragmentation by adding a political level to the problem when Functional Airspace Blocks (FABs) were created along political interest lines rather than traffic patterns, as was the original intention [32] .

¹ http://ec.europa.eu/transport/modes/air/single_european_sky/index_en.htm

² <http://www.sesarju.eu/discover-sesar/history/background-ses>

The European air navigation service is financed on a cost-recovery³ basis, meaning that charges levied on the users of the airspace are set to cover all the associated costs. Airspace users therefore have a very strong interest in and motivation for, seeing the costs of providing the services reduced while the overall efficiency of the system increases. Viewed from the perspective of the airspace users, their own air traffic management related costs arise in two main forms: paying for the service itself and the cost of delays and sub-optimal routings resulting from the inherent inefficiencies in the fragmented system. If the cost of service provision is higher than it should be and losses are added due to sub-standard service quality (as was seen in the past [34]), airspace users are facing a very difficult financial equation.

Various European initiatives over the years have improved the situation somewhat and due to new EU rules, Air Navigation Service Providers (ANSP) are now obliged to keep their rates as low as possible while also improving their efficiency [28]. What has not changed is the fragmentation and the number of en-route air traffic control units, a fact that limits the effectiveness of the measures designed to lower costs and improve efficiency.

It is interesting to note that while the Communication, Navigation and Surveillance (CNS) and communications capabilities of aircraft have improved, the ground infrastructure of air traffic control units and their capabilities are still often ill equipped to make full use of the new aircraft capabilities. This remains true in spite of the Single European Sky initiative and the technology innovations available from the SESAR project.

2.2 Project Scope and Objectives

Today's progress towards SES objectives is perceived as slow⁴: the steps taken towards enhanced collaboration between various air navigation service providers (ANSPs) are sometimes considered ineffective⁵, the implementation of functional airspace blocks (FABs) to defragment the European landscape of national ANSPs and enable economies of scale has had limited success, and the R&I cycle is still too long. In this context, the question of how to provide the appropriate organizational structures, institutions and incentives for new operational concepts and technologies to yield the expected results stands high on the European policy agenda. The introduction of **competition** has been proposed as a means to **provide the right incentives** for the realization of the high-level objectives of the SES, through the speed up of the innovation cycle and the fostering of more efficient operations. On the other hand, competition does not prevent every market failure (e.g. negative externalities) and, depending on market conditions, liberalization can also have undesired outcomes, such as the emergence of oligopolies or monopolies. Besides, competition does not exist abstractly, but is influenced by the legal and regulatory framework. Hence, the successful

³ From an airspace user perspective they still pay 100% of the service even if there is a demand sharing component

⁴ http://europa.eu/rapid/press-release_SPEECH-13-703_en.htm

⁵ E.g.: <http://aviationweek.com/aftermarket-solutions/has-single-european-sky-project-failed>

introduction of competition requires a comprehensive impact analysis to evaluate different regulatory approaches along a variety of dimensions.

The main research question of COMPAIR is “how to introduce competitive incentives in the ATM sector so as to best contribute to the achievement of the European high-level policy objectives for aviation.” In reply to this, the project has pursued the following objectives [38]:

1. propose a set of **new institutional market designs** for the introduction of competition in the European ATM sector;
2. define a framework allowing a **comprehensive assessment** of the impact of different institutional market designs on ATM stakeholders and society at large;
3. develop a variety of **economic and network simulation models** allowing the **evaluation** of the proposed regulatory approaches along the dimensions identified as relevant in the assessment framework;
4. assess the **feasibility and acceptability** of proposed institutional changes for various market actors;
5. propose a vision and derive **policy recommendations** for the implementation of those new institutional structures identified as most beneficial for the European ATM system.

2.3 Work Performed

2.3.1 Introducing the four COMPAIR scenarios

COMPAIR focused on four potential ways to introduce competitive elements in the ATM sector. These options were based on the initial ideas at the outset of the project proposal, which have been further fine-tuned in a variety of ways: literature review & desk research, a workshop with the Advisory Board Members, face-to-face interviews with selected respondents and a survey which was sent out to a broader set of ATM actors. This first assessment was made qualitatively in D2.2 [3]; first results were discussed during the first workshop (D6.3) [12]. For an overview of deliverables we refer to Table 2.

Option 1 – Performance regulation with variations in ownership and governance models

The ownership form of ANSPs varies over countries, from government agencies to government owned corporations to semi-public, semi-private firms (for profit and not-for-profit). There is also variation in the consultation processes by ANSPs of ATM stakeholders before making strategic decisions. In some countries, extensive consultation procedures are in place, whereas in others formal processes are currently under development or do not exist. The composition of an ANSP governance board may be designed to reflect the presence of specific skills or different opinions of ATM stakeholders. This variety may give rise to performance differences and the establishment of causal links between governance structures and performance.

This option fits within the research question of proposing market designs, which introduce competition in European ATM. While it does not directly introduce competition, it does so indirectly via two ways. Firstly, by introducing some form of vertical integration (market based or board based), competition is introduced in the DNA of the ANSPs as shareholders/board members do act in a competitive environment. Secondly, performance regulation in the form of yardstick competition could be introduced.

Option 2 - Unbundling

Unbundling is the process by which a large company with several different lines of business retains one or more core businesses and sells off the remaining assets, products, services, etc.

The provision of Air Traffic Management can be subdivided in the following components:

- 1) Network management: currently EUROCONTROL is in charge and is supported by national ANSPs
- 2) En-route air traffic service (ATS) provision
- 3) Terminal air traffic service (ATS) provision (incl. approach and tower control)

The unbundling of ATM services could start with the separation of terminal air traffic services. This is the activity where most direct benefits can be realised and which also is the easiest to separate. Unbundling of terminal ATS happens already today at a number of airports in Sweden, UK, Spain and Germany, which have appointed their local tower ATC provider through a public tender process[4]. The evidence on the effect of these market tenders is limited up to now, but it seems that the experience has overall been positive [4]. The approach for unbundling terminal ATS provision would thus be competition for-the-market.

As a second step, a number of en-route air traffic services could also be unbundled. These are mainly ATM support services, not the core ATC activities. These services are not necessarily monopolistic in nature and could therefore be supplied by independent service providers. These providers can sell their services to ANSPs. Unbundling of these support activities could lead to a competition in-the-market for service provision. Support services that are typically cited as candidates for unbundling are:

- Meteorological services (MET)
- Aeronautical information services/management (AIS/AIM)
- Communication, navigation and surveillance services (CNS) – this is mainly an infrastructure maintenance and management function

Further outsourcing of ATM activities could involve more specialised ATM activities with closer links to core air traffic control service:

- Airspace organization and airspace management
- Provision of contingency services

However, without a change in ownership form or the strengthening of the price cap approach, there is little interest in cost efficiency hence little interest in unbundling from the viewpoint of ANSPs.

Option 3 – Tender of licenses for en-route air traffic services

Option 3 concerns the tendering of a license to operate core en-route air traffic services, namely the provision of air traffic control, in a specific geographical area and for a certain period. The tender process is repeated after each fixed period, which could lead to contract renewal for the incumbent provider or to a new provider supplying the market. The form of competition under this institutional option is thus that ANSPs compete for-the-market, i.e. they compete for the right to provide ATM services in a certain geographical area for a certain period.

The geographical scope of the tender can correspond to the area of an air traffic control centre or even a national charging zone. This time-based tendering process can over time also lead to consolidation among European ANSPs. Certain ATS providers will be successful and be able to further improve their service provision thanks to learning effects. They may take over other providers, which are less successful, thereby reducing fragmentation and enabling economies of scale through a market driven process.

Contract conditions should also include performance incentives with respect to capacity, environment/flight-efficiency and safety to ensure that selected ATM operators are responsive to various performance dimensions.

Option 4 – Flight centric, sector-less operations

Sector-less operations in itself is not an “institutional design option”, but it will have institutional consequences. It can also increase the scope of competition in the ATM sectors, with ATM providers competing on a per-flight basis or per-airline, rather than per geographical zone. The sector-less scenario also acts in COMPAIR as an example of the effects of technology changes on the institutional structures.

Overview of the four scenarios

The table below summarizes the four scenarios.

Table 1 Overview of possible institutional market designs proposed for increasing competitive dynamics

	Responsibility for air traffic safety	Provision of ATM services towards airlines	Property rights for ATM services	Form of competition (focus COMPAIR)	Timeframe
1 Governance	National	Several providers, one for each charging zone	National – ANSPs	None	Short term (<5 years)
2 Unbundling	National	Several providers for support services, one for each charging zone	National- ANSPs	Competition in the market possible for support services	Mid term (by 2030)
3 Tendering	National	Several providers, one for each charging zone	National – government bodies	Competition for the market	Mid term (by 2030)
4 Sector less operations	EU	Single ATM provider for a single trajectory	Transferred to EU level	Competition in the market	Long term (by 2050)

Source: [3]

2.3.2 Methodologies for assessing the four scenarios

A first qualitative assessment based on literature, a survey and interviews was made in D2.2 [3]; first results were discussed during the first workshop (D6.3) [12]. These scenarios were then quantitatively assessed using different quantitative approaches based on

- economic modelling (using mixed goal functions) [5],
- econometric estimations (stochastic frontier analysis) [5],
- game-theoretic concepts (game tree and two-stage network congestion game) [6]
- and agent-based simulations (agent based auction model) [7].

The aim of these modelling approaches was to understand the potential impact of these four scenarios. Scenario 1 (governance) and scenario 2 (unbundling) are discussed in D3.2 [5], while scenario 3 (tendering) is discussed in both D4.1 [6] and D4.2. [7] Scenario 4 (sector less operations) is discussed in D4.2. [7] The results of D4.1 and D4.2 are also summarized in D4.3 [8] (see Table 2 for an overview of the deliverables).

These assessments were then shared with stakeholders in a workshop (see D6.4 [13]) and in individual interviews to discuss the feasibility of the outcomes, possible hurdles for implementation etc.

2.4 Key Project Results

This section describes the key modelling results and the feedback received from stakeholders.

2.4.1 Modelling results

Option 1 – Performance regulation with variations in ownership and governance models & yardstick competition

This option focusses on the link between the performance of ANSPs and their ownership form. The theoretical economic model described in [5] suggests that the effort to achieve cost efficiency will be higher in the case of public companies with a board of stakeholders composed of airspace users and in the case of private companies in which stakeholders are also shareholders. The importance of strong national interests, on the other hand, encourages technology purchases from local suppliers or relatively powerful labour unions, which are likely to decrease efficiency. A stochastic frontier analysis estimation of the production and cost function of 37 European ANSPs over nine years suggests that the public-private ownership achieves statistically significant higher cost and production efficiency levels compared to either a government cooperation or state agency [5]. The coefficient estimates are significant and have the expected signs. Note that input prices for labour costs (wages) seem to carry a greater importance in comparison to capital costs. This observation may be explained by the higher share of labour costs at the ANSP total cost level currently. With respect to the cost function and economies of scale, [5] finds that a 10% increase in traffic, given the same airspace, corresponds to a cost decrease of around 10 to 15% on average. Structural differences in air traffic characteristics between ANSPs are important in explaining productivity and efficiency performance differences. Seasonality and traffic complexity seem to be particularly relevant. For en-route service, it was found that there are large differences across Europe based on a stochastic cost frontier analysis. The figure below shows the statistically different estimates across the ANSPs. When comparing average efficiency levels across ANSPs, we see that the efficiency levels of ten of the ANSPs lie above 0.7- with MUAC, NATS and SkyGuide at the top. Eighteen of the smallest ANSPs scores lead the bottom of the rank with efficiency estimates below 0.4. This means that there is room for serious improvement.

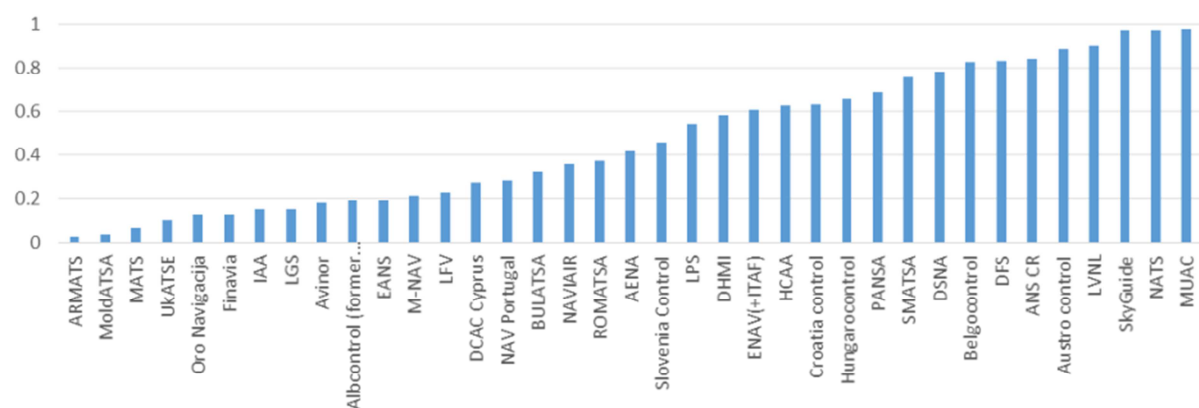


Figure 1 Average production efficiency Estimates per En-route ATC provider – source [5]

With respect to terminal control we observe similar tendencies.

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Option 2 - Unbundling

Unbundling is the process by which a large company with several different lines of business retains one or more core businesses and sells off the remaining assets, products, services, etc. Unbundling is done for a variety of reasons, but the goal is always to improve performance. In the case of a monopoly market, unbundling of non-core activities can introduce competition for part of the market. Within ATM, a key example is the unbundling of tower control.

The experience of introducing competition by outsourcing tower control services shows [5]:

1. Competition for tower control services is at present only introduced in a few European countries and in each of these countries only part of the market is opened for competition. There are two motivations for the opening of the market for airports. The first is a reduction of costs; factual information suggests that cost reductions of 40% or more could be possible. The second motivation is transparency in the subsidies given to regional airports in many countries. Regional airports do often not pay for tower control and this gives rise to inefficient operation of regional airport activity.
2. In those countries where the tower control activities were liberalized, there was important resistance and lobbying from the side of the incumbents and the unions. In some countries, the unions managed to protect the salaries and benefits of the existing local Air Traffic Controllers (ATCO's). The incumbents were able to renegotiate existing contracts and prolong their position for another term, avoiding competition for some years. At the same time, this treat of competition led to renegotiations for the benefit of the airports.
3. One of the major drivers of liberalization were the airports when they are private or when they face strong competition. For these airports to succeed in a successful renegotiation or successful tendering operation the national legal framework has to clearly allow the airports to choose their tower services provider.
4. As only some countries have a legal framework that allows organizing competition, one may call upon EU directives to help introducing effective competition. However, the example of electricity production liberalization where it took 5 to 10 years before EU directives were implemented shows the initiatives remain largely in the hands of the member states.

A similar analysis can be made for other services which can be outsourced such as MET, CNS, (AIS/AIM), etc. The main difference is that it will not be the airport that will outsource, but the ANSP itself. While airports are often privatized and/or face strong competition, this is less the case for ANSPs – reducing the drive for cost efficiency.

Option 3 – Tender of licenses for en-route air traffic services

This option was assessed by two models: a game-theoretic network model [6] and an agent based model [7]. Both models showed that the creation of for-profit ANSP companies and the introduction of competitive tendering processes would

- Likely lead to the defragmentation of the skies because companies would bid for more than one airspace.
- Lead to lower charges than occurs today, in part due to the economies of scale achieved through defragmentation and in part due to the bidding process that creates a competitive environment at least once every five to ten years.
- Another advantage of this system would be the potential to remove the economic regulatory bodies currently involved in setting the price caps of the existing system.
- Based on the results of the multiple analyses, it would likewise appear that another aim of the Single European Sky initiative⁶ could be facilitated, namely the adoption of new SESAR technologies.

There are however also some points of attention:

- According to the agent-based simulation [7], the results suggest, for Europe, that a maximum market share of 20% ensures sufficient competition.
- It is important to ensure a sufficient number of competitors for the auction process to be successful over time [6][7].
- The order in which the Member States undertake the auctions has a strong impact on the local charges in each country, but the global network effect is not as important. Member States adopting the auctioning system earlier are at an advantage [7].
- Finally, the duration of licenses shows different outcomes, with the shorter, five-year periods leading to less efficiency gains in the short-term, but higher levels of competition in the longer term [7].
- The transport equilibria outcome appears to be closer to achieving the Single European Sky objectives under for-profit company competition than non-profit. In the case of non-profits, the charges decrease below the current price cap but to a lesser extent than the for-profit case. Moreover, it is less likely that all ANSPs will adopt the SESAR technologies as the current results suggest that only the larger ANSPs will choose to invest. However, without auctions, the non-profit result is superior to that of for-profits or the current system [6].

These conclusions are made on the base of two case studies, covering about half of the European airspace. Their geographical context is shown in the figures below.

⁶ https://ec.europa.eu/transport/modes/air/single_european_sky/ses_2_en

Figure 2: Geographical context case study 1 – source: [6]

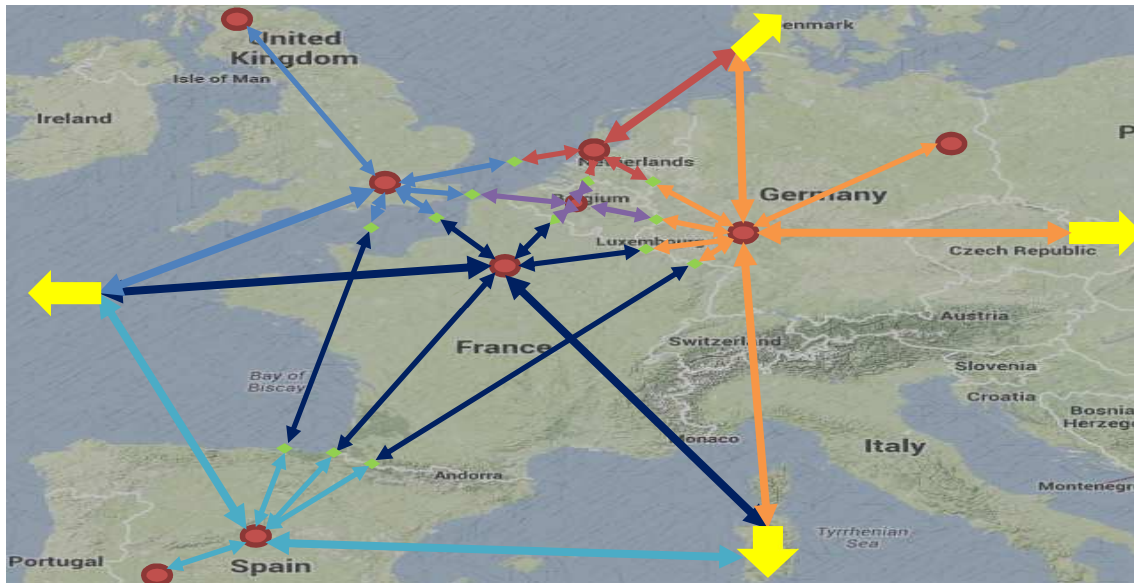
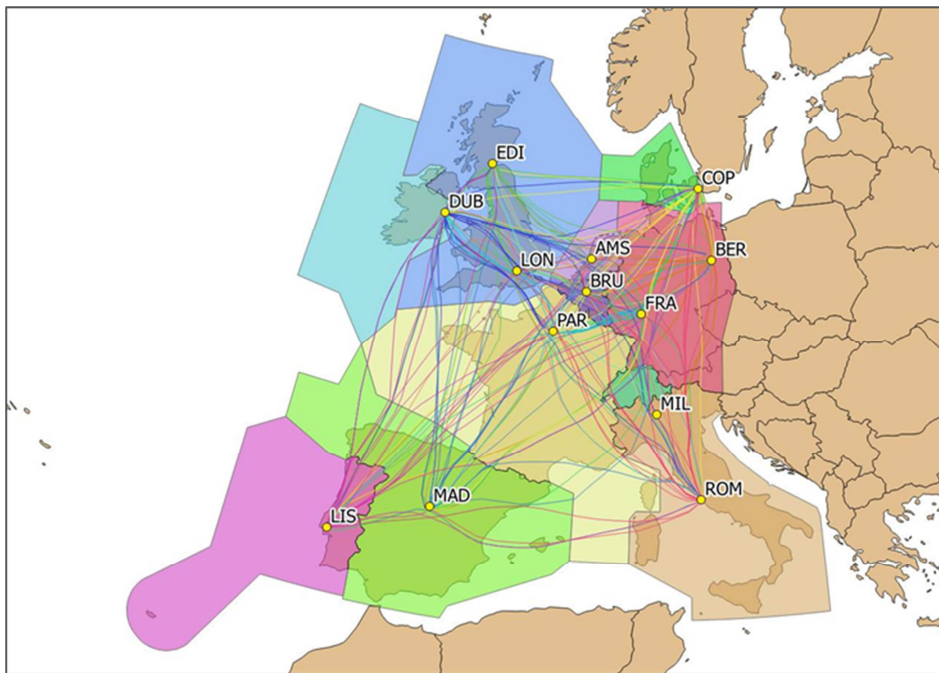


Figure 3: Geographical context case study 2 – source: [7]



Option 4 – Flight centric, sector-less operations

Using agent-based modelling, [7] simulated a futuristic sector-less scenario in which ANSPs provide air navigation services to flights from origin to destination (OD). ATCOs can work at any OD pair and ANSPs can provide air navigation services in all European regions. Hence, there is no preference to work on specific routes. To explore this idea in a simple manner, the project members decided to

simulate a market design similar to the electricity market, in which airlines submit their bids and ANSPs simultaneously submit their ask prices⁷ of controlled flight-kilometres to the Regulator, which chooses some price p that clears the market. In this model, ANSPs have the incentive to invest in improving their efficiency and reduce their costs, otherwise their productivity relative to competitors will decrease and they may be out of the market.

In the case of the sector-less scenario, with air traffic services provided on an origin-destination pair basis, it is observed that the most efficient ANSPs control an increasing market share until they reach the maximum market share allowed by competition regulation. The results of the simulation suggest that, since the dominant ANSPs tend to increase their market share in each auctioning process, the maximum market share permitted is a necessary measure in order to avoid the emergence of a monopolistic ANSP serving the entire European market.

Overall results

The results show that governance/ownership matters and impacts performance. COMPAIR also finds that unbundling – or even only the treat of unbundling can lower costs substantially. However, as ANSPs do not face strong competition, the result might be less substantial for services which are to be outsourced by ANSPs (rather than by airports) [5].

The applied models ([6][7]) suggest that introducing competition for the market via outsourcing service provision may lead to a reduction in charges by up to half the current levels. It would also appear that auctioning the service is likely to lead to defragmentation of the European system as companies win more than one auction. According to the agent-based simulation, the results suggest that, within the case study, a maximum market share of 40% ensures sufficient competition. The companies will be large enough with sufficient financial backing that they will be in a position to invest in new SESAR technologies. Both modelling approaches derive results suggesting that for-profit companies are highly likely to invest in such technologies thus encouraging adoption faster than appears to be occurring today. Note that it is important to ensure a sufficient number of competitors for the auction process to be successful over time. Finally, according to the game-theoretic model, non-profit companies would be strictly preferable to both the current state agency and to a government corporation if auctions were not introduced.

2.4.2 Stakeholder feedbacks

Within COMPAIR, special emphasis was given to gather stakeholder feedback in different stages of the project. Two workshops [12][13], advisory board meetings, interviews, presentations at conferences and other workshops and a survey ensured the technical approach was balanced with the validation of the experts. The main stakeholder views collected by the project can be summarized as follows:

⁷ The “ask price” is the minimum price a seller is willing to receive. A bid price on the other hand represents the maximum price that a buyer is willing to pay for the service.

- There is general agreement that at least some competition is needed if the efficiency of the European air navigation service environment is to be improved;
- Most stakeholders agree that the main obstacle in the way of achieving such an improved environment is the lack of sufficient political will to initiate and execute the changes;
- There is a feeling that the current auctioning process for terminal control is a good basis for going forward.

In the following paragraphs we show some individual statements. The consortium members do not necessarily share the views mentioned below, but they represent opinions, which seem to be agreed by a significant part of the stakeholders.

The invited experts made the following statements during the workshops, advisory board meetings, interviews, presentations at conferences and other workshops:

Current situation – short term forecast – boundaries for competition:

“Some say that a level of competition is possible in the short term as well, but seeing the slow development of the ATM in general, it is not sure that there will be a high level of competition. From the ANSP point of view, now they have a kind of competitive cooperation. However, the competition is not about the market, rather about the influence that one could have on the future. Today, the driving force behind innovation is not the competition itself, but rather the feeling that eventually it will be introduced and the ANSPs should be prepared for that. ANSPs also try to find new possibilities like in the case of the drone question which opens up a new market. So to an extent ANSPs compete already; at the same time, due to the nature of the ATM system, they should also cooperate.”

Current situation – short term forecast – possibilities for competition:

“The states would keep the current approach until the EU will provide a strong argument for introducing competition and it may become mandatory for all member states. Once the opening of the market is mandatory, according to most stakeholders the unbundling will have the biggest potential. There are already some initiatives in the supporting activities towards opening for the market, but not in the core business.”

“The cases like Hungarocontrol providing services in Kosovo or Maastricht providing radar and flight plan services for Slovenia show that it is possible not to invest in infrastructure, but to buy the service. Some form of unbundling is foreseen when some providers would provide the SWIM services about where the aircraft is and where it will be and allow communication between ATC services. This unbundling of basic information is expected to come from SESAR. The costs will be completely flat and you will manage to squeeze in more traffic at the same costs.”

“In the US, 42% of the staff are ATCOs and the rest is support staff and in Europe 30% are ATCOs and 70% are support staff (Eurocontrol & FAA (2016)). In ACR, there are 90% of ATCOs and only 10% of support staff. This may be an extreme case, but it indicates that there is room for consolidation.”

Situation by 2030:

“It is ambiguous to say that competition will be introduced by 2030 as there is a trend now that the countries are more aware of their national interest. This will slow down the process of relinquishing of the national monopoly on the airspace. On the other hand, the new technologies will completely change the market and the rules of the game.”

“There will be new concepts coming from SESAR which would allow the aircraft to separate itself against the rest. Once you do this, you no longer have the natural monopoly. Therefore, it may be that the situation in which ANSPs operate will change completely.”

The role of technology change

“The reasons for ANSPs to invest in technologies are that, first, there are regulations, there is SES and SESAR plus there are incentives and funds from the EU. Additionally, with the centralised services there are new services and functions which lead to the situation when fewer players will be involved. Some ANSPs may feel that not being in the loop, not following the developments and not being involved with SESAR would cost them the influence they may have or may not have on the future situation. This is another strong incentive for investing into the new technologies for ANSPs.”

“New technologies will have an impact on better utilising capacity as well: with the introduction of new technologies, the workload will be more predictable than today as now we have 20 % of sectors with 40 % of traffic load. The system now is to some extent empty and generates unused capacity, which makes the current system inefficient. In some areas, the current system is crowded and this generates delays. This is because the capacity cannot be transferred from one sector to another. In the sector-less ATC it is clear that there is an aircraft to control, so the necessary resources should be provided.”

“An important way of technology change is providing services remotely. This does not require a huge investment as might be thought. Even if much larger airspaces are considered, they are manageable and the new technology available allows having all the necessary information to manage the air traffic at any given airspace.”



“Drones are also meant to be a game changer: we have to think completely different, as drones will manage themselves. The drones will have lots of equipment on board; they will know where the obstacles are and where the other users are. The ANSPs will be more like data aggregators. Still they would require information on the airspace and the conditions they operate in. The ANSPs and ATC will not be separating anymore; they will manage the airspace. Maybe new parties will be involved into competition. Besides or instead of national ANSPs there might be newcomers, like Google, Amazon, etc.”

The most likely scenario:

“I see the eventual evolution to a for-profit ANSP model, with auctions for service contracts. The results of the research indicating that this model leads to the best results is convincing but also consistent with my intuition and experience in other industries.”

“...as tenders are put forth to offer services outside their home countries, it is natural that such non-profit entities will be tempted to bid on them, again suggesting motivation to become a for-profit entity. I see an evolution toward the for-profit model analysed by the research team going through environment with a mix of models...”

“Based on the summary of scenarios, in my opinion the most likely scenario – without any regulation and pressure from the institutional level - is Scenario 1 (the base-run scenario with ANSP which likely represent the objective of the current state agency or government corporation). However, with sufficient incentives from the political level, a trend towards scenario 5 could be possible (and in my view desirable).”

“Scenario 1 appears to be the most likely scenario in case the member states continue to use sovereignty related challenges to prevent a development towards a more competitive market, where cross border activities and operations in other countries should be common and desired as it seems necessary in order to achieve the required scale effects.”

“It is noteworthy that in the Middle East region – unarguably a region with many critical military operations and delicate sovereignty challenges – ANS provision through tender processes is not uncommon and private providers such as SERCO operate en-route airspaces over many different countries.”

“If there will be a move towards a more competitive ANS en-route market (for example as a consequence from a successful liberalization of the TANS segment), it would seem that for-profit organizations would be more suited to manoeuvre on the financial markets to find most favourable financing solutions for their investments and that would have the necessary “natural” and market-driven incentives to maximise efficiency to the benefit of themselves and the users.”

“As Air Navigation Services are in reality several quite different services provided to airspace users, where some services relates to defined airspace while others are not, it is hard to talk about business scenario for Air Navigation Services in general.”

“Nations may easily transform their current ANSP bundles into non-profit organizations in similar fashion as Nav Canada, or even for-profit organizations. European Nations may also agree to collaborate and establish a non-profit company together. But that would still be on a monopoly basis.”

“Establishing a real market for Air Navigation Services would in my opinion require an unbundling both in service type and in flight phase. Currently Air Navigation Services can be unbundled according to the formal definition of the term, into: Navigation service, Communication service, Surveillance service, Meteorological services for air navigation, Aeronautical Information service and Air Traffic Service. Currently Air Navigation Services is also divided into En-route air navigation and Terminal air navigation, and it can be unbundled in this dimension also.”

“It is more likely to be able to establish a market for some of the unbundled/individual services than a market for the same national bundle that is the norm today. Currently some nations have been able to introduce competition for Terminal Air Traffic Service for a specific airport, or maybe only the Aerodrome Control service for a specific airport.”

“If European nations really want to, it would be possible to unbundle the services and then provide most or all services on a competitive basis. Meteorological services for air navigation, and Aeronautical Information service are candidates for large geographical areas, while Air Traffic Services are candidates for smaller geographical areas. We also see that some of the unbundled ANS may be performed by an aerodrome operator (in competition with other pure ANS providers) because some unbundled services are only related to a single aerodrome.”

“All European Air Navigation Services can be completely run by for-profit and non-profit organizations with tenders but that will require quite some effort at political level.”

“It is difficult to conclude which is the more likely scenario. I think the sector less based operations scenario is unlikely be 2030. Regardless of the technological developments the regulatory and cultural steps required are, in my opinion, too great for that time scale. With unbundling I believe there will be too greater resistance from the incumbents and I’ve not been convinced that there are benefits to unbundling ANSPs other than in separating the aerodrome services from area control service. In the aerodrome service, remote towers are likely to drive the greatest competitive benefit and lends itself well to the auctioning process.”



“Auctioning, as your latest modelling shows, could bring real benefits. Should the current incumbents be privatised prior to the auctions – there would be a significant question in investors’ minds over returns if they are not guaranteed at least a minimum exclusive period. An alternative would be to allow private companies to bid and then take over the assets of the public incumbents as part of that process – the auctioning would be the route to privatisation. This would work in the fully public providers across the EU but not in the case of NATS where it has private property rights and an exclusive licence. These are not small hurdles but they could be worked out through in series of legislative packages. I am also left wondering whether the labour force would be sustainable, given current regulatory requirements on ATCOs.”

“I continue to consider that that best approach to competition in air navigation is at the aerodrome level. At the en route level, I believe a key driver will be further EU integration, as the key factor holding back competition is state sovereignty. Countries being seen to be in ‘control of their skies’ will always favour a fragmented European airspace. This factor should not be underestimated.”

To what extent will the European air navigation business competitive by 2030:

“By 2030 there should be a limited use of competition mixed with the existence of non-profit models used in various counties. The drivers for more extensive use of competitive models will be cost reduction, with the primary push coming from flight operators, and, perhaps more significantly, the need for capacity expansion and general improvement in the performance of the overall air transportation system. This push should come not just from airlines but the general public and government bodies.”

“The degree to which the US might achieve better performance due to having a single ANSP for its entire geographic area, compared to the fragmented ANSP structure in Europe, should provide motivation for new ANSP structures. The European Commission certainly would need to play a very substantial role.”

“It can be assumed that the pressure to introduce competition will stem from the fee-paying users of the airspace and from users/stakeholders that are affected by insufficient capacity provided by the legacy ANSP. In absence of an inherent interest to succumb the monopoly status within the legacy ANSP and the National regulatory bodies, this pressure will probably have to be amplified through the political and institutional framework pressuring the member states to open up for a more competitive ANS market.”



“In my view, a possible scenario on the path to a fully competitive market will be an evolution starting with the liberalization of the Terminal ANS market and then including larger and more complex airspaces towards the opening up for competition of the En-Route airspace across the Union. Such an evolution is likely to yield several advantages for the stakeholders such as the possibility to become familiar with ANS tendering /auctioning processes, the development of a supporting regulatory framework that can assure a level playing field and the development of a common understanding regarding operational- and organizational- performance criteria necessary in a safety/security/ national-infrastructure critical environment.”

“Furthermore, insights in cost-transparency achieved in the less ‘sovereignty-critical’ operational environments will provide ANSP to prepare in a more robust way for the more complex calculations and models required in the provision of offers for multi-year En-Route services.”

“By 2030, I see the European T-ANS market as predominantly open for the competitive bidding for ANS services. This is likely to lead to the emergence of new private-owned or ANSP owned for-profit actors in the market and a reduction of ANS costs for mainly the airports and in a wider sense the airspace users.”

“European ANS can be competitive by 2030 by working on unbundling and starting with some clearly defined services, like approach and aerodrome control services, or just aerodrome control service to specific airports, but with a strong objective to continue with other air navigation services. As the benefits of competitively performing services are observed and understood the rest will follow.”

“The driver for competitive business in ANS will be the airlines (including airlines unions like IATA, A4E etc) that experience that Air Navigation Service charges is becoming an increasingly large portions of their operating expenses. The driver should also come from politicians elected by citizens that does not accept expensive and inefficient air navigation services being provided to the airlines they use for travel, and pay for their ticket - where Air Navigation Service charges is included.”

“Up to 2030 that leaves yardstick regulation and auctioning. The development of regulation is clearly the low hanging fruit in this instance and can be easily achieved by 2030. I believe that given limiting factors of sovereignty and the invested interests of the incumbents moves further than this will be difficult.”

"I believe we will still be in an economically regulated environment with National incumbents by 2030. But we may see the development of competition due to technological changes in certain areas. It will take strong political will to move the en route to a market-based outcome."

2.5 Technical Deliverables

Reference	Title	Delivery Date ⁸	Dissemination Level ⁹
Description			
D1.1 [1]	Project Management Plan	29/09/2016	Confidential
This document is the Project Management Plan of the COMPAIR project. The Project Management Plan defines how the project is managed, planned, monitored and controlled. It includes the project organisation structure, work plan, management, procedures, risk and issues management, communication and dissemination, and the implementation approach for the Ethics requirements.			
D2.1 [2]	Internal report on assessment framework	02/09/2016	Confidential/Public*
The purpose of this document is to define an assessment framework allowing the evaluation of the different institutional designs proposed by COMPAIR in a consistent and comparable manner throughout the entire project. The assessment framework will be an input for the specification of the outputs of the COMPAIR models. This will ensure that the same indicators are defined in a consistent manner across the different models, so that we can benefit from the synergies and complementarities between such models.			
* Following the project members decision this Deliverable is accessible on the COMPAIR website, despite being marked confidential in the Grant Agreement			
D2.2 [3]	Report on institutional design options	31/01/2017	Public
Within this deliverable COMPAIR develops a list of concepts on new institutional approaches for air traffic management. This includes a detailed description of their features and a qualitative characterization of the potential effects. This is based on an initial proposal of concepts, which are further fine-tuned based on literature and stakeholder input.			

⁸ Delivery data of latest edition

⁹ Public or Confidential



D3.1 [4]	Modelling framework guidelines	30/01/2017	Confidential/Public*
The purpose of this document is to develop a set of common modelling guidelines to ensure that differences between modelling outcomes are driven by institutional designs studied and not by differences in model inputs. Guidelines address the model inputs: modelling horizon, the assumptions underlying the models and the potential sources for input data. * Following the project members decision this Deliverable is accessible on the COMPAIR website, despite being marked confidential in the Grant Agreement			
D3.2 [5]	Report on Economic Analysis	27/05/2017	Public
This deliverable focusses on two questions: 1) Is there a link between ANSP performance and ownership? And 2) What is the potential for unbundling? To assess the relationship between performance and ownership the cost and production function of European ANSPs were estimated econometrically. Based on a simple economic model, it was derived that effort/efficiency will be higher in the case of public companies with a board of stakeholders and in the case of a private company where stakeholders are also shareholders. To assess the potential for unbundling, the main economic mechanisms were illustrated using tower control as an example.			
D4.1 [6]	Report on network game-theoretic model	10/12/2017	Public
This deliverable focusses on whether it is possible to introduce competition <i>for</i> the market in ATC in Europe. A two-stage, network, congestion game in which multiple ANSPs bid to serve Member State airspace was developed. The results suggest that introducing competition for the market may reduce charges by up to half the current levels. It would also appear that auctioning the service is likely to lead to defragmentation as companies win more than one auction. Finally, it would appear that for-profit companies are highly likely to invest in SESAR technologies thus encouraging technology adoption faster than appears to be occurring today.			
D4.2 [7]	Report on agent-based auction model	03/12/2017	Public
This report studies two possible institutional designs for the introduction of competition in ATM. The first design consists in the tendering of licenses to operate en-route air navigation services in specific geographical areas for a certain period of time. The second scenario consists in the provision of air traffic services on a sector-less, Origin-Destination pair basis. These institutional designs are investigated by means of agent-based modelling and simulation, which allows us to study the resulting processes from a dynamical perspective. The influence of different parameters on the resulting level of technology adoption, the emerging market structure and the air navigation charges up to 2050 was also investigated.			
D4.3 [8]	Quantitative impact assessment summary report	06/12/2017	Public
This report summarizes the main conclusions from two modelling approaches. The results of both models suggest that introducing competition for the market via outsourcing may lead to a reduction in charges by up to half the current levels. It would also appear that auctioning the service is likely to lead to defragmentation of the European system. According to the agent-based simulation, the results suggest that, for Europe, a maximum market share of 20% ensures sufficient competition. The companies will be large enough with sufficient financial backing that they will be in a position to invest in new SESAR technologies.			

D5.1 [9]	Final Project Results Report	1/02/2018	Public
This report expresses the COMPAIR vision on the future for ATM sector in Europe from an institutional perspective. It describes the projects' view on potential pathways towards new institutional designs for the European ATM sector. These institutional elements will likely include more competitive dynamics that should lead to performance improvements on various ATM key performance areas. It also investigates different ways of implementation. This report also discusses potential drawbacks and ways of addressing perverse incentives in new institutional designs. The report starts with a concise executive summary which outlines the main idea of the project, the approach taken, the main results and recommendations.			
D6.1 [10]	Project website	29/09/2016	Public
Public website including all the communication and dissemination material produced by the project. www.compair-project.eu			
D6.2 [11]	Project Dissemination plan	01/12/2016	Public
The PMP includes a Communication and Dissemination Plan, further detailing the implementation of the foreseen communication activities, and for planning the dissemination of project results.			
D6.3 [12]	Workshop report 1	12/04/2017	Public
This report discusses the first public COMPAIR workshop held in Madrid on the 7th of March 2017. At this workshop the COMPAIR results of the first year were discussed in order to receive feedback from the stakeholders present. This report includes the document which was sent beforehand to the participants, the minutes of the workshop, the presentations and concludes with how the consortium will use the input received at the workshop.			
D6.4 [13]	Workshop report 2	08/01/2018	Public
This report discusses the second public COMPAIR workshop held in Brussels on the 20th October 2017. The overall goal of the workshop was to present and discuss the models the COMPAIR project has developed. These models explore the possibility to include competitive elements into the Air Traffic Management. Within the workshop the models were discussed and feedback from the participants was requested with respect to applicability, possible hurdles and potential side effects. This report could also be read as the minutes of the workshop.			
D7.1 [14]	POPD – Requirement No2	01/09/2016	Confidential
D7.1 – POPD-Requirement No. 2 of the Ethics requirements of the COMPAIR project – Competition for Air Traffic Management details the informed consent procedures that will be implemented with respect to data protection consent.			
D7.2 [15]	POPD – Requirement No1	01/09/2016	Confidential
D7.2 – POPD-Requirement No. 1 of the Ethics requirements of the COMPAIR project – Competition for Air Traffic Management details the procedures that will be implemented for data collection, storage, protection, retention and destruction and confirmation that they comply with national and EU legislation.			

D7.3 [16]	POPD – Requirement No5	29/03/2016	Confidential
D7.3 – POPD-Requirement No. 5 of the Ethics requirements of the COMPAIR project – Competition for Air Traffic Management provides a copy of the ethical approvals for the collection of personal data by the National Data Protection authority.			
D7.4 [17]	NEC – Requirement No6	01/09/2016	Confidential
Within D7.4 the COMPAIR Consortium confirms that ethical standards and guidelines of Horizon2020 will be rigorously applied, regardless of the country in which the research is carried out. This entails that the research conducted at the non-EU institute present in the consortium (HUJI) will adhere to the same ethical standards and guidelines as the ones that apply for the other consortium partners.			
D7.5 [18]	H – Requirement No3	04/08/2016	Confidential
D7.5 – H-Requirement No. 3 of the Ethics requirements of the COMPAIR project – Competition for Air Traffic Management details the informed consent procedures that will be implemented with respect to the consent to participate in the study.			
D7.6 [19]	H – Requirement No4	01/09/2016	Confidential
D7.6 – H-Requirement No. 4 of the Ethics requirements of the COMPAIR project – Competition for Air Traffic Management details the procedures and criteria that will be used to identify/recruit research participants.			

Table 2: Project Deliverables

3 Links to SESAR Programme

3.1 Contribution to the ATM Master Plan

The project has shown that a faster update of SESAR step 1 technologies as outlined in the 2012 ATM Master Plan [37] is possible under certain scenarios. These investments can reduce costs by half.

The following table describes the progress the project has made in increasing the level of maturity. Given the nature of the work, it is not possible to link this to a specific OI Step and Enabler. We have opted for the OI step of “increasing awareness”.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
	<i>Increased awareness of potential of competitive elements within ATM</i>	<i>The COMPAIR project showed that there are potentially huge performance savings could be made should competitive elements be able to play a role. Auctioning would also likely lead to defragmentation of the skies as companies would bid for more than one airspace. In addition, a faster uptake of technology is expected. Furthermore, it also showed that governance is important and can impact efficiency. Given the current structures, economies of scale are exists but are rather limited. However, this is partly due to the fact that today airspaces are relatively small in Europe</i>		

Table 3: Project Maturity

This work is not directly linked to and OI Step and Enabler.

3.2 Maturity Assessment

The table below is an extract of the Maturity Assessment tool.

Founding Members



Table 4: ER Fund / AO Research Maturity Assessment

ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
TRL-1.1	Has the ATM problem/challenge/need(s) that innovation would contribute to solve been identified? Where does the problem lie?	Achieved	Within D2.2 [3] (and in a previous project ACCHANGE) some of the problems hindering efficiency and uptake of technologies have been identified. These are linked to the existence of national monopolies, fragmentation and home bias.
TRL-1.2	Has the ATM problem/challenge/need(s) been quantified?	Achieved	Within D2.2 [3] these problems have been qualitatively raised. Within 3.2 ATM production and efficiency functions have been estimated showing quantitatively the role of economies of scale (influence fragmentation) and governance.
TRL-1.3	Are potential weaknesses and constraints identified related to the exploratory topic/solution under research? - The problem/challenge/need under research may be bound by certain constraints, such as time, geographical location, environment, cost of solutions or others.	Partial - Non Blocking	Within the quantitative modelling (D3.2 [5], D4.1 [6] and D4.2 [7]) constraints and weaknesses have been identified. This was supplemented with qualitative information from stakeholders. The assessment is not complete as - for example - the influence of technologies beyond SESAR has not been explicitly modelled.
TRL-1.4	Has the concept/technology under research defined, described, analysed and reported?	Achieved	D5.1 [9] provides a summary of the description and analyses made



TRL-1.5	Do fundamental research results show contribution to the Programme strategic objectives e.g. performance ambitions identified at the ATM MP Level?	Achieved	COMPAIR has shown that the introduction of competitive elements within ATM could potentially half the charges, reduce fragmentation and lead to an uptake of new technologies (D3.2 [5], D4.1 [6] and D4.2 [7]) Under certain scenarios the models show a faster uptake of the SESAR Step 1 technologies as outlined in the 2012 ATM Master Plan [37]. These investments could lead to a reduction in costs by half.
TRL-1.6	Do the obtained results from the fundamental research activities suggest innovative solutions/concepts/capabilities? - What are these new capabilities? - Can they be technically implemented?	Achieved	The approach and toolset developed in COMPAIR could be used to demonstrate the gains of, for example investments in SESAR technologies, in a business case.
TRL-1.7	Are physical laws and assumptions used in the innovative concept/technology defined?	Not Applicable	
TRL-1.8	Have the potential strengths and benefits identified? Have the potential limitations and disbenefits identified? - Qualitative assessment on potential benefits/limitations. This will help orientate future validation activities. It may be that quantitative information already exists, in which case it should be used if possible.	Achieved	Given the scope of the project, this has been achieved. The results are clear; identifying aspects which should be further researched and/or detailed.



TRL-1.9	Have Initial scientific observations been reported in technical reports (or journals/conference papers)?	Achieved	Results have been reported at several conferences. For a list please see the different progress reports.
TRL-1.10	Have the research hypothesis been formulated and documented?	Achieved	This is mainly done in D2.2 [3]
TRL-1.11	Is there further scientific research possible and necessary in the future?	Achieved	Further research into this topic is possible and necessary. This could consist of relatively small steps: from finetuning the current modelling (adding more countries/regions to both the econometric exercise (D3.2) [5] and to the case studies in D4.1 [6] to D4.2 [7]). Other aspects of interest are - Focus on distributional effects and adding more players to the models. What would be the effect on the users (passengers and cargo), airports, nations,... Who wins and who loses? And can the winners compensate the losers? - How to set up a good auction? Which are the necessary elements to achieve the potential benefits identified in COMPAIR? - The investigation of the role of further technology changes (beyond SESAR), the



			link with airports, the role of UAS
TRL-1.12	Are stakeholder's interested about the technology (customer, funding source, etc.)?	Partial - Non Blocking	COMPAIR is not discussing a specific technology. Note that stakeholders are very interested in the work and the results The approach and tools developed could be further developed in which case they could be used by, for example PRB or DG Move, to demonstrate the gains of certain technologies in a business case.

4 Conclusion and Lessons Learned

4.1 Conclusions

The overall goal of COMPAIR was to study various institutional and market design approaches for introducing competition for en-route ATM services, in order to assess their potential contribution to the European Single European Sky objectives. The project was also required to propose a vision for the implementation of the most desirable institutional structures.

The options to be examined by the project were originally set at the time of the project proposal, however they were refined based on literature and stakeholder input and qualitatively assessed once the project started its work [3].

The options examined were the following:

Option 1 – Performance regulation with variations in ownership and governance models

Option 2 – Unbundling

Option 3 – Tender of licenses for en-route air traffic services

Option 4 – Flight centric, sector-less operations

It was established that Option 1 could be a candidate for implementation in the short term, in view of the fact that there are already examples of this approach [5].

Option 2 would require substantial changes in the attitude of the ANSPs who appear to have little interest in unbundling in the current ownership structures. The project concluded that realistically, this option would only be a candidate for medium term implementation [5].

Option 3 could potentially lead to consolidation among the European ANSPs, eliminating some of the current fragmentation as well as a reduction of charges in the competitive environment. However, political and institutional constraints would appear to make this option also a candidate for the medium term only [8].

Option 4 was special in that it assumed an important change in the way the air traffic control service works, supported by further technology developments. Potentially able to reduce the charges to about half of their current level in real terms, this option can only be seen as a longer term solution as the required environment cannot be created sooner [7].

The COMPAIR project made extensive use of stakeholder feedback (including, but not only [3], [12] and [13]) to both develop and validate its work. The main stakeholder views collected by the project can be summarized as follows:

- There is general agreement that at least some competition is needed if the efficiency of the European air navigation service environment is to be improved;
- Most stakeholders agree that the main obstacle in the way of achieving such an improved environment is the lack of sufficient political will to initiate and execute the changes;

- There is a feeling that the current auctioning process for terminal control is a good basis for going forward.

The project has generated a vision for the implementation steps it considers essential for the success of bringing a competitive environment into reality. These range from further studies of what other regions and industries are doing to creating an institutional environment that is able to support competition. It is also proposed that the COMPAIR developed options be further evaluated and improved if necessary, with the due participation of all aviation stakeholders, including the airports and airspace users also. The consideration of upcoming disruptive technologies, the need to resolve airport capacity issues and the timely updating of the European ATM Master Plan are also seen as necessary steps on the way to achieving a competitive air traffic management environment.

4.2 Technical Lessons Learned

As this is not a technological project, technical lessons can play a dual role

- The technical lessons learned from the modelling exercises
- The role of technologies on our outcome.

As the technical lessons learned from modelling are very specific to the scenarios, this section focuses on the second element.

4.2.1 Looking further: the role of competition in long-term scenarios

The COMPAIR project has looked at various options to realize competition as a means to speed the deployment of the SESAR technologies. So, the competition scenarios developed in COMPAIR will necessarily operate in the SESAR environment which is not that different from the existing environment in terms of the air traffic management paradigm used. Therefore, it is important to highlight that the COMPAIR institutional changes are expected to promote efficiency and the quicker deployment of SESAR technologies but they may not necessarily support the paradigm change that will be forced by the disruptive technologies which will change not only the “how” of service provision but also the “what”. Consequently, the changes being proposed by COMPAIR to bring in competition must be seen as a medium term solution with the real paradigm change coming in the longer term future (2030-2050) the proposed forms of competition may need to be reconsidered in view of the major changes in the required services and how they may be delivered.

Looking further in the future, the air traffic control environment is potentially facing the upcoming of disruptive technologies that might alter the status quo and force the legacy solutions out of the picture. These disruptive technologies will start to take effect in a time-frame that follows the deployment of the SESAR technologies, which are still legacy solutions. This move will be strengthened even more by the ever-increasing pressure from the airspace users for more efficient and lower cost service provision coupled with a wholesale shift of traffic patterns and aircraft operating modes. Electric propulsion, personal air transport, UAS and the like might change the landscape in hitherto never seen ways and magnitude and by the end of the period under review (2050) the whole meaning of air traffic control service provision will have to be redefined to accommodate the changes. In many ways, air traffic control service provision might go through an evolution that will be similar to what happened in the cockpit earlier where technology relentlessly

pushed out the third crewmember. The change will happen not because of technology itself but only if there is a commercial pressure to change.

It is important to note that the changes brought by the post-SESAR technologies will affect the very basis of how we prevent and avoid collisions to-day with the emphasis necessarily shifting towards higher levels of automation and re-distribution of tasks between air and ground. This is essential and unavoidable if the highly complex air traffic operating modes of the future are to be safely accommodated. Competition for providing those advanced services, combined with leveraging the new capabilities of the aircraft also, might take very different forms from those we can envisage to-day. It is also important to keep in mind that the disruptive technologies will appear primarily on aircraft and they will have been fully validated from a safety perspective. As a result, safety concerns will no longer extend ATM technology uptake.

Recognizing, that competition in air traffic control service provision is an appropriate tool to improve efficiency in European airspace, any arrangements and changes made to bring in such competition must be made with a clear view of the longer term future where competition as we know it to-day will need to be redefined in light of the potential major changes in the required air traffic services and how they will be delivered in 2050 and beyond. In other words, competition should be seen as an important improvement in the short to medium term but beyond that it is likely that new tools (possibly including new forms of competition) are appropriate for the paradigm shifts brought by the disruptive technologies will need to be defined.

4.3 Recommendations for future R&D activity

4.3.1 Other implementation issues

The COMPAIR focus

Following its original task description and the focus this required, COMPAIR examined the possibilities of introducing competition into air navigation service provision mainly from an ANSP perspective and on the basis primarily of commercial and institutional considerations. Therefore a first step of further research is of course the further improvement of the models themselves. This could include

- Extending the models such that they include all Member States and not only a selection.
- Relaxation of some of the assumptions in the current models.
- Adding distributional effects: including airports, consumers (cargo, passengers) etc. to show benefits and costs for all actors.

Other issues to be addressed

The scenarios created and the conclusions drawn are realistic in themselves, however, their feasibility is predicated on the assumption that a number of issues, not specifically addressed by COMPAIR, are eliminated or brought in line with the demands of a competitive environment.

In the following we will provide a summary of the most significant such issues, together with a rationale of why they are seen as problematic. Finding solution for these issues was not a task of COMPAIR, but it is important to highlight them and they could be seen as next research phases.

The most important issues to be addressed are the following:

- **Airport capacity** – Over the past several years ANSPs did manage to add capacity to the en-route environment and as a result, most of the delays now are generated by a lack of airport capacity. This problem comes mainly from a lack of runways in Europe. Making the en-route environment more efficient via the introduction of competition has a limited impact if aircraft continue to face delays because of airport capacity issues. Ideas about using bigger aircraft and having fewer flights did not catch on, simply because flight frequency (convenient departure time) is not something that passengers want to give up. The airport related SESAR tools at best will, help in more fully exploiting the existing capacity but will not be sufficient to address the shortage of capacity. Opening up secondary airports to more traffic has its limits as demonstrated by the low cost carriers (LCCs), whose organic growth is no longer possible without starting services to mainline airports and introducing connections to legacy carriers. Consequently, the only solution is to build new runways. This is a very difficult question in Europe and there are very few plans for new runways on the continent. Even where new runways are contemplated, it takes anything up to 2 decades before the process of obtaining a building permit is completed.
- **The growth of UAS for various services as well as the increasing reality of urban personal air transport** will act as a major disruptive technology with some of the new capabilities these aircraft will possess definitely finding their way to bigger aircraft also. Capabilities like sense and avoid are going to transform the need for air traffic services in a way not seen since the introduction of radar and the disappearance of the flight engineer from the cockpit. This will bring a real paradigm change and may alter some of the conclusions. The effects of such disruptive technologies should be carefully studied and evaluated. This is needed to ensure that what is being implemented in the short to medium term to promote competition does not in time become an obstacle to further development.
- **Update the SES ATM Master Plan** to reflect the possibilities being brought and offered by the upcoming, post-SESAR disruptive technologies. This update should contain target times that reflect the actual needs and technical possibilities rather than the lowest common denominator that could be agreed upon.
- **Define how the introduction of both legacy and later disruptive technologies** will be coordinated and aligned with aircraft equipage to ensure that aircraft capabilities are brought in line with the services offered in the new competitive environment in a way that ensure benefits to the airspace users and avoids undue burden and uncoordinated ground implementation.
- **How to set up the auctions.** Within COMPAIR the beneficial effects of such a system were shown, but when setting up an auction it is very important to set the parameters right.

4.3.2 The way forward

In this description of the way forward we assume – based on the modelling results and the experiences in other sectors - that introducing competition into the delivery of air traffic control services brings substantial improvements in efficiency. In order to create a credible road map for developing a better air traffic control delivery environment, the following steps would appear to be necessary.

1. Look into the role of the FABs. As long as the ANSPs exist within the FABs, it would be very difficult to introduce competition (between FAB members).
2. Maintain an institutional environment that can support competition. This environment is to be created both at European and at member states level. Under environment we mean not only the legal measures, but also the overall political, administrative, economic landscape that can support better efficiency and which is competition friendly in general
3. Review the options for promoting competition between service providers and evaluate the possible options from the perspective of the most likely developments to be expected in the 2030-2050 timeframe to ensure that institutional changes and subsequent technology choices fit seamlessly into the longer term developments. It is very important to ensure that any changes successfully implemented in order to promote competition do not later turn out to be impediments and blocking factors in the way of the paradigm changing developments.

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Note that also D2.1 and D3.1 can be found on the project website despite being marked confidential in the Grant Agreement. This was decided by the project members.

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Appendix A

A.1 Glossary of terms

Term	Definition	Source of the definition
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Table 5: Glossary

A.2 Acronyms and Terminology

Term	Definition
ACR	Aviation Capacity Resources – private, international ANSP
AIS/AIM	Aeronautical Information System/Management
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CNS	Communication, Navigation, Surveillance
FAB	Functional Airspace Block
HUJI	The Hebrew University of Jerusalem
ICAO	International Civil Aviation Organisation
LCC	Low Cost Carrier
MET	Meteorological services
Nommon	Nommon Solutions and Technologies S.L.
OD	Origin-Destination
SESAR	Single European Sky ATM Research
TML	Transport & Mobility Leuven
UAS	Unmanned Aircrafts

Table 6: Acronyms and technology

