# ADAPTING CAPACITY OF AIR NAVIGATION SERVICE PROVISION IN EUROPE

## BETWEEN SCYLLA AND CHARYBDIS

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## Abstract

*Current air traffic forecasts predict an annual growth in flight movements of up to 2.7 percent. However, uncertainties with regards to actual traffic figures and flows remains, posing significant challenges for air traffic management and air navigation services. This paper analyzes different capacity enhancing measures regarding both: the operational as well as the economic perspective. Furthermore, spatial and temporal aspects have been considered in the evaluation.*

## 1 Introduction

The provision of Air Navigation Services (ANS) in Europe has gained increasing attention recently, both from an academic side as well as from policy decision makers [1], [2]. Given the nature of its business, an Air Navigation Service Provider (ANSP) is considered to possess a 'natural' monopoly position [3].

Due to the 'historical' development of Air Traffic Control, currently 38 independent Air Navigation Service Providers are covering the European Airspace, dealing with heterogeneous and evolving traffic characteristics in time and space. Since the traffic volume does not spread evenly in the airspace, the increasing and more volatile demand poses new challenges in capacity provision for ANSPs.

In order to match the objectives of Flightpath 2050 [4], further capacity expansions are required. This might be very challenging, especially for service providers working in congested or complex airspaces. Subsequently, a reliable traffic forecast would be essential to provide the required capacity.

However, ANSPs have to deal with a lot of uncertainties regarding actual demand. In addition, an efficient capacity provision is aggravated by unanticipated traffic patterns. The differences between planned and actual traffic has a direct influence on the efficiency of ANS provision. In general, the underlying trade-off for the ANSP means 'riding the razors edge': If capacity exceeds demand, average costs are too high, reducing efficiency; on the other hand, if capacity provision is not sufficient, quality decreases, leading to delays and reroutings. Subsequently, an unpredicted change of traffic has an immediate effect on the performance of Air Traffic Management in Europe, which aims at balancing capacity provision and traffic demand.

This paper investigates the operational and economic aspects of capacity provision, focusing on ANSPs in Europe. It further analyzes the relation between short-, medium- and long-term capacity-enhancing measures and the costs resulting from capacity adaptions. Section 1 deals with the traffic demand in the European airspace as well as current and future challenges. The provision of Air Navigation Services, their structure as well as the evaluation of ANS performance is focused in section 2. Covering temporal and spatial aspects; section 3 discusses the operational opportunities and economic consequences of capacity enhancing measures. A quantitative analysis is provided in section 4. Section 5 provides a conclusion and draws a way forward.

# 2 Background

## 2.1 European Air Traffic Demand – Current and Future Challenges

The European airspace is one of the busiest in the world. In 2016, on average 29,000 aircraft crossed the continent each day, with a peak of 35,937 flights on June 30th [5]. The total pan European demand summed up to 15.35 Mio IFR Flight hours and 15.43 Mio Airport Movements, aggregated to 19.49 Mio Composite Flight Hours.

As shown in Figure 1, the spatial distribution of demand is not evenly: The most frequented routes are within the core area of Europe, where seven large Hubs are located within a 1,000 km diameter. Subsequently, these ANSPs are faced with continuous challenges in capacity management.

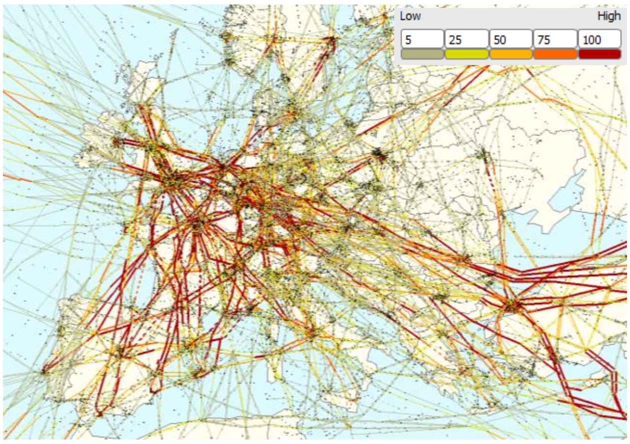


Fig 1: Density Plot of European Air Traffic (Source: NEST)

Moreover, deviations between planned and actual traffic may occur due to several factors on different operational levels as well as multiple time horizons. It is often stated, that the volatility of European air traffic increases due to, inter alia, political reasons (e.g. Ukrainian crisis), weather phenomena or natural disasters, airline decisions (sudden take-up of new city pairs) or regulatory frameworks (e.g. pan-European differences in unit rates for ANS provision) as illustrated in Fig 2.

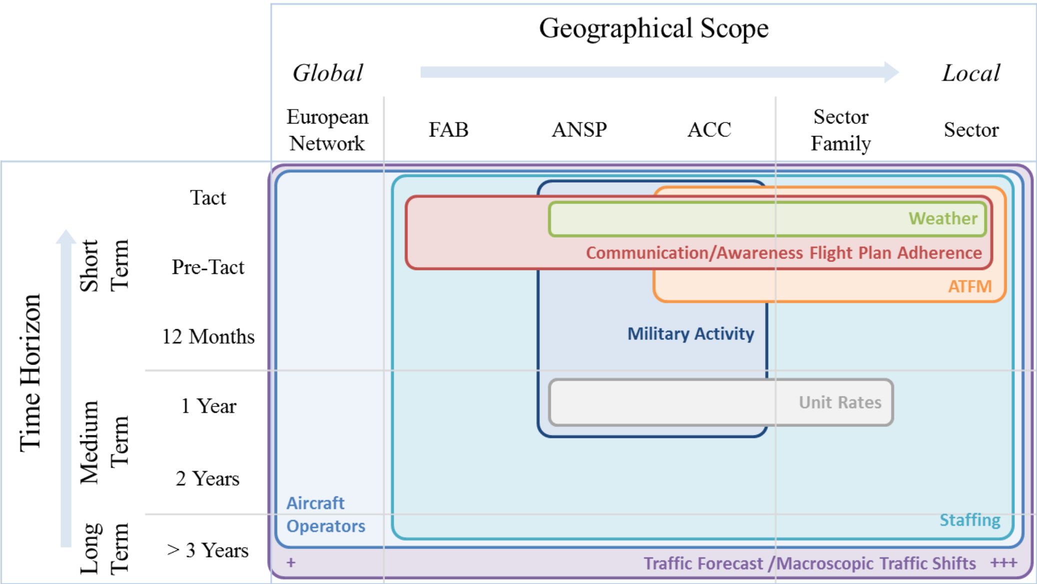


Fig 2: Temporal and geographical scope of uncertainties in planning [6]

These influencing factors may also impede (the accuracy of) air traffic forecasts. Long term forecasts for 2050 assume average annual traffic growth between 0.3 and 2.7% [7]. In the minimum scenario, this means a forecasted number of flight movements of 10.5 million flights, while the maximum scenario predicts 26.1 million. The long-term forecasts thus indicate an uncertainty of 15.6 million flights. However, based on these forecasts, the future challenge will be basically the provision of additional capacity. Subsequently, future capacity provision is significantly challenged by two factors: traffic growth per se and uncertainty about scope and distribution.

The uncertainties about quantity and regional distribution of actual traffic demand pose a major challenge in capacity provision today as well in the future. As shown in Figure 2, traffic forecasts are relevant for all time periods and operational levels. Subsequently, a precise traffic forecast may be seen as crucial for efficient capacity provision. However, forecasts and actual traffic numbers often did not match in the past. Figure 3 shows the differences between forecasted and actual traffic figures in a pan-European context.

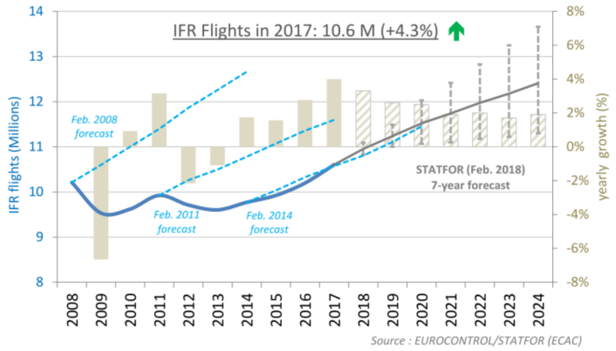


Fig 3: Traffic Forecasts and actual traffic in Europe

Forecasts may be even more complex for individual ANSPs, since various effects may influence the regional distribution of traffic. Fig 4 illustrates the actual traffic demand between 1992 and 2016 as well as the forecasted traffic growth for Germany based on the years 1994 to 2018.

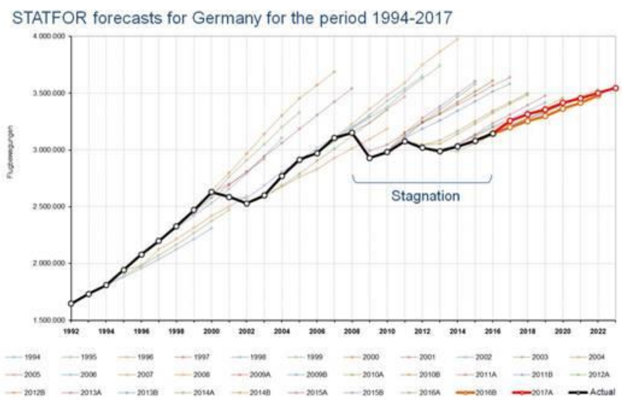


Fig 4: Forecasted and actual traffic for Germany (STATFOR)

Obviously, in most cases the actual traffic figures were much lower than forecasted. This overestimation of traffic growth may lead to increasing costs and decreasing cost efficiency in a medium and long term perspective (see section 3.2 and 3.3), caused by investments in human resources and additional systems but low utilization.

## 2.2 Provision of Air Navigation Services

In order to meet the demand of the airspace users, Air Navigation Services (ANS) provide capacity to ensure a safe and efficient traffic flow. The main task of an ANSP is to avoid airside collisions. Therefore, Air Traffic Control Officers (ATCOs) separate the traffic vertically and horizontally.

European ANSPs deal mostly with commercial IFR-Traffic, which represents a share of 90% of all controlled movements (70% in US airspace) [8]. Furthermore, this type of traffic is the main source of revenue for European ANSPs.

Air Traffic Control is divided into ’terminal’ and ’enroute‘ services. They differ significantly in operational terms [9] and represent the main outputs of an ANSP [10]. In order to manage the challenges of air traffic complexity, especially in congested areas, an ANSP is structured in operational levels (Area Control Centers, Sector Groups, Sectors) as shown in Fig 5. Each level is characterized by specific objectives and subject to constraints as well as environmental influences.

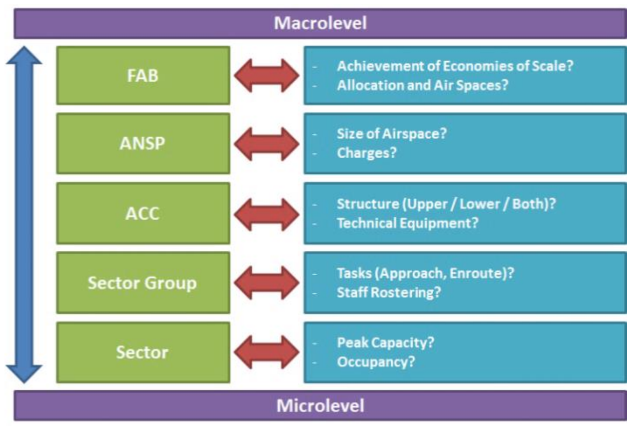


Fig 5: Operational levels of an ANSP and their features

Enroute procedures are influenced by several determinants, such as geography or traffic characteristics. Depending on the operational size of an ANSP, these services are provided in several Area Control Centers (ACCs) to cover a specific area. These areas can be defined by different characteristics. For example, volume and 3-D-shape of the airspace controlled by an ACC can be very different as well as the scope of tasks fulfilled by the ACC. In FABEC (FAB Europe Central), there are ACCs dealing only with Upper Airspace (e.g. Maastricht UAC), only with Lower Airspace (e.g. Munich ACC) and with both airspaces (Lower and Upper, e.g. Zurich ACC).

The number of operations within a sector is mainly determined by the Capacity Default Value (CDV). It is either defined by entries per hour or by maximum occupancy counts. It is a common practice to split or collapse (merge) sectors in order to adapt capacity to demand, expressed by the sector opening schemes or configurations respectively.

Due to the structure and the different tasks of the 38 ANSPs and 63 ACCs, the ANS provision in Europe is characterized by a high level of heterogeneity [11]. Each unit optimizes procedures and tools according to its needs [12] in order to provide a sufficient capacity. The balancing of capacity and demand is required at any operational level; however, if not achieved on sector level it has direct impact on service quality.

## 2.3 Performance Benchmarking

Since the late 1990s, EUROCONTROL has enhanced efforts to benchmark the ANS provision within Europe. The performance of an Air Navigation Service Provider depends on the use of production factors (such as ATCO hours) and the generated output (e.g. controlled flight hours). Furthermore it is determined by endogenous (internal) processes and exogenous factors, which could have an influence on the use of resources (Inputs) or service provision (Output).

Efficiency analysis in an ANSP context is a rather new field in research. Previous studies, conducted by EUROCONTROL, focus on benchmarking ANSPs within Europe [13] or comparing Europe with the US [14]. These official reports represent a first approach to ANSP benchmarking.

Within these efforts to derive best practices and potential improvements, EUROCONTROL developed a System of Key Performance Areas (KPAs) and Indicators (KPIs). One of the main operational KPAs is ‘Capacity’, defining EU-, and FAB-based targets for enroute-delay [7].

An increase in traffic volume usually requires the provision of additional capacity. However, the KPA “Cost-Efficiency” might be affected in a negative way. Regulators assume that ANSPs are subject to economies of scale. Consequently, an increase in traffic would lead to lower unit costs and subsequently to lower charges. Actually, the contrary may be the case as in a relatively saturated airspace the provision of additional capacity may lead to a disproportional increase in total costs and subsequently to higher unit costs. In addition, if capacity is kept at existing levels in an environment of increasing traffic, delays will go up. Higher delays will lead to costs on the side of the airspace users and passengers. Subsequently the total economic costs, which are a sum of the costs of delays and the unit costs, may increase. Recent developments have shown that the total economic costs have increased and have led to a suboptimal situation (see Figure 6) [15].

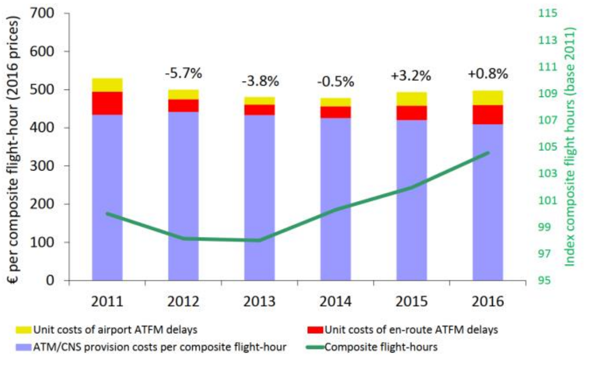


Fig 6: Costs per Composite Flight Hour including Delay Costs [16]

# 3 Operational and Economic Perspectives of Capacity Provision

## 3.1 Overview

For an economic evaluation of capacity measures, several characteristics of ANS provision have to be considered. ANSPs use particularly two production factors: Labor (in particular ATCOs) and capital.

The general trade-off between costs of capacity provision and costs of insufficient capacity is relevant for short-, medium- and long-term decisions on all operational levels. Furthermore, section 2.1 addressed uncertainties regarding forecasted traffic volumes and flows, resulting in a 'decision under uncertainties'.

From an economic point of view, spatial aspects have to be considered as well. Despite several initiatives towards a "Single European Sky", European ANS provision is still heterogeneous, as discussed in section 2.2. These heterogeneities, especially in terms of labor costs and traffic characteristics, additionally lead to different costs of capacity provision.

## 3.2 Short Term Perspective

According to Figure 2, the short term perspective may be divided into a tactical, pre-tactical and strategic period. In order to adjust capacity to demand, the only option is to vary the staff (either by using extra hours or by granting a leave) in order to split or merge sectors. Increasing (planned) capacity is limited by institutional (e.g. union agreements, staff rostering) and technical restrictions (e.g.; number of sectors or ATCO work positions). Subsequently, on the day of operation capacity is determined by the available human resources, limiting the maximum number of sectors and their corresponding capacity default value (CDV) [16].

The splitting of sectors increases capacity as long as the airspace affected is still large enough – however, the splitting of sectors increases the workload for coordination with the other sectors in charge of a traffic flow. Hence, splitting sectors leads to an increase in capacity in a diminishing way while the inputs (ATCOs and controller working positions) increase in a linear manner (however, some ACCs use multiple planner or executive ATCOs in order to increase capacity).

A prerequisite for the splitting sectors is a sufficient size of the airspace. Moreover, other factors matter, such as the complexity of the different flows, the traffic composition such as IFR/VFR, civil/military aircraft and a possible special use of airspace (e.g. parachute). Generally, the larger, more uniform and less complex the airspace, the easier is the splitting of a sector, e.g. in the Northern part of Norway, Sweden and Finland. Taking this into account, a split of a sector poses operational challenges and leads to high costs of additional capacity provision in areas with relatively small scale sectorization and high traffic and high overall complexity. This is in particular the case in the so-called European Core Area combining the airspace of Western Germany, North-East France, Belgium and the Southern part of the Netherlands which is highly used by large air traffic flows, has considerable military traffic to handle and has also a high portion of VFR traffic. For instance, there are nine functional airspace blocks in Europe, but FABEC, being the FAB which is dealing with the air traffic in the core area of Europe, manages 55% of all European controlled flights [17]. The share of Military IFR traffic is e.g. in Germany 1.5% and VFR traffic has a share of 4.5% at German international airports [18].

However, in some cases a sector split is not limited by geographical or traffic determinants, but due to staff shortage within the ACCs or sector groups. In this case, a flexible staff rostering may contribute to an improved capacity management. This could be implemented via the use of extra hours, the commitment of office ATCOs, buffers in staffing or standby shifts [12]. Furthermore, a sector split causes a sharp increase in average costs. On the other hand, increasing saturation of an elementary sector leads to decreasing average costs. The associated average cost curve is shaped like a sawtooth.

In the strategic horizon (up to 12 month), further measures by an ANSP to respond to traffic demand are possible by adapting procedures. Staff rostering is limited by the total annual working hours. Usually, there is a corridor defined in which the working time may deviate (less or more hours) to allow some flexibility for the rostering and hence for the employee as well as for the employer. Any additional working hours may either be reached by individual arrangements between an employee and its employer or by collective agreements with the employee's council or the trade unions. Additional capacity is mainly dependent on the flexibility of staff rostering, especially regarding the possibility and willingness for extra shifts as well as their reduction in times of low traffic demand.

## 3.3 Medium Term Measures

Medium Term is the time span in which an ANSP is able to hire extra staff, mainly as "ab-initio" (i.e. from scratch) or as a "ready-entry" (i.e. who has worked as an ATCO before). Subsequently this time span is between two and six years.

It goes without any saying that the amount of ready-entries is limited as well as the capabilities to train staff both theoretically as well as On-the-Job. In addition there is a trade-off between training ATCOs for a larger number of sectors, which will prolong the training and potentially increases the failure rate and the costs, and training ATCOs for a lower number of sectors reducing training costs as well as the flexibility for the shift rostering. Finally, there is the need to predict not only traffic figures for a continent, a FAB or a country but rather for traffic flows to allow a precise planning in which area more ATCOs will be needed – otherwise trained ATCOs may be available but in areas where there is little demand while in areas with additional demand there is a lack of ATCOs resulting in delay costs.

The resource planning of ANSPs follows a lengthy and complex procedure. On one side, the amount of needed ATCOs for rostering is determined by the forecasted traffic evolution and the subsequently needed sectors and their opening hours. Based on existing and planned projects additional resources may be needed. On the other hand, the current staff needs to be assessed and the amount of fluctuation, retirement, part-time, medical cases and maternity/paternity leaves (just to name the predominant ones) are simulated. The delta per licensed sector group plus a certain buffer for a failure rate during the training period is the needed amount of ATCOs to be trained. In this calculation the maximum amount of on-the-job-trainees needs to be considered as at one time there is only a limited amount of on-the-job-trainings possible.

Considering the differences between forecasted and actual traffic figures, training and employment is characterized by a high uncertainty regarding the number of employed ATCOs. Subsequently, targets in the KPAs Environment, Capacity and Cost Efficiency may be missed by the ANSPs.

## 3.4 Long Term Measures

In the long-term ANSPs can only react by both hiring and training even more ATCOs or by investing into ATM-System which allow more controller working stations with more sophisticated tools leading to higher capacity and safety levels. Long-term is some six to twelve years.

An estimation of the costs of such investments is very challenging as they depend on various factors, such as the demand of additional capacity, the life cycle of the existing hard- and software, the amount of working positions, the needed training etc. It can roughly be estimated that approx. 11% of the total service provision cost in the core area are capital expenditure [16].

## 3.5 Regional differences in capacity provision

The costs of investment in labor as well as in capital differ significantly within Europe. In 2016, annual employment costs per ATCO were between 14,625€ (UkSATSE / Ukraine) and

262,291€ (LVNL / Netherlands). Costs per ATCO hour were between 10€ (UkSATSE) and 225€ (DFS / Germany). Subsequently, an increase in the input "labor" has different effects on cost efficiency.

As an example, in the Ukraine 18 ATCOs cause the same annual costs as one ATCO in the Netherlands. Furthermore, according to IFATCA the average costs of training an ATCO is approx. 600.000 € [19]. This figure is not considering that there is a certain failure rate during the training period; hence the costs for a successful ATCO training are even higher. Also these costs may vary significantly between the respective states.

According to Figure 7, the states of the European core area are characterized by the highest costs per ATCO (the only exception is the French DSNA). As mentioned above, this region also has to deal with the highest traffic numbers and complexity scores. Subsequently, the need for investments in ATM and CNS equipment is higher than in states with a lower amount of traffic. Since capacity extending measures are limited (see 2.3), an increase in traffic demand poses a big challenge for these ANSPs.

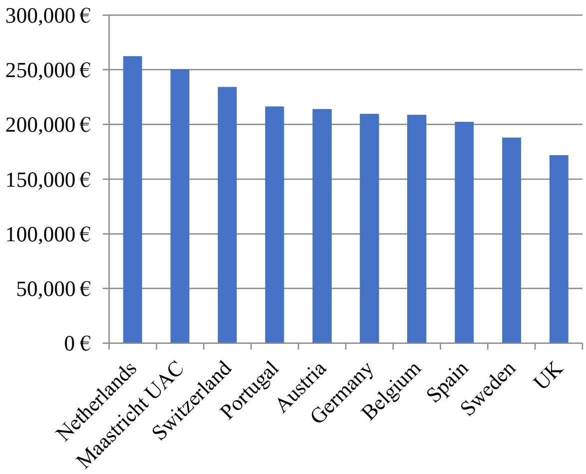


Fig 7: Annual costs per ATCO

ANS efficiency is influenced by a sufficient staff rostering, requiring inter alia a high flexibility. A further cost determinant are the actual annual working hours of an ATCO. According to ACE data, the average ATCO hours per ATCO in OPS vary between 934 hours (DFS) and 1,990 hours (MATS / Malta). Assuming an average of about 1,812 annual working hours per ATCO (referenced to the working time in the USA), the total pan European extra costs due to reduced working hours are 730 Mio € [20].

# 4 Cost effects of changes in demand and of capacity expansion

## 4.1 Short term analysis

Data for 37 European ANSPs is provided by the ACE reports [13]. Between 2011 and 2014 only 13 of these ANSPs did not change their maximum number of sectors. Moreover, seven of these ANSPs did not change the annual number of sector hours, i.e. capacity provision was kept constant. For these ANSPs, most costs can be considered to be fixed costs; therefore a change in traffic affects average costs predominantly by influencing the degree of capacity utilization.

Figure 8 shows the year on year percentage changes in the number of flight hours controlled (demand) and in average costs. All cost data is real data (i.e. inflation adjusted) in the respective national currency. [1] However, we excluded Moldova from the analysis due to very high changes in traffic volumes (over 25%).

Six ANSPs kept the maximum number of sectors between 2011 and 2014 but changed the number of sector hours. Therefore, it might be assumed that these ANSPs changed the annual working hours per ATCO and/or the total number of ATCOs. In this group, we excluded Macedonia from the analysis, again due to very high changes in traffic.

Figure 9 shows the relationship between the percentage change in demand and the percentage change in average costs per flight hour for ANSPs with a changing number of sector hours. The slope of the regression function is steeper as in figure 8, indicating a stronger effect of traffic changes on average

[1] The ACE report only uses one currency (EUR), therefore changes in the exchange rates influence cost data.

costs, which is in line with the expected higher share of cost variability.

Moreover, also for ANSPs changing the number of sector hours, a high share of total costs is fixed, leading to decreasing average costs per capacity unit (i.e. sector hour). Figure 10 shows the relationship between the percentage change in the number of sector hours and the change in average costs per sector hour.

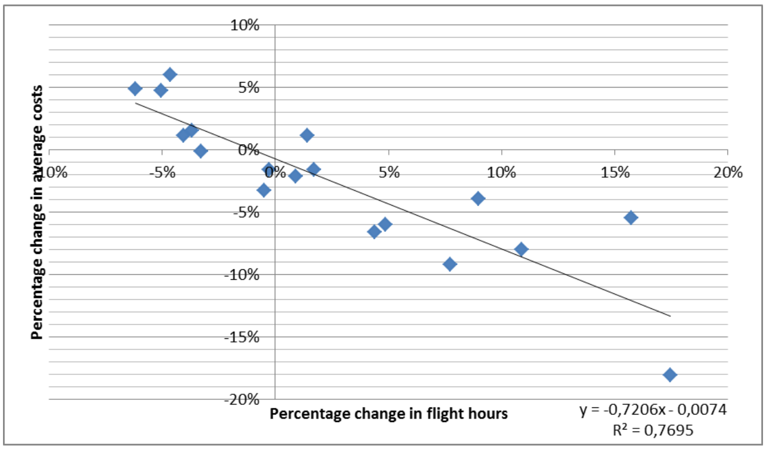


Fig 8: Relation between percentage change in flight hours and percentage change in average costs per flight hour for six ANSPs with constant number of sector hours

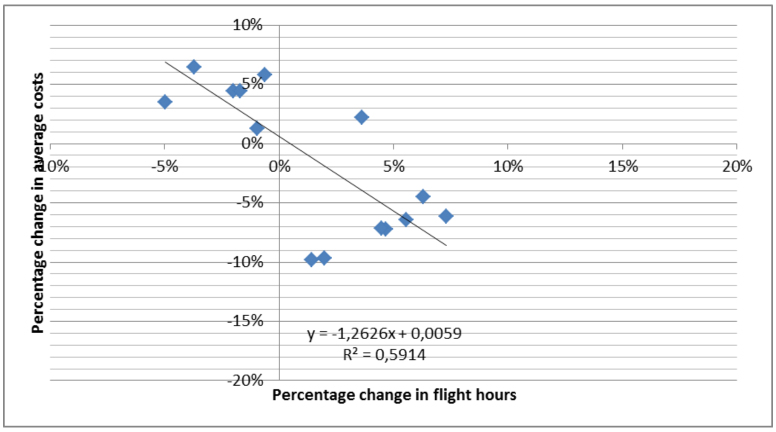


Fig 9: Relation between percentage change in flight hours and percentage change in average costs per flight hour for five ANSPs with constant maximum number of sectors and a changing number of sector hours

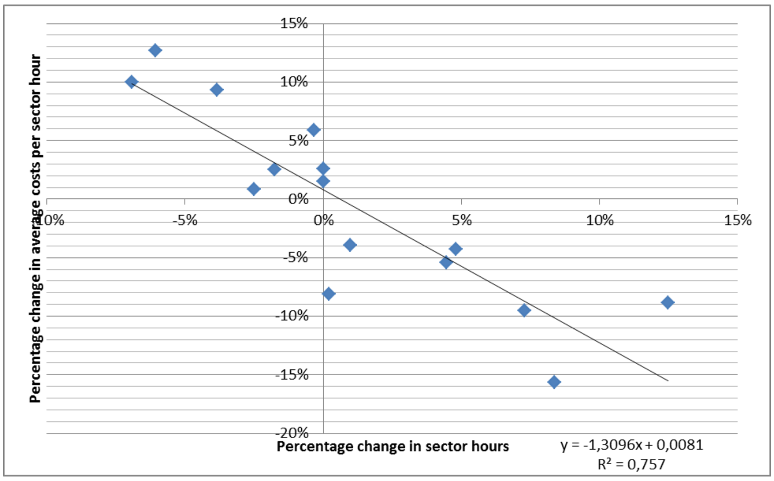


Fig 10: Relation between percentage change in sector hours and percentage change in average costs per sector hours for five ANSPs with a constant maximum number of sectors and a changing number of sector hours

### 4.2 Long-term aspects

In the long term, the airspace structure might be changed in order to increase capacity. In the period between 2011 and 2014, 24 European ANSPs changed the maximum number of sectors. However, in several cases, the number of sectors decreased (e.g. Norway, Germany, Italy, UK). Moreover, some ANSPs increased the number of sectors in some years and reduced it in others (e.g. Spain).

Almost 50% of all European ANSPs increased the number of sectors between 2011 and 2014. In most cases only one sector was added in one year. However, there are also several examples of two increases during those four years, and some ANSPs added more than one sector. Interestingly, examples exist where an ANSP increased the maximum number of sectors but kept the number of sector hours constant (or even reduced it).

The Polish ANSP PANSA might serve as an example of the expected effects of an increase in the maximum number of sectors. In 2014, the number of sectors was increased from eight to nine (+12.5%). In this year, the number of sector hours increased by almost 17%, accompanied by an overall cost increase of 15%. Since total controlled flight hours only grew by 1.5%, average costs per flight hour increased by 13.5%.

## 5 Conclusions and Way Forward

Today, Air Navigation Services represent capacity restraining factors in commercial traffic, especially in regions with high demand. Assuming an annual growth of 2.7%, the management of airspaces will face even more challenges in the future.

This paper shows that traffic forecasts have not shown sufficient accuracy to serve as a basis for an optimal allocation of capacity. The provided capacity is dependent on several factors and influenced by temporal and spatial developments. An expansion of capacity requires an investment in human resources and / or technology. Nevertheless, possibilities for taking these measures are limited, especially in congested areas. Long term measures focus on enhancement of digitalization and new systems as well as alternative approaches of air space management. As a consequence of inaccurate forecasts and volatile traffic demand the allocation of capacity with its different planning horizons cannot be optimal.

In order to meet the challenges ANSPs need to have enough robustness to meet the demands of traffic volatility especially in the short- and medium-term.. One option is to foresee buffers both on the labor as well as the capital side. However this implies that ANSPs would have to be enabled to introduce such a flexibility measure into their investment plans. The risk of lacking capacity leading to delays or detours would be lowered; on the other hand total cost of capacity provision would increase. Regulation should consider the two contradictory effects by balancing them out and realizing the efficiency optimum in this respect.

Other possibilities to enable a more flexible capacity provision should be considered as they would allow an adaptation to traffic variations. Concepts such as the Cross-Border-Areas could be beneficial as requirements from airspace users can be more easily met in an airspace structure which does not follow national borders. Another measure could be a total new reversed approach in which the airspace structure rather adapts to demands and requirements like the dynamic sectorization approach: sector borders would change accordingly to shifted traffic flows [21]. The implementation of such concepts may lead to an improved utilization of capacity.

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