[EN-A-004] Air Traffic Management Performance Benchmarking - A disaggregated approach

(EIWAC 2017)

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Abstract: 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. Due to the historical development of Air Traffic Control, currently 37 independent Air Navigation Service Providers (ANSPs) are covering the European airspace coordinated by EUROCONTROL. The current structure of European Air Traffic Management (ATM) is expected to lead to inefficiencies. In the last two decades, several approaches have been developed to benchmark ANSPs and to identify potential improvements. Furthermore, academic studies dealt with alternative concepts, e.g. concerning air space structures or charging schemes. However, since existing studies basically cover the highest operational level, i.e. the ANSP itself, these benchmarking efforts are based on aggregated data. To understand the mechanisms and influencing factors behind the performance indicators, reciprocal effects and determinants caused by the other operational levels should be considered. This paper describes an approach to benchmark ANSPs in a disaggregated way. It shows differences on sector levels as well as the available data sources and discusses potential endogenous and exogenous determinants for efficiency.

Keywords: Benchmarking, ANSP, Disaggregated Approach, Sectors, Sector Groups

1. MOTIVATION AND RESEARCH GAP

The European airspace is one of the busiest in the world. In 2016, on average 28,000 aircraft crossed the continent each day, with a peak of 34,600 flights on September 9th [1]. The high number of flight movements as well as the rising market share of Low Cost Carriers in Europe pose new operational challenges to ANSPs and lead to an increasing cost pressure. Consequently, productivity and cost efficiency of ANSPs has gained increasing attention recently.

The primary aim of performance assessments is to determine which ANSP achieves the highest (rank of) productivity or efficiency. Furthermore, the analysis should derive influencing factors and, subsequently, indicate measures for efficiency improvements. Previous research, conducted by EUROCONTROL, focusses on benchmarking ANSPs within Europe [2] or comparing Europe with the US [3].

These official reports represent a first approach to ANSP benchmarking. However, potential improvements regarding benchmarking methodology, information content and root cause analysis can be identified. Since an ANSP, like almost any other company, uses multiple inputs to produce multiple outputs, a two-dimensional analysis is not appropriate in the context of ATM benchmarking. Moreover, the reports neither differ between technical, scale and allocative inefficiency, nor do they cluster or classify ANSPs, e.g. by demand or other characteristics. Furthermore, endogenous and exogenous effects, which might have a positive or negative influence on efficiency, are not quantified. Finally, the evaluation is executed at a high operational level.

Academic studies have dealt with some of the shortcomings of the official reports listed above. They mainly focus on improvements regarding benchmarking methodology as well as optimizing airspaces, e.g. the proposed Functional Airspace Block (FAB) concept of Single European Sky [4], or flight trajectories [5].

However, these studies also address a high operational level, represented by an ANSP or FAB, and therefore are based on aggregated data.

The aggregative nature of the research is basically due to limitations of the available data. EUROCONTROL reports [2], [6] as well as academic studies [7], [8] are based on data submitted to the Performance Review Unit (PRU), which mostly covers data on ANSP level. However, these figures represent average (and partly self-aggregated) data, which could distort efficiency values and probably conceals important information. Furthermore, the tasks and determinants of the subunits are heterogeneous (see section 2).

We conclude that in order to identify economic mechanisms and efficiency drivers, the aggregated approach (on ANSP level) has several significant shortcomings. A first disaggregated approach evaluating the performance of Area Control Centres (ACCs) in the FAB European Central (FABEC) area was provided by [9]. This paper focusses on benchmarking lower operational levels, especially sectors.

2. BENCHMARKING APPROACH FOR THE SECTOR LEVEL

ANSPs are characterized by a complex company structure where each unit on different operational levels (Area Control Centres, Sector Groups, Sectors) may define its own objectives and is subject to specific constraints as well as environmental influences (Figure 1).

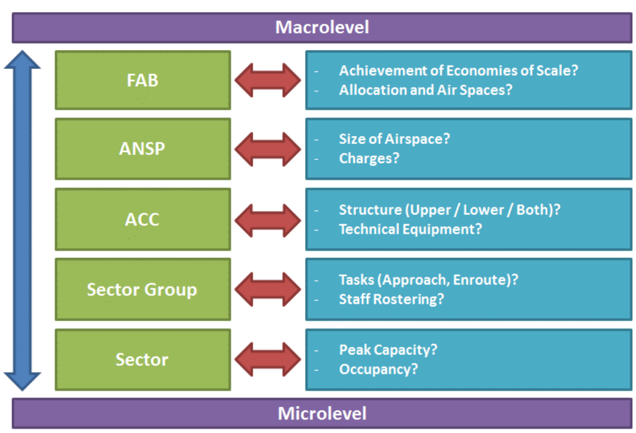

Figure 1 Operational Levels of an ANSP

These differences are not only relevant between the respective operational levels, but also between different units on the same sublevel. As mentioned in section 1, aggregated data does not take into account that the tasks and determinants of any subunit of an ANSP are characterized by a large heterogeneity. For example, sectors, being the smallest operational unit, could be responsible for controlling upper airspaces, lower airspaces or approaches.

Operations within a sector are mainly determined by its capacity. The declared capacity (Capacity Default Value, CDV) is either defined by entries per hour or by maximum occupancy counts. It is common practice to split or collapse (merge) sectors in order to adjust capacity to demand, expressed by the sector opening schemes or configurations respectively. However, splitting a sector increases the demand for production factors which has a negative influence on productivity. On the other hand, if demand exceeds capacity, the unit causes delays and/or detours. Potential reasons for a lack of capacity are weather, staff shortages or military activities. Furthermore, the capacity is determined by structural characteristics like complexity or, especially for approach, the share of heavy and light aircraft.

Based on these observations, a high predictability of traffic (quantity and flows) is indispensable for an appropriate planning of capacity provision and staff rostering. However, planned and actual 4D-trajectories may differ due to several reasons, e.g. delays, Temporarily Restricted Areas (TRAs) and charge induced detours (Figure 2).

Figure 2 Difference in planned (red), actual (green) and direct (blue) trajectory of a flight from Bergamo to Corfu.

Heterogeneity can not only be observed for traffic or airspace related determinants. Procedures, calculation methods and technical equipment differ between the subunits as well as working philosophies and planning standards. Each of these individual determinants may have an influence on sector productivity and efficiency. A major challenge for an analysis on the sector level is the lack of comparable information. First of all, it has to be taken into account whether a (potential) determinant can be quantified. Therefore, it could also be necessary to define new indicators or factors. Furthermore, since the definition of some determinants is not consistent between units, it may be necessary to adapt this information. If a specific determinant cannot be quantified, the analysis can only be based on qualitative methods.

As part of our research activities, potential influencing factors have been identified in cooperation with ANSP experts in FABEC context. For clarity reasons, the indicators were grouped into four clusters

- Staff
- Traffic
- Airspace
- Operations

and divided into hard factors (quantitative) and soft factors (qualitative).

Based on these indicators and taking heterogeneity into account, our study consists of three approaches for further analysis.

First, we built up a data base for further analysis (see section 3). By applying benchmarking methodologies, like Data Envelopment Analysis, it is possible to evaluate the sectors regarding their performance. In a second step, potential determinants of efficiency can be identified. This analysis requires further preparatory work, e.g. collecting (and if necessary correcting) the actual opening times and configurations for each sector. Analysing the difference between planned and actual traffic also allows for an assessment of the predictability of traffic in the different parts of the airspace.

Second, since not all determinants can be quantified, a questionnaire was developed to cover all potential differences, such as calculation methods or regulations. In order to identify and discuss differences, all ACCs of the FABEC area (excluding the ones of French DSNA) were interviewed. The questionnaire covers individual particularities of airspace, Air Traffic Flow Management (ATFM), Staff, Traffic and Operations. Furthermore, the questionnaire is designed to identify comparable sectors regarding traffic characteristics, e.g. a high share of arrival traffic or a high number of route intersection points (complexity). In addition, the implementation of supporting tools will be evaluated.

Third, in order to combine the qualitative and the quantitative analysis, we perform an expert survey to evaluate the influence of the previously identified factors on productivity. A second stage statistical analysis allows us to estimate, how different factors could affect sector performance. In addition to the assessment there is a more detailed description provided by the experts, which will help to get more insights, especially regarding the interpretation of the results of the quantified analysis.

A further focus of investigation, necessary for a comprehensive analysis, is based on complexity scores. Official reports [2] as well as academic studies [7] state that complexity should have a significant influence on performance. However, this relationship has not been analysed thoroughly yet. The complexity score is defined as the product of traffic density and a structural index. The structural index first sums up all horizontal, vertical and speed interactions between airspace users. This sum is then divided by all traffic interactions. The traffic density indicator describes the distribution of traffic throughout the airspace and is calculated as the ratio between the sum of all traffic interactions and the sum of all flights. These indicators are time based and geographically limited by a 20nm x 20nm x 3000ft cell. That means, an interaction is represented by the simultaneous presence of two aircraft within a cell. Since traffic flows are volatile, complexity values may vary according to its components [10].

3. DATA

As stated in section 1, previous studies were based on PRU data. This data is expected to be biased with respect to some indictors and for some ANSPs [4]. Furthermore, the data is available on ANSP level only, in some cases also on ACC level. However, in order to benchmark sectors, it is necessary to acquire new data sources. A promising option is represented by the Demand Data Repository (DDR2) provided and hosted by EUROCONTROL. With the modelling tool NEST, it is possible to visualize and analyze airspace and traffic characteristics, such as planned and actual trajectories, sector configurations, occupancy counts etc. (Figure 3).

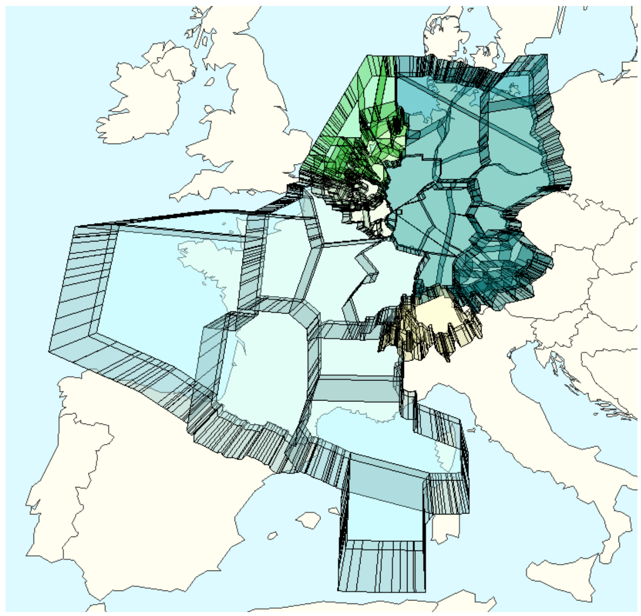

Figure 3 Airspaces in FABEC area, illustrated by NEST

As mentioned before, DDR2 data is available for planned, initial and actual traffic figures. This enables an investigation whether sectors are confronted with a low predictability of demand, comparing planned and actual traffic. However, a significant divergence was identified since NEST does not update real sector opening configurations for actual traffic figures, but adjusts the opening hours for the planned sector configuration. Consequently, the sector opening times are incorrect; some (planned) sectors may not even have been opened at all. To solve this problem, it is necessary to gather actual sector opening times from ANSPs. The data is not yet fully available and has to be corrected due to logging or transcript errors. In some cases, this leads to unfitting opening and closing time stamps.

The quantitative analysis is further based on a list of potential determinants. Figure 4 illustrates examples for factors of each cluster discussed in chapter 2. About 50 factors have been identified and analyzed based on the database, the survey and the questionnaire. However, since data is not comprehensively available, some of the hard factors have not been evaluated yet.

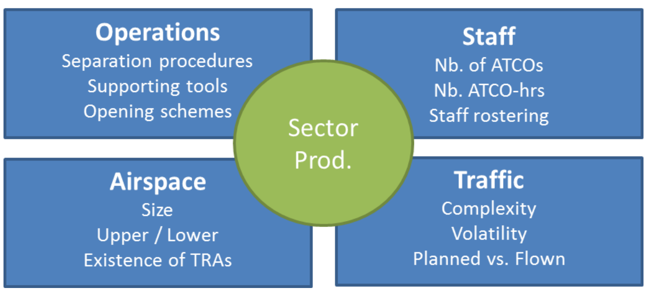

Figure 4 Examples for determinants of sector productivity

For complexity scores, EUROCONTROL publishes reports on ANSP level. Furthermore, it is possible to calculate the scores for sector groups by using NEST. This enables an analysis of fluctuations on a weekly and daily basis.

4. FIRST RESULTS

Since the benchmarking of sectors is work in progress, only preliminary results are presented in this section. Furthermore, due to sensitivity of data, all information is anonymized. However, some basic results are provided, especially regarding performance determinants.

Two basic performance indicators for benchmarking on the ANSP level are gate-to-gate productivity and cost-efficiency. However, since the assessed units (ANSPs) differ significantly with respect to the services which are provided, a gate-to-gate perspective has many limitations. For instance, in case of Maastricht Upper Airspace Control (MUAC), the ANSP is only responsible for en-route traffic, which is expected to be less complex due to the low share of climbing and descending flights. Other ANSPs (or ACCs) are responsible for lower and/or terminal airspace traffic only, or provide services for all types of airspace (Figure 5). These limitations are eliminated by benchmarking on sector, sector group and partly also ACCs level. However, even at these disaggregated operational levels performance values differ significantly, requiring additional investigation.

ANSP	Provided Services		
	Upper	Lower	Terminal
MUAC	X		
Belgocontrol		X	X
ANA Luxembourg			X
Skyguide	X	X	X

Figure 5 Heterogeneity in provided services

For traffic analysis, similar elementary sectors were identified and compared regarding the maximum number of entries and occupancy. These indicators allow for an assessment of a sector's productivity. A first analysis shows that the differences are significant, which has to be further investigated applying quantitative methods.

With respect to staff, differences in the flexibility of rostering could be identified. This is due to legal regulations and procedural instructions. In case of capacity adjustment, a high flexibility enables an ANSP to split sectors, thereby reducing delays, detours and cancellations. Additional differences in planning are represented by the use of buffers. If demand forecasts are successively updated and become more reliable, it is possible to reduce these buffers, enabling an improved staff rostering. Other determinants, like the implementation of a multi-sector-planner (MSP) or single ATCO-operations (e.g. on night shifts) as well as the distribution of tasks between executive and planner controller were discussed, but no significant differences could be identified.

In the case of airspaces, no significant differences were found. Splitting and collapsing sectors is a common practice to adjust capacity to demand. The management of airspace changes was similar in the respective units, too.

The biggest differences were observable in the operations cluster. First, every unit uses supporting tools, e.g. for trajectory prediction. However, the complexity and reliability was judged to be different. It was stated that some systems do not function continuously, requiring alternative approaches (so called work arounds) causing additional workload for controllers. For the planned Free Route operations, these systems have to be harmonized and – in general - more flexible.

Second, in some sectors it is common practice to give directs, while others focus on a high degree of flight plan adherence. Both philosophies have advantages and disadvantages. Flight plan adherence is important for the predictability in downstream sectors. The provision of directs increases throughput and reduces flight time as well as emissions. These procedures are supported by trajectory predictions, avoiding conflicts with other airspace users. This prediction is, in most cases, not determined by sector frontiers. That means, an ATCO could also provide a direct to an intersection point belonging to another sector, which is applied in one of the considered units. Thereby, the flexibility of ATM is improved.

Third, Air Traffic Flow Management is based on different systems for information management and data exchange. Architecture and abilities of these systems are different. E.g., as stated above, the declared capacity is calculated in different ways and either determined by the maximum occupancy count, or by the entries per hour, or both. The capacity planning and adjusting procedures differ slightly between the units.

Fourth, all units use Controller Pilot Data Link Communication (CPDLC), but in a different scope and for different tasks. It enables to communicate e.g. squawk or level changes between ATCOs and Pilots. However, the experts stated that CPDLC has no influence on productivity.

5. CONCLUSIONS AND WAY FORWARD

The paper shows the variety of determinants for productivity on the sector level. These differences are driven by a high heterogeneity of these units regarding technical equipment, procedures and/or use of capacity and performance indicators.

This study is just a first step in order to gain insights in the economic drivers of sector productivity. Since the database has not been completed yet, a comprehensive root cause analysis was not possible.

However, first qualitative results show that the provision of directs and the cross-sector management are appropriate measures to increase throughput and, subsequently, productivity. However, deviations from planned trajectories by the provision of directs may lead to a lower predictability in downstream sectors. The analysis further shows, that adjusting ATM procedures, represented by the virtual shift of sector frontiers, will lead to performance improvements. Therefore, it supports the approach on dynamic sectorization of airspaces [9]. This could be seen as an intermediate step to and a precursor of sectorless ATM.

By identifying effects and defining factors in all four clusters, we create a basis for quantitative analysis. The database is under construction yet. The disaggregation level allows to cluster sectors regarding operational determinants, e.g. by offered service (upper, lower, terminal/approach) which enables an assessment of specific measures to improve performance.

As a further research hypothesis, complexity is expected to have a high influence on performance. A complexity metric was introduced by EUROCONTROL. However, it is uncertain whether this calculation method could be used for all sectors due to the different tasks (approach, upper, lower). Therefore, we will not only use this metric but also develop adjusted indicators.

FIGURES, TABLES AND EQUATIONS

ACKNOWLEDGMENTS

We thank the members of the Performance Management Group (PMG) for their support. Furthermore, we like to thank Deutsche Flugsicherung GmbH, especially Thomas Hellbach, Christoph Czech and Juan Espinar Nova, for collecting and mining the data. Finally we would like to thank the FABEC Area Control Center representatives for the cooperative efforts to identify best practices.

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