Free Routing Airspace in Europe

Implementation concepts and benefits for airspace users

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***Abstract*—The European aviation industry is exposed to major challenges such as profitability and efficiency, environmental sustainability and capacity constraints, economic difficulties and rising concerns due to non-leveled playing fields. That clearly demonstrates the necessity for further investments into newer, more efficient concepts. One of these concepts is Free Routing Airspace. In a Free Routing Airspace, the airspace user may freely choose a flight path using user-defined segments between published or user-defined points. This option of a flexible flight planning allows an optimization of the flight trajectory best suited to the business requirements of each individual airspace user. However, the general Free Routing Airspace concept offers many different kinds of implementation possibilities. This paper estimates the benefits of Free Routing Airspace in Europe for an airspace user. To that end, extensive representative flight samples have been calculated with the help of the flight planning system Lido/Flight from Lufthansa Systems GmbH & Co. KG. The calculated trajectories have been evaluated primarily in terms of overall costs reductions, but also in terms of fuel saving. The results of the analysis show that the concept has significant saving potential and efficiency benefits when compared to the current traditional Air Traffic Services route network. Both, the total operating costs can be reduced, and the environmental goals such as a reduction of greenhouse gas emissions can be achieved through fuel saving. This highlights that the concept of Free Routing Airspace is an important step for the future of the European aviation industry.**

Keywords-, Free Route, Free Routing Airspace, Trajectory optimization, Environment and energy efficiency

I. Introduction

Future challenges of the European aviation industry need improved processes of many kinds. For airline operations, the fuel costs still share a high part of direct operating costs [1]. Even though in 2015, the fuel price was relatively low, the savings have been weakened by the appreciation of the US dollar [2]. In 2014, an average of 25.8% of an airline's total costs was fuel expenses, and only 0.9% of the ticket costs remained as profit [3]. In addition to the price of oil, more and more environmental concerns are facing the airline industry. IATA asked for the airline industry's commitment on a carbon neutral growth by 2020 [4]. Already today, congested airspaces in some areas in Europe cause frequent flight delays or disruption, and traffic forecasts by key stakeholders of the airline industry predict further growth (e.g., [5], [6], [7], [8], [9], and [10]).

These challenges make it necessary to develop more cost- or fuel-efficient routings. One of the key concepts in this regard is Free Route. In European airspace, the term Free Route (FR) is the overarching term for both operations in a Direct Routing Airspace (DRA) and operations in a Free Routing Airspace (FRA). DRA has already been implemented in some Air Traffic Management (ATM) sectors in Europe, and it can be seen as a first step towards the concept of FRA. The implementation of the DRA concept should be completed in 2017 [11]. According to the European Organization for the Safety of Air Navigation (EUROCONTROL), DRA is an "Airspace defined laterally and vertically with a set of entry/exit conditions where published direct routings are available. Within this airspace, flights remain subject to air traffic control." [12] In contrast to DRA, FRA introduces a new concept of flight execution. Instead of choosing a trajectory based on a fixed network of waypoints interlinked with airway segments, the airspace user is allowed to choose a trajectory using user-defined segments between published and/or user-defined points.

The aim of this paper is to estimate the benefits that a Free Routing Airspace provides for the Airspace Users with regard to flight efficiency, both in terms of costs and fuel savings. Confirming the general results from an earlier publication [13] with regard to fuel consumption, this paper, based on recent and future Free Route developments in Europe, especially focuses on the cost saving potential for different airspace designs. We start with an introduction of the Free Routing Airspace concept in Section II. In Section III we elaborate on the current status of Free Routing Airspace in Europe and show the progress already that has already been made but also how different the implementations are. In Section IV we describe in detail the environment used for our trajectory calculations. In Section V we present the results of the trajectory calculations and discuss what impact different design options of a Free Routing Airspace have on the potential benefits. Finally, in

Section VI we provide a conclusion and an outlook on possible follow-up studies.

II. The Free Routing Airspace Concept

Free Routing Airspace - or Free Route Airspace as called in the European Route Network Improvement Plan (ERNIP) - is defined in ERNIP part 1 as: "A specified airspace within which users may freely plan a route between a defined entry point and a defined exit point, with the possibility to route via intermediate (published or unpublished) way points, without reference to the [Air Traffic Services] (ATS)] route network, subject to airspace availability. Within this airspace, flights remain subject to air traffic control." [14] Mandated by the European Commission, operations in FRA will become the standard in 2022 for flights above FL310 [15]. In a FRA, the airspace user has a much greater choice in selecting its desired flight trajectory. Nevertheless, dependent on the implementation of FRA the concept is subject to some restrictions. However, the NM and the Air Navigation Service Providers (ANSPs) should only restrict the airspace if sufficient traffic separation cannot be ensured, if airport and sector capacity reaches its limits or if flights are planned through restricted airspaces. Apart from the economic and ecological challenges, this solution might address the airspace capacity problems, too. Some of those restrictions can be related to the entrance and exit conditions. In these cases, it is only possible to enter and exit the FRA via defined waypoints. Of course, special used airspaces such as danger or temporary restricted airspaces need to be avoided. In this case, additional waypoints (either published or if allowed user-defined) are needed to circumnavigate the restricted area. Fig. 1 shows an example airspace with some restrictions. The blue line with dashes and dots represents the lateral boundary of the FRA. The green arrows depict allowed trajectories; the red arrows depict not allowed trajectories. For example, waypoint ENTRA is used only for entry and not exit into the airspace, while waypoint ENTXY can be used for both, entry and exit. The shown routing to ENTXY crosses a Temporary Reserved Airspace therefore circumnavigation is needed. In a FRA this can be done via the closest waypoints (one published and one user-defined), whereas in a traditional airway system the detour might be much longer. In another case, the shortest trajectory from waypoint ENTXY to EXITZ is not possible, because the trajectory would cross the airspace boundary while no published exit and entry waypoints at these boundary crossings are established. Therefore, the trajectory is detoured via an in this case published waypoint.

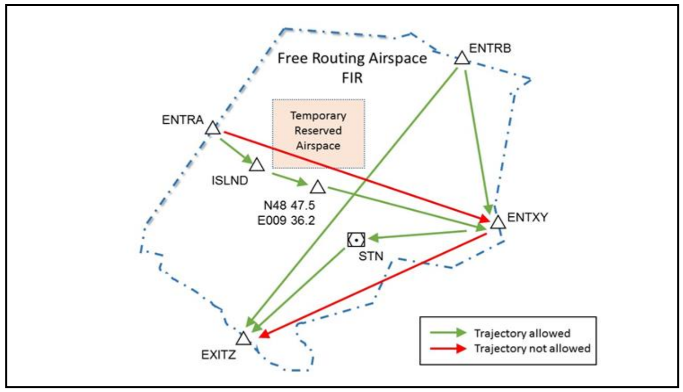

Figure 1. Example of a Free Routing Airspace

In Fig. 2 we show exemplarily the routing options for a flight from London Heathrow (EGLL) to Moscow Domodedovo (UUDD) in January 2016. Clearly visible are the already existing Free Routing Airspaces over Denmark and Sweden (dense green area at the top) and over Hungary (dense green area at the bottom). Over Germany (slight left of the center) many DCT (Direct) segments have already been introduced in addition to the existing ATS route network, allowing for more routing options compared to for example the area around Moscow (right).

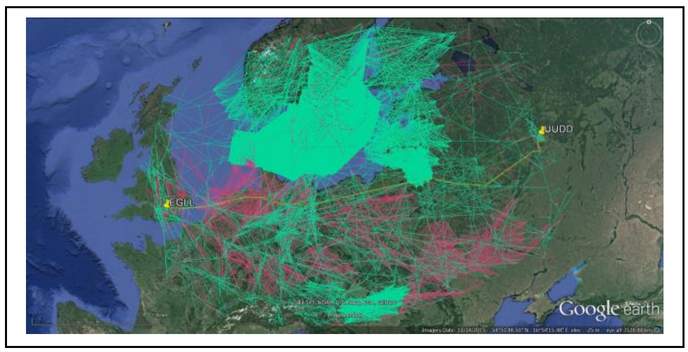

Figure 2. ATS Route Network with TFR - EGLL-UUDD, Map data: Google, Data SIO; NOAA; U.S. Navy, NGA, GEBCO, Image Landsat

The introduction of a Free Routing Airspace changes this picture dramatically. In Fig. 3 only a small area around London is shown that demonstrates the enormous number of possible routing options.

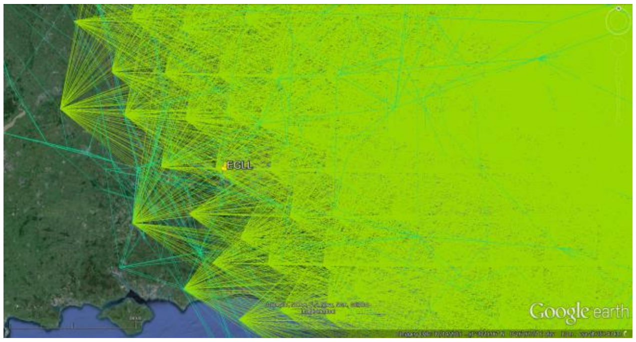

Figure 3. FRA segments EGLL-UUDD, Map data: Google, Data SIO; NOAA; U.S. Navy, NGA, GEBCO, Image Landsat

III. THE STATUS OF FREE ROUTING AIRSPACE IN EUROPE

The development and implementation of a European Free Routing Airspace was initiated and coordinated by EUROCONTROL in 2008. The implementation of Free Routing Airspace forms part of a common Flight Efficiency Plan developed in cooperation between IATA, Civil Air Navigation Services Organisation (CANSO), and EUROCONTROL [16].

Even if Free Route is managed from a consolidated European level, the respective regulation of the airspace is at the responsibility of each member, such as ATS units, Functional Airspace Blocks (FABs), or states. For the time being, members have not published official documentation regarding standardized operational requirements on a European level for the Free Route user. Unfortunately, that leads to many different interpretation possibilities by each member. Such differences are:

- flight planning rules
- the vertical entrance and exit into the airspace
- the lower and upper boundary of the airspace
- intermediate (published and unpublished) points for flight planning
- minimum or maximum segment length
- availability (day, night, 24 hours)

EUROCONTROL published with Part 2 - ERNIP – ARN version 2015-2019 a document, which contains different packages including measurements for efficiency and capacity improvements from participating members, by today and until planned status of 2019. These packages cover 50 different FRA implementation projects [17].

The importance of these projects is underlined by EUROCONTROL. EUROCONTROL states that if the planned projects of the ERNIP Part 2 -ARN version 2015-2019 will be fully implemented in 2019, “flying distances would be reduced by 20 to 25 million NMs”, or equivalents of “120,000 to 150,000 tons of fuel saved” and therefore “emissions of 400,000 to 500,000 tons” would be reduced [17].

As a summary, Table I provides an overview over the already implemented Free Route projects across Europe, sorted by Functional Airspace Blocks [17]. The intensified cooperation across borders within Functional Blocks is expected to reduce safety risks, costs, while at the same time increasing capacity and efficiency.

TABLE I. LIST OF FUNCTIONAL AIRSPACE BLOCKS AND PROJECTS, SOURCE: [17]

FAB	Member	Main projects
South West Spain FAB (SW FAB)		Partial implementation of Direct Routing (DCT)
	Portugal	Full FRA already implemented
	Spain	Additional FRA projects definition required
UK-Ireland FAB (UK/IE FAB)		BOREALIS airspace project
	Ireland	Full FRA already implemented
	Scottish UIR	FL255+
		Phase 3 FRA Prestwick ACC FL255+
FAB Europe Central (FAB EC)		The South-East and Central West projects
		FRA FABEC X-BORDER 365+
BLUE MED FAB		FRAIT - IT Phase 3 (FRA FL365+)
	Malta	FRA FL105+
	Greece	FRA FL315+
	Italy	FRA FL305+
FAB Central Europe (FAB CE)	Implementation of FRA in gradual steps between 2014 and 2020	
Danube FAB		Cross border FRA night
		Cross border FRA FL105+
Baltic FAB		FRA FL105+
North European (NE FAB)		NEFRA project
Denmark/Sweden (DK/DE FAB)		Cross border FRA that was already achieved
		Cross border DK/SE FAB, NE FAB and NEFRA project

IV. MATERIALS AND METHODS

For the trajectory calculations in this paper, the flight planning software Lido/Flight by Lufthansa Systems GmbH & Co. KG has been used. It is designed to generate and find optimized trajectories. Either the trajectories are optimized to find a Minimum Fuel Track (MFT), Minimum Costs Track (MCT), Minimum Time Track (MTT), or Minimum Distance Track (MDT). For the calculation process, Lido/Flight considers current flight-related information, such as Traffic Flow Restrictions (TFR), NOTAM of airports, airspaces, and traffic, current and prognoses weather, and aircraft performance. It is able to run an automated flight planning process. Customers around the world such as Lufthansa, Emirates, or Singapore Airlines can proof the validity and the efficiency of the flight planning software [18].

As the scope of this paper is to demonstrate the possible benefits for an airspace user, it was decided to use a single homogeneous Free Routing Airspace that covers most parts of Europe, except Russia and Eastern-Ukraine. This helps to avoid inefficiencies due to cross-border routing restrictions (see Fig. 1).

The dimensions of the used airspace are shown in Fig. 4.

Figure 4. Lateral layout of Free Routing Airspace, Map data: Google, US Dept of State Geographer, Data SIO; NOAA; U.S. Navy, NGA, GEBCO, Image Landsat

Within the scope of this paper, trajectories with and without Traffic Flow Restrictions (TFRs) using the ATS route network during Aeronautical Information Regulation And Control (AIRAC) cycles 1513 and 1601 have been calculated. These TFRs are high-complex rules, which are set-up by the respective authorities to allow a seamless traffic flow. At the same time, TFRs lead to capacity improvements and more efficient and safe usage of airspace. EUROCONTROL describes the TFRs as “commonly known as route availability restrictions and Flight Level Capping” [19]. Lido/Flight has an integrated module to evaluate such TFR from the RAD, the Aeronautical Information Publication (AIP), or from NOTAMs into the flight planning process. Within Lido/Flight, the user has the possibility to include different kind of restrictions to the database. For the trajectories in Free Routing Airspace no TFR rules were taken into account, as many of those restrictions are attached to segments, which (depending on the actual implementation) may not be present anymore in a Free Routing Airspace. Therefore, current restrictions would have to be redefined based on volumes by the authorities.

With regard to the flight planning options the minimum segment length between two consecutive waypoints remains constant at 20 nm for all calculations. The maximum segment length is varied in the different samples. If user-defined points are used, they are initially generated on a grid with one point every 0°30’ for both, latitudes and longitudes. Both values are chosen from previous experiences through testing in Lido/Flight.

The vertical boundaries of the Free Routing Airspace are set-up as follows:

- Lower: ground level (GND)
- Upper: flight level (FL) 660

In some parts of Europe, the lowest transition boundary of Free Routing Airspace (refer to Chapter III or Table I) begins in FL105 (Malta (BLUEMED) or in the DANUBE FAB). However, the lowest transition boundary of FRA is usually much higher and can only be used from FL255 or above, or even higher with a lowest transition of FL365 or above. Most commercial flights typically operate between en-route altitudes of FL290-FL410. Consequently, these Free Routing Airspaces can only be used for the cruise part of the flight and not for the climb or descent part. However, as the purpose of the present work was not to compare the current layout of the European FRA, but to evaluate possible benefits due to future airspace design, GND to FL660 are used as vertical boundaries. The horizontal Entry and Exit into the airspace has to be on an ATS route network segment.

With respect to the weather a constant wind and temperature scenario for the en-route portion of the flights is used to exclude en-route weather related effects in the results Standard weather from June, which is the month with the highest traffic volume, was chosen as the reference scenario. For a comparison of the effect of the wind on the design parameters of Free Routing Airspace, three sets of flights have been calculated with International Standard Atmosphere (ISA) and zero wind conditions.

In order to eliminate possible variations we limit ourselves to a single aircraft type. To that end, we chose the aircraft that is responsible for the majority of flights within Europe, the A320 and in particular an Airbus A320-211 with CFM56 engines [20]. For all flights, a constant payload of 14,016 kg is anticipated, which represents a load factor of 80%. Finally, the weight of the aircraft including payload, but without fuel – zero fuel weight (ZFW) – is constant at 57,496 kg. The maximum allowed take-off weight (MALTOW) is 73,500 kg.

In some instances the load of 80% leads to performance issues; in these cases the load is reduced to the maximum possible load.

For the purpose of assembling a representative set of flights data from Eurostat for the year 2014 is evaluated. The data contains in total 12,063 different commercial city pairs (including intercontinental ones), between which 1.3 billion passengers were carried [21]. When the Eurostat data is reduced by focussing only on European city pairs (omitting intercontinental city pairs), 9,477 city pairs were remaining, accounting for 1.1 billion passengers. This is further reduced to finally only include the top 997 city pairs (based on total passengers carried), with a share of 300 domestic and 697 international city pairs. With 576 million passengers, the flight set represents 52% of carried passengers within Europe. This is based on the actual flight frequency per city pair, however, in our analysis the flight frequency is considered as equal among all city pairs (1 flight each per sample). The average great circle distance in the flight set is 549 nm. Fig. 5 shows a histogram of the great circle distance.

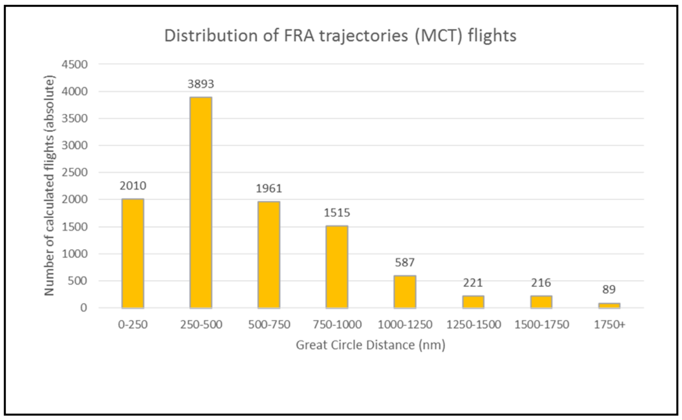

Figure 5. Distribution of flight distances in the flight set

The number at each bar is the total number of calculated flights with Free Route MCT trajectories in that distance group (summarized over all samples). In total, 10,492 flights are analyzed. It can be seen that most flights are within the distance classes of 250-750 nm and with a strong focus on the group of flights between 250-500 nm. The high number of flights within distance classes from 250 to 500 nm can be explained because of a relatively high share of domestic flights within this set.

Using this set of flights, a total of eleven samples with different airspace parameter and meteorological conditions grouped in four scenarios are considered within the scope of this paper. For every single flight in each sample, four different trajectories are generated. These trajectories are the Minimum Fuel Tracks (MFT) and the Minimum Costs Tracks (MCT), each calculated once in an airspace with conventional ATS routings and then in a FRA environment. The MFT minimizes the fuel consumption, and the MCT minimizes the total direct operating costs. They consist of aircraft time cost, fuel cost, and ATC charges.

In total, about 42,000 different trajectories are reflected in this analysis. Table II gives an overview of each used sample and scenario configuration.

TABLE II. OVERVIEW OF USED SAMPLE CONFIGURATION

Sample / Scenario (number)		Date of flight	Configuration parameter				
			MIN segment length (nm)	***MAX segment length (nm)***	***TFR (YES/NO)***	***User-defined points (YES/NO)***	***WXR***
1	1	12/18/15	20	100	NO	YES	June
2	1	12/12/15	20	250	NO	YES	June
3	2	01/06/16	20	100	YES	YES	June
4	2	12/29/15	20	175	YES	YES	June
5	2	12/24/15	20	250	YES	YES	June
6	3	01/08/16	20	100	YES	YES	ISA
7	3	01/10/16	20	175	YES	YES	ISA
8	3	01/09/16	20	250	YES	YES	ISA
9	4	12/19/15	20	100	NO	NO	June
10	4	12/20/15	20	100	NO	NO	June
11	4	12/11/15	20	250	NO	NO	June

The first three scenarios are represented by sample 1 to sample 8; scenario 4 is represented by sample 9 to sample 11. The difference is that scenarios 1 to 3 are calculated with user-defined points, while scenario 4 is not considering those points. A process of reducing selected waypoints is applied when user-defined points are taken into consideration. This is due to the huge amount of additionally generated waypoints; and, therefore, to reduce calculation times. Due to this waypoint reduction process, the results of the samples with considered user-defined points are not directly comparable to the results of the samples without consideration of user-defined points. However, the concept of Free Routing Airspace in contrast to Direct Routing Airspace permits in general the consideration of user-defined waypoints, such as geographical coordinates or by bearing and distance. Therefore, most of the results (scenario 1 to 3) in this paper are focusing on the FRA trajectories, which take into account user-defined points. However, as user-defined points could also increase the complexity, an outcome from a symposium with EUROCONTROL was the desire in terms of airspace design, to avoid the "use of FRA points defined by geographical coordinates or by bearing and distance." [22] To cover this, scenario 4 is intended to analyze possible benefits of the FRA concept, but without consideration of user-defined waypoints.

V. Quantitative analysis of Free Routing Airspace design options

Fig. 6 shows a bar and a line chart with the number of calculated FRA trajectories with benefits over ATS trajectories. The x-axis represents the sample number; the y-axis represents the number of calculated flights. The yellow bars show the number where FRA trajectories result in less total costs than ATS trajectories (MCT). The green bars show the number where FRA trajectories result in less fuel consumption than ATS trajectories (MFT). The grey line shows the overall number of calculated routes (ATS trajectories) per sample.

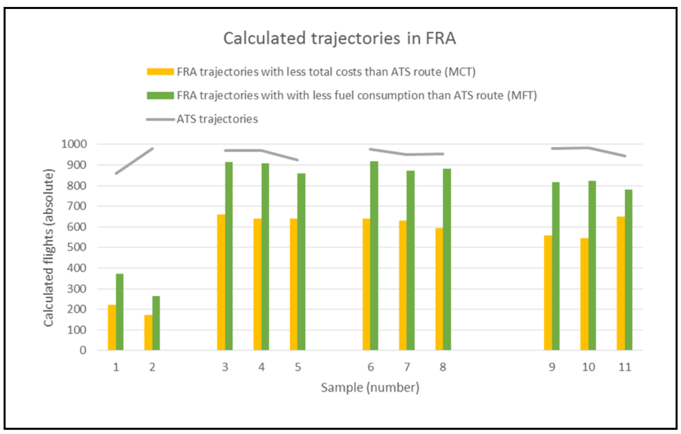

Figure 6. Ratio of trajectories in FRA with less total costs and less fuel consumption compared to ATS trajectories

The first eight samples cover three different scenarios, all calculated with user-defined points. Sample 9 to sample 11 represents scenario four and they are calculated without user-defined points. The number of calculated routes is lower in sample 1. In all other samples, the line keeps mostly constant at around 950 calculated flights per sample. The number of FRA trajectories, which result in less total costs and less fuel consumption than ATS trajectories (MCT and MFT) was significantly lower in sample 1 and sample 2.

However, it can be seen for the majority of all calculated routes, that the FRA trajectories achieved better results compared to ATS trajectories. Still, there are routes where no improvements due to FRA could be achieved. The reason for this is probably the dense ATS network, which is already optimized for current traffic flow in some parts of Europe.

A. Total costs reduction due to Free Routing Airspace

Even though not all routes could be further optimized with FRA trajectories for different reasons, an overall reduction of total costs is possible with FRA trajectories. Fig. 7 represents the total costs reduction possibilities due to FRA trajectories. This chart covers only data of all flights with positive results of FRA trajectories compared to ATS trajectories. The x-axis shows the sample number, the y-axis the relative result of total costs reduction per sample, which is the average of the cost reductions of the single flights.

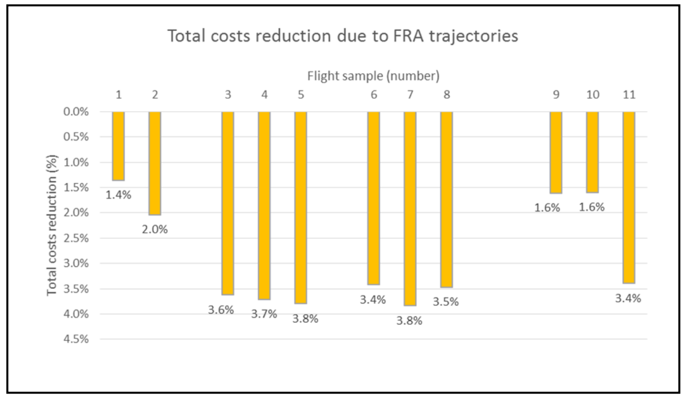

Figure 7. Total costs reduction (percentage) due to FRA trajectories per sample number

The first two samples achieve a total costs reduction of 1.4% and 2.0%. This value appears to be low if compared to sample 3 to 8, which achieved total costs savings between 3.4% an 3.8%. However and different to sample 3 to 8, sample 1 and 2 are calculated without actual day-by-day traffic flow restrictions. In this case, the calculated ATS trajectories follow directly and without detours the least costs tracks on the ATS network. Therefore, the differences between the MCT on an ATS network without TFR and the MCT in a FRA achieve lesser results. A similar observation can be made by looking at sample 9 to 11. These three samples were calculated without taking into account TFRs, as well.

Scenario 2 (samples 3 to 5) shows that an increase of the maximum segment length of a FRA trajectory has almost no effect on the achieved efficiency gain, if user-defined points are considered. This result can be explained by the fact that the usage of user-defined intermediate points mitigates the effect of different maximum allowed segment lengths as the user-defined points can be inserted to generate segments with the required length. The slight difference in the results between set

3, 4, and 5 are most probably attributable to different day-by-day NOTAMs as the sets were calculated on three different days. This shows that this influence can be considered as minor.

Scenario 3 (samples 6 to 8) highlights that wind conditions do have an influence on the results. The trajectories with typical June winds (scenario 2) achieved on average better results in terms of total costs efficiency than under no wind condition in scenario 3. However, the magnitude of the effect is certainly dependent on the exact weather conditions chosen. The chosen statistical weather data for June represents mostly light wind conditions in the European atmosphere. In further follow-up studies, conditions of stronger wind are planned to be used for the calculation and analysis.

In Fig. 8 we present the results for scenario 4 (samples 9 to 11) in more detail. The x-axis represents the respective distance group (see also Fig. 6), the left y-axis the achieved relative reduction of total costs, and the right y-axis represents the difference of achieved total cost reduction of sample 11 compared to sample 10. Sample 9 and sample 10, which basically are identical in the parameter setting but were calculated on different days, led to consistent results. Taking into account longer maximum segment lengths of 250 nm in sample 11, there is a pronounced change in the total cost reduction. This increase is because scenario 4 does not take into account user-defined points and, thus, being able to use up to 250 nm segments allows much more flexible routing options. Due to the non-homogeneous density of ATS routes across Europe, it would make for an interesting analysis to look at probable different regional maximum efficiency gains.

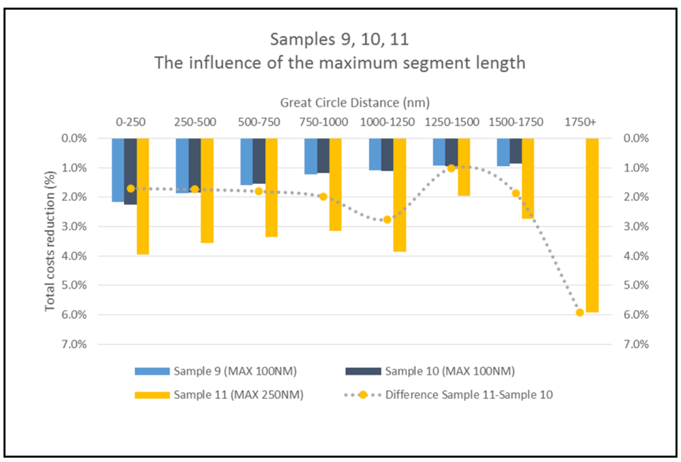

Figure 8 Scenario 4 – The influence of the maximum segment length

B. Fuel consumption reduction due to Free Routing Airspace

In Fig. 9 we show a similar analysis as for the cost reduction in Fig. 7, but for the achieved reduction of fuel consumption due to FRA trajectories. Again, this chart covers only data of all flight trajectories with positive results achieved due to FRA. The x-axis shows the sample number, the y-axis the relative result of fuel consumption reduction per sample.

Qualitatively the results are comparable to those for the cost reduction. Quantitatively, there are differences, however they can be explained by the fact that minimum cost and minimum fuel tracks may result in completely different trajectories both, for the ATS route network and the Free Routing Airspace. This is due to the fact that minimum cost tracks take into account factors like ATC charges and, thus, the route extension compared to the great circle distance may be larger in order to avoid certain regions with high ATC charges. In contrast to that, minimum fuel tracks are closely following the great circle distance route optimized for the current wind situation.

The first two samples in Fig. 9 show that the achieved results in fuel consumption reduction are not that high compared to those of flight samples 3 to 8. This is again due to the fact, that the first two flight samples are not considering any TFRs for the ATS trajectories. The same is valid for samples 9 to 11, as they are calculated without taking into account any TFR as well. Without TFRs, the ATS trajectories are guaranteed to be able to use the airway segments determined to be optimal. Thus, the maximum efficiency gain of FRA trajectories is reduced.

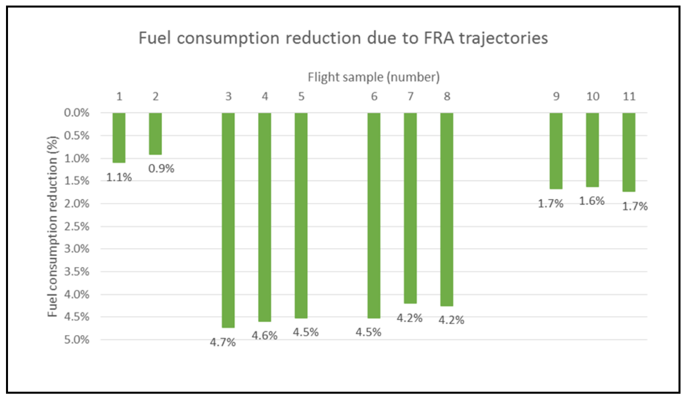

Figure 9. Fuel consumption reduction (percentage) due to FRA trajectories per sample

Similar to the analysis of the cost reduction, the fuel consumption improvements are not dependent on the maximum allowed segment length if user-defined points are allowed (samples 3 to 5). As wind effects are factored in for the calculation of the Minimum Fuel Track, samples 6 to 8 show an effect of the prevailing weather conditions. As discussed above, the effect is rather small.

VI. Conclusions and Recommendations

Free Routing Airspace in Europe is one of the ATM concepts that are expected to provide the highest benefits for the Airspace User. However, as of today there are different implementations with respect to the characteristics of the Free Routing Airspace in the different countries. This has an effect on the maximum efficiency of the FRA trajectory compared to the ATS trajectory used nowadays. In this paper we used extensive trajectory calculations to evaluate the effect that Free Routing Airspace has on both cost and fuel efficiency for different scenarios and Free Routing Airspace design options. Our data show that airspace users can expect high cost and fuel savings for all evaluated scenarios. With regard to the design options we showed that they have an influence but also that they are not independent of each other, as for example the maximum allowed segment length did not matter as long as user-defined points were allowed to be used.

Our results were calculated for an optimum Free Routing Airspace from an airspace user point of view. Clearly, there is a need for some restrictions in the Free Routing Airspace in order to be able for ATC to handle the traffic, which would, however, have a negative effect on the achievable benefits. Therefore, these restrictions should be as many as needed, but as few as possible. Once more Free Routing Airspaces are implemented in Europe; follow-up studies could evaluate the effect of these restrictions.

In summary, it is evident that the introduction of Free Routing Airspace is an important step for airspace users towards improved flight efficiency both in terms of cost and fuel, which in turn is also beneficial for the environment.

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