FLIGHT EFFICIENCY STUDIES IN EUROPE AND THE UNITED STATES

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Abstract

The paper presents two similar studies carried out in the field of flight efficiency, one by Eurocontrol Experimental Centre, one by the FAA.

The studies calculate the excess distances of flights as the difference between the actual flight path length and the direct route length. The results of the EEC study suggest that aircraft fly around 10 percent excess distance compared to direct routes. In the US the inefficiency is around 6 to 8 percent. The cost of flight inefficiency is evaluated.

The important division of flight inefficiency between terminal and en route airspaces is explored. 70 percent of the total excess distance flown in the US is found to take place within terminal airspace and the remaining 30 percent in en route airspace. The European study supports this finding based on the results for certain airport pairs.

Differences between direct routes and wind optimal routes as well as the impact of weather in flight efficiency are also discussed.

Introduction

Background

Flight efficiency is a generic term that can refer to different concepts and definitions. Each actor involved in air transportation activities has its own perception of flight efficiency. From all viewpoints, flight efficiency always involves trade-offs (safety versus capacity, fuel cost versus time cost, ground versus airborne delay, noise versus emissions, etc).

A reduction of few miles in flight length by using more direct routes can result in significant savings on a yearly level. A study by Eurocontrol Performance Review Commission [1] has estimated the cost to airlines of one additional mile flown to vary between 4 and 16 Euros (depending on the aircraft type). IATA claims an average value of $12.5 per additional mile [2].

Both Eurocontrol and the FAA have a keen interest in quantifying inefficiencies in the current ATM system. With improvements in the collection of flight track data, both organizations can begin to better understand flight efficiencies and the potential value of improvements.

Within Eurocontrol, the impact of ATM on the environment has only recently been included in ATM policies and strategies (such as [3]). Eurocontrol is interested in how well the ATM system is able to respond to user demand and allow aircraft to fly the most environmentally efficient route.

A recent reorganization of FAA created the Air Traffic Organization (ATO), which segregated investment decisions for air traffic control into two different divisions: En route and Terminal. Because terminal capacity and efficiency problems can be analyzed locally, it is easier to measure the potential value of terminal improvements than it is to measure en route improvements. For example, numerous queuing-based models support the estimation of reductions in delay associated with terminal capacity increases[1]. Using these models, the value of increased terminal capacity can be projected at both current and future demand levels.

In the en route environment, the potential value of new technologies and procedures is not as clear. While it is assumed that the overriding factor constraining the US National Airspace System (NAS) is terminal capacity, the relative value of en route versus terminal area investments has not been fully explored.

1 Models include: TAAM, NASPAC, DPAT, and standard queuing based modeling used by the FAA's ATO Performance Analysis Division.

Objectives of the paper

This paper presents two studies carried out in the field of flight efficiency; one in Europe, one in the US. The Eurocontrol Experimental Centre's research project focused on the evaluation of flight efficiency and its environmental and economic impacts. FAA's study considers a pool of potential benefits related to improved en route procedures and air traffic control automation. Both approaches are first described separately with a subsequent section identifying the commonalities and the main differences. It must be noted that the initial study by FAA has already been presented in the 2003 ATM seminar [4]. In this paper FAA describes some of the new work carried out as well as discusses some of the issues raised in the previous seminar. The Eurocontrol study presented in the paper uses a part of the old FAA work.

The paper focuses on horizontal flight efficiency.

Eurocontrol Flight Efficiency project

Objectives

The goal of the research carried out by Eurocontrol Experimental Centre and ISA Software was to introduce performance indicators that can be used to measure the flight efficiency and its impact on the environment in Europe. The Eurocontrol Performance Review Unit has also been involved in the beginning of the study by initiating some ideas as it is part of the PRU's responsibilities to measure and monitor the different aspects of European ATM efficiency. Most of the research described in this paper is part of the 2003 Flight Efficiency study [5].

The specific objectives of the parties involved in the flight efficiency project are to:

- Calculate performance indicators that measure flight efficiency and identify areas where European ATM system performance could be improved.
- Ensure an annual assessment of indicators that identifies evolving trends in these indicators, while improving each year the quality and quantity of data used.
- Assess the environmental impact of flight extension.
- Assess the economic impact of flight extension on airlines and environment.
- Progress towards 'enhanced indicators' and build a comprehensive framework for the measurement of flight efficiency.

This paper describes how horizontal distance inefficiency indicators were computed based on the comparison between real radar trajectories and theoretically optimum trajectories. Indicators have been calculated for duration and fuel burn as well [5] but they are not discussed in this paper since distance inefficiency was the easiest element of comparison between the studies of EEC and FAA.

Methodology

The flight inefficiency distance indicator is used to measure how closely the actual (and eventually the planned) horizontal path flown by an aircraft approaches the optimum horizontal path between the departure and destination airports. Two sets of data were needed for the calculations: (1) the actual trajectories flown by the aircraft and (2) the optimum trajectories the aircraft could have flown, or the pilots/operators would have chosen to fly, if no air traffic control or environmental constraints existed.

Actual trajectories

The actual trajectories were derived from Eurocontrol's Enhanced Traffic Flow Management System (ETFMS) Correlated Position Reports (CPR). CPR data is processed radar track data containing records for flights starting and ending within the European Civil Aviation Conference (ECAC) area; thus intercontinental flights were not included in the analysis. Additionally, not all European countries participated in ETFMS when the study was underway and therefore only partial radar coverage of European traffic was available. The Air Navigation Service Providers (ANSPs) providing the data for this study are shown in Figure 1.

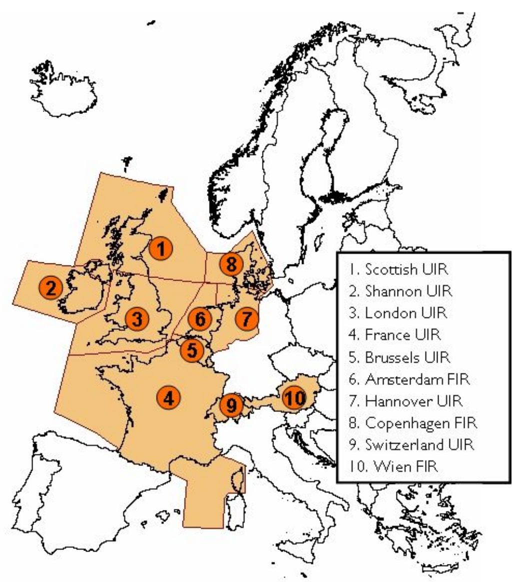

Figure 1. ANSP's providing the study's CPR data

The CPR data (containing geographical position and flight identifier) was correlated with flight plans from the Central Flow Management Unit (CFMU).

Optimum trajectories

The horizontal component of optimum trajectories was defined as the great circle distance. In a simplified view of aircraft flight management, this direct route is considered as the cheapest option, as it minimizes fuel costs. In reality, aircraft often do not follow this direct route since airlines have to make tradeoffs between several factors, such as meteorological conditions, which may lead to definitions of optimum which differ from great circle distance. However, great circle distance was chosen because it provides the advantage of being a constant benchmark (independent of individual strategies) against which actual trajectories can be compared from year to year. Furthermore, for short trips in the European airspace it is reasonable to assume that weather affects route choices less often than in the case of long-haul (intercontinental) flights.

Macroscopic analysis of flight efficiency

A general analysis of European flight efficiency was carried out basing on earlier studies [6], [7]. Some filtering of the radar data was necessary to keep only 'complete' trajectories and avoid misinterpretation of results due to extrapolation. Qualified flights met the following criteria:

- The altitude of first and last radar data point less than 3,000 feet (FL 30)
- Flight duration longer than 15 minutes
- Flight comprises 3 phases: climb, cruise, and descent.
- Different origin and destination airports.

These criteria were intended to capture complete trajectories containing the effect of the terminal area [5]. Short flights for which flight efficiency indicators are not pertinent were thus excluded.

Excess distance for each flight was defined as the difference between the actual flight path length and the direct route length (great circle distance between the first and last point of the filtered trajectories, see Figure 2). The inefficiency indicator was calculated as a percentage of the direct route.

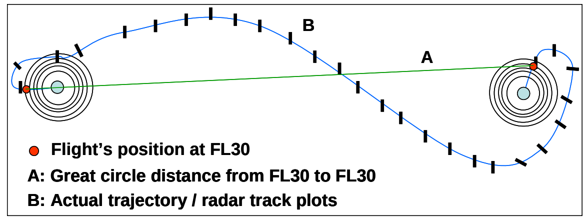

Figure 2. Route references used for the macroscopic flight efficiency calculations

Microscopic analysis of flight efficiency

The assessment of flight efficiency on a European-wide scale rapidly encounters limitations as far as the interpretation of results is concerned. When starting to investigate the reasons for 'inefficiencies', and how to define new indicators capturing all aspects of flight efficiency, the need to adopt a more microscopic view became quickly evident.

An analysis was made applying the methodology introduced by the FAA [4], namely the use of 50nm radius rings around the departure and destination airports to cut the trajectories[2] (see Figure 3). The part between the rings is considered representative of the en route portion of the flight. These trajectories were compared to the full trajectories from airport to airport (using only flights that met the criteria of having the first and last radar point from FL30 or lower and interpolating the distance between the airport and the first/last point).

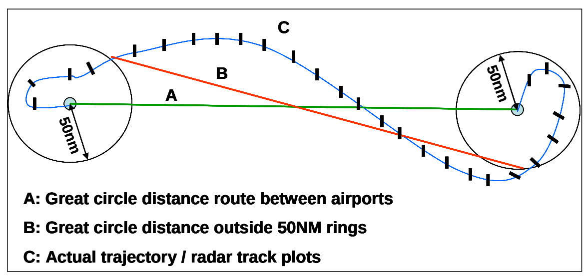

Figure 3. Route references for the microscopic analysis

The methodology was applied to certain airport pairs as this was seen beneficial on three levels:

- The analysis should provide the opportunity to observe particular segments of the route network and to identify causes for route design extension as well as strategies for network utilization.
- It should allow comparison of flight efficiency across airport pairs, and possibly

[2] RAMS Plus air traffic simulator was used to apply the 50nm radius rings around airports to cut the trajectories.

progress towards some benchmarking indicators.

- The methodology allows a comparison to FAA's work and provides a means to separate the terminal and en route portions of the flight.

The airport pairs for the microscopic analysis were chosen to represent relatively long distance traffic (considering the reduced geographical coverage of data), while showing different patterns of traffic volume and relative inefficiencies (as discovered during the macroscopic analysis). The airport pairs to be analyzed were:

- London Heathrow - Geneva
- Paris Orly - Nice
- Copenhagen – Birmingham

Investigation of these airport pairs was meant to be an initial test towards advanced indicators and different route references; it was not intended to serve as an immediate benchmark of these airport pairs nor a comparison of European ANS providers.

Traffic sample

The CPR data sample obtained for the study included traffic for one week in March and one week in June 2003. Of all European traffic during the 2 weeks, approximately 5 percent (over 16000 flights) was left to be used in the study after applying the stringent filters described earlier. Studied flights could be commercial, military, or general aviation flights, which had submitted flight plans indicating departure and destination airports within the Eurocontrol area.

Results

Macroscopic analysis

The results of the flight efficiency analysis have been calculated individually for each sample day, for each week, and for the full data sample. Results are displayed for the flights in the range of 200 – 1100 km. This reduced range is justified by the fact that for long flights, wind plays an important role in the choice of routes, making the observation of excess distances hardly interpretable as inefficiency. Also, there were few long distance flights in the traffic sample. Flights shorter than 200km were not included because of the wide dispersion of results for these flights.

For the 2-week traffic sample, the **distance inefficiency indicator was on average 10.2 percent** for flights between 200 and 1100 km. However, the results are sensitive to flight length. Figure 4 shows that a decreasing trend is obvious, with the lowest inefficiency (around 7.5 percent) for the flights in the range of 800-1000 km. The trend seems logical as the terminal areas (having manoeuvring constraints and thus expected lower efficiency) play a proportionately greater role in short flights.

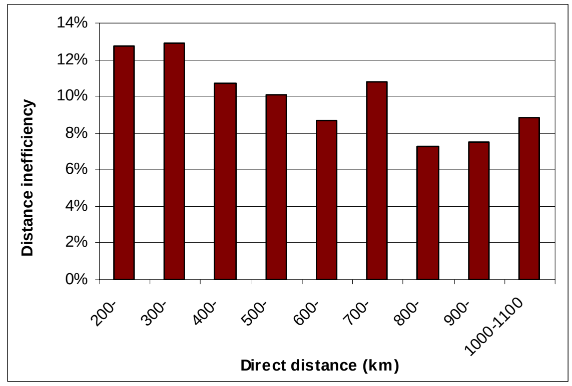

Figure 4. Distance inefficiency as a function of direct distance

A comparison of daily results revealed that weekends seem to be more efficient than weekdays, probably due to reduced traffic levels and therefore fewer ATC constraints, in addition to reduced military zone impacts.

Comparing the results obtained to the 2002 study [6] shows an overall deterioration in flight efficiency, despite the fact that exact differences are impossible to quantify due to minor changes in the methodology between the two study years (see [5] for a detailed comparison).

The study included an economic evaluation of flight inefficiency [5]. The 'minimum cost' scenario quantified the extra cost for the airlines to be around 1000 million Euros per year. An additional cost was calculated for potential impact on climate change due to excess emissions. This was estimated to be at least 100 million Euros in Europe each year.

Microscopic analysis

Table 1 presents the primary results of the airport pairs analysis. (See [8] for more details.)

Table 1. Airport pairs analysis results

	Excess distance flown		Distribution
	Airport-to-airport	**Outside 50nm rings**	**Terminal area / En route**
London Heathrow - Geneva	9.8 %	3.1 %	75% / 25%
Paris Orly - Nice -	9.4 %	1.5 %	88% / 12%
Birmingham - Copenhagen	19.3 %	12.0 %	36% / 64%

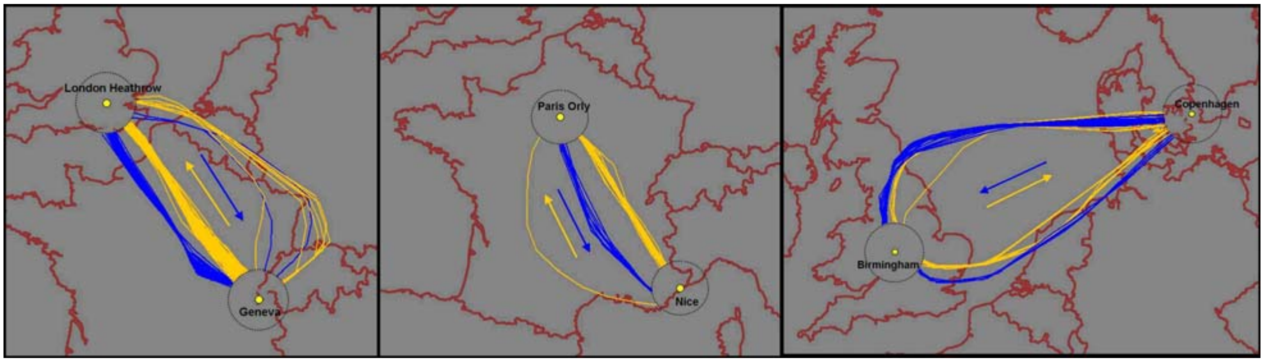

Figure 5. Actual trajectories outside the 50nm radius rings for all studied airport pairs

Figure 5 visualizes the actual trajectories which are discussed in the following paragraphs.

Paris Orly-Nice and London Heathrow-Geneva have similar airport-to-airport inefficiency (which is close to the European average). However, the en route trajectories between Paris and Nice are more efficient and as much as 88 percent of the excess distances for this market result from the terminal area. Although the en route portion of the trajectories is very direct, there is a difference in the two directions; flights originating from Paris seem to have a slightly less efficient choice of route.

The results for London Heathrow-Geneva show that with an overall flight extension of almost 10 percent, only 3 percent occurs in the en route phase. Some flights were avoiding the French airspace on one day of the two weeks and this resulted in high distance inefficiencies for that day. This event can be explained by a French public sector strike on that day which likely impacted ATC operations during several hours. Consequently, the inefficiencies can be assumed to be slightly lower normally. In the north-south direction the en route efficiency was lower (4.2 percent compared to 2.6 percent in south-north direction).

Birmingham-Copenhagen doesn't have as much traffic as the other two airport pairs so it won't be analyzed in detail here. However, the results for this market (and the visual inspection of trajectories) suggest that the flights have to avoid a military zone or their entrance to the UK airspace is restricted and therefore the en route efficiency is low.

The results of the analysis with airport pairs support the assumption that much of the inefficiency observed in the macroscopic analysis is due to the terminal area procedures within the 50nm radius rings. Exceptional events such as ATC strikes or weather can lead to huge deviations. Differences between airport pairs are significant. It was also observed in an on-going study (as yet unpublished) that for equal distance trajectories (or even slightly longer trajectories) airlines often choose to fly where the en route charges are the lowest. This situation seems to occur particularly between Czech Republic and Germany, two adjacent countries with significant differences in their route charges (which are almost three times higher in Germany).

Conclusions

The Eurocontrol Flight Efficiency study described in this paper measured the inefficiency of flights in part of Europe. The findings suggest that the aircraft fly around 10 percent excess distance compared to direct trajectories. Flight efficiency increases as a function of flight length which is expected since the most inefficient trajectories are those used in the terminal areas. Furthermore, the results show degradation in flight efficiency since 2002, which in turn implies increased fuel burn and additional environmental impacts due to ATM.

An initial analysis by airport pairs enabled us to identify some reasons behind inefficiency, as well as the division of inefficiency between the terminal area and en route portion of flight.

Future work

Currently Eurocontrol is analyzing the feasibility of automatic production of flight efficiency indicators on a regular basis. This includes an investigation of alternative data sources as well as different tools. Such automatic system would allow the understanding of the drivers of ATM flight efficiency and the monitoring the environmental performance of flights in the whole European airspace.

FAA Flight Efficiency studies

Objectives

The FAA has several tools and initiatives meant to affect the efficiency of flights in en route airspace. A first step in estimating the effectiveness of en route programs is to determine the maximum possible benefit if all flights were optimized. Analyses of individual programs can then determine the fraction of this “benefits pool” that a tool or initiative addresses.

In this section, we review some previous efficiency results related to horizontal efficiency in en route airspace, address some concerns about the indicators used, and present some recent results for comparison with the older study and with the current Eurocontrol work.

Summary of past work

In a past work [4] we broadly defined en route inefficiency as distance, flight time or fuel burn in en route airspace in excess of that which would occur if each sampled flight were the only aircraft in the system. The aim of that report was to develop a pool of possible benefits for direct routes. The past study described the sources of en route inefficiency focusing on inefficiencies in the route structure. The study included an estimated benefits pool due to route inefficiencies that accounted for necessary conflict avoidance.

The en route inefficiency was defined by the amount of additional distance an aircraft flies in comparison to the shortest possible great circle route of flight. We chose distance to avoid accounting for winds, which highly affect estimates based on flight time (the difference between great circle routes and wind optimal routes will be explored in the next subsection). The choice of distance limits our ability to examine speed control and ignores delays taken on the ground due ground stops, etc.

In the study, we first examined Enhanced Traffic Management System (ETMS) data for a single day (April 10, 2002), comparing actual tracks, current structured flight plan routes, and great circle routes. This analysis provided an initial indication of the flight distance savings possible from NAS-wide Free Flight.

The data source was ETMS track data from the FAA Air Traffic Airspace Laboratory (ATALAB) [9]. The ETMS archives contain flight track data (sampled approximately once per minute) for IFR traffic, as well as structured waypoint information for filed flight plans. For both the actual tracks and filed flight plans, we included only flights that had non-null departure and arrival. Since our focus is on the contiguous U.S., we also removed international flights and those departing from or arriving to Alaska, Hawaii, or Puerto Rico. We further filtered the data by excluding flights that arrive and depart from the same airport (so-called “round robin” flights). This removed many military training flights and general aviation flights for which shortening distance or time en route is not a desired outcome. We considered removing all other military and general aviation traffic from the set as has been done in other studies, but since there is little justification for this, and the results did not change appreciably, we elected to retain these flights. The final traffic sample contained almost 40,000 flights.

To isolate en route and terminal airspaces, we considered the terminal area to exist within a 50 nm radius around both the departure and arrival airports. We then defined the en route portion to exist only between these 50 nm radius rings. Using this definition, flights under 100 nm are excluded from the analysis set. This method is very similar to that described in the Eurocontrol section (see Figure 3).

Table 2. ETMS excess distance results from [4]

	Method 1: Airport to Airport		**Method 2: Outside 50 nm circles**	
Metric	Actual	Plan	Actual	Plan
Mean (nm)	28.5	22.0	9.3	10.0
Sum (nm)	1,296,556	1,141,967	369,968	427,803
% flight	7.7	6.9	2.4	3.1

Table 2 presents the results of the excess distance calculations. As expected, the excess distance using the airport-to-airport method (Method 1) is much higher than that from the circle-to-circle method (Method 2), signifying that restrictions in the terminal area cause much of the excess distance. In fact, focusing on the sum of the actual track data, we find that 71 percent of the total excess distance takes place within terminal airspace and the remaining 29 percent occurs in en route airspace.

Excess distances for actual flight tracks using Method 1 tend to be larger than the flight plan excess distances, no doubt due to the fact that the flight plans do not include all terminal area details and restrictions. This trend reverses in the en route portion of the flight, where excess distance for actual flight plans using Method 2 is slightly less than for flight plans. This may result from direct routings granted by en route centers or pilots cutting corners near flight plan waypoints, or it may occur because all corners are necessarily cut off in actual track data because of the finite sampling rate.

The preceding calculation of excess distance treated each plane separately, ignoring all interactions with other aircraft. In order to refine this estimate, we then considered the effects of aircraft-to-aircraft conflicts (and the necessary maneuvering to maintain required separation) on the potential direct routing benefits pool. We used NASA's Future ATM Concepts Evaluation Tool (FACET) [10] to simulate flights on both structured routes and direct routes. This model considers aircraft climb and descent profiles, counts potential conflicts, and has the ability to perform some conflict resolution. In order to account for conflicts in our benefits pool estimation, we devised a method to calculate typical distance penalties for different types of conflicts. We then used information from both the model and the actual data to refine the benefits pool estimate. The results showed a decrease in the potential benefits pool between 6 and 16 percent.

Using the excess distance, we then calculated yearly delay costs based on mean cruising speed and direct operating costs per minute. Finally, we compared this estimate with results from past similar studies (see Table 3). For details about the individual calculations or the comparison, see [4].

Table 3. Comparison of potential cost savings for direct flights from [4]

Study	**Annual Benefit (dollars)**3	**Number of Eligible Flights per day**	**Daily Benefit per Eligible Flight (dollars)**
FAA 2002 [4]	699M-786M	39,753	51.3 – 57.6
Delta Airlines[11]	42M – 92M	2,000	61.2 – 134.1
MITRE ETMS[12]	~700M	29,045	70.3
MITRE TERMINAL AREAC[13]	620M	31,000	58.3
NASA Ames[14]	107M–279M	5399 - 9488	57.8 – 85.7
Seagull Technology[15]	557M – 652M	40,437 – 50,157	37.9 – 40.1

3 The FAA 2002 study and the Seagull Technology study are presented in 1998 dollars. Both MITRE studies were published in January 2000 and use Air Transport Association cost values but do not specifically document a year. The NASA Ames study uses a value of $29/minute without reference. The Delta Airlines analysis was published in 1996, but the reference to this study in the NASA Ames document does not detail the reference year.

Concerns

After presenting the results from the preceding study, a number of concerns were raised about the validity of the benefits pool calculations. One concern suggested that en route inefficiency outside of the 50 nm rings includes maneuvering for terminal related delays. The reason we chose a 50 nm ring was to account for the Terminal Radar Approach Control (TRACON) boundary (on average 40 nm from airport) plus an additional 10 nm buffer. While there is certainly some terminal-related maneuvering outside of 50 nm for large hub airports, there are many more non-hub airports included in the study for which 50 nm would be considered well beyond the terminal area. We think 50 nm is a good tradeoff considering the current facility boundaries and the variation in airports.

Other concerns included the use of direct routes as a surrogate for wind-optimized routes and the inability to account for convective weather responsible for en route inefficiencies. We address these concerns in the next subsections.

Direct routes vs. Wind optimal routes

Great circle routes are frequently used as benchmarks in National Airspace System (NAS) efficiency and cost/benefit analyses. Some analysts have suggested that such routes are inappropriate benchmarks, and may even require more fuel than currently flown routes. These analysts believe that wind-optimal routes, not great circle routes, are the most appropriate benchmarks. However, wind optimal routes (which we define as those which minimize total flight time given a constant cruise airspeed and altitude) are difficult to calculate, and thus not frequently used in analyses. Additionally, it may not be possible, given current technology, for dispatchers to specify true wind optimal routes or for pilots to fly those routes.

To address this concern we compared wind optimal routes with great circle routes in order to quantify the differences. Using forecast weather data from the Rapid Update Cycle (RUC) model and flight data from the Enhanced Traffic Management System (ETMS) archive, we found the wind optimal route for each flight in the NAS for a historical day.

We also compared the direct routes and wind optimal routes to actually flown routes, as recorded in the ETMS data archive. While we use actual ETMS track points, the times used in the analysis are not actual flight times. Rather, the times that we use in this analysis are hypothetical, as they are based on how long it would take to fly the actual route at the filed airspeed and altitude with the plane being affected by the wind. That is, we do not take into account the plane's actual changes in airspeed and altitude when calculating its expected time of flight, as these changes would render any comparison to the calculated wind optimal time useless. Therefore, we compare the expected time of flight along the actual flight path to the time that would be required to traverse the wind optimal route.

We find that the difference between the simulated times required to fly the great circle route and the wind optimal route was, on average, 19.3 seconds (Table 4). We also find that the difference between the expected time of flight based on the actual track and the wind optimal time is, on average, 100 seconds. This shows that approximately 80 percent of the time based inefficiency of flying the routes on the day in question could be made up by flying the great circle route.

Summary statistics for the NAS-wide wind optimal, great circle, and actual route comparisons are presented in Table 4.

Table 4. Time differences between wind optimal, great circle, and actual routes, April 10, 2002

	Great Circle – Wind Optimal	Actual – Wind Optimal
Mean	19.3 sec	100 sec
Median	0.04 sec	66.7 sec
Standard Deviation	44.5 sec	112 sec

Using the results from the wind optimal calculation, we see that there can be significant differences between wind optimal and great circle routes. However, the median statistics suggest that large differences are only seen by a small percentage of the flights. Most of the flights see little or no time savings by flying on the wind optimal route (relative to a great circle route). Also, the excess distance flown on the wind optimal route compared to the great circle route is usually small. These two results suggest that the wind optimal route is often close to the great circle route. This, combined with the difficulty of maintaining a complete wind forecast archive, gives credence to the case of using great circle routes instead of wind optimal routes as an analytical benchmark.

What is "good" weather

One of the assumptions in our previous work was that we had chosen a "good" weather day. While we did examine weather records before making a day selection, the choice was somewhat arbitrary. We agreed that a new method should be devised to index and normalize weather effects in the NAS.

In [16] the authors proposed an approach to construct an en route weather index. They used the densities of lightning strikes and flight plan tracks to generate an estimate of the impact of the severity of convective weather on en route efficiency. From this estimate, they compute a daily index, which can be used to normalize for the effects of varying en route weather.

The approach essentially scales cloud-to-ground lightning strike data by the number of flights that *planned* to be in the vicinity of the lightning. Flight plans are used instead of actual tracks, since aircraft will likely have maneuvered or been delayed in order to avoid thunderstorms. Initial flight plans, on the other hand, should reflect where users actually desired to go, given airspace constraints. For the calculation details see [16].

Since [16], we have calculated this en route weather index for years of data. When comparing the en route weather index to measures of delays, we find a good correlation. We use the gate arrival delay compared to schedule from the Aviation System Performance Metrics (ASPM) database. When an ordinary least squares regression is computed for the months when convective weather is highest, May through September, for the years 2000 through 2004, we find an R^2 of approximately 0.5. This is a reasonable correlation between the en route weather index and delay.

New results

To compare with the 2002 results and the newer Eurocontrol results, we chose a more recent very good weather day (May 6, 2004) using the weather index as described above. For this comparison, we only examined the actual track and the great circle track (we did not repeat the FACET flight plan analysis or the conflict avoidance). The same methods outlined in the summary of previous work section were used to filter the data and calculate excess distances of nearly 40,000 flights. Table 5 presents the results.

Table 5. ETMS excess distance results

	Method 1: Airport to Airport	Method 2: Outside 50 nm circles
Metric	Actual	Actual
Mean (nm)	30.5	9.6
Sum (nm)	1,208,274	379,127
% flight	5.7%	1.8%

The new numbers are surprisingly similar to those reported in 2002 [4]. Focusing on the sum of the actual track data, we find with this data set 69 percent of the total excess distance takes place within terminal airspace and the remaining 31 percent occurs in en route airspace. The new results are consistent with the 2002 data. The new results also imply that weather was not a large factor in [4]. Further study would be needed to determine if the slight increase in the fraction of delay taken en route is significant or only an artifact of only using one day of data.

Some anecdotal information indicates en route congestion has increased considerably in the past few years. Part of this growth is attributed to Regional Jets replacing Turbo Props and large increases in high performance business jets. Using two years of ETMS data we found that while overall en route traffic increased only 3 percent from 2000 to 2004, traffic above flight level 280 increased more than 20%.

Conclusions

Although the focus of the two studies described in this paper differed somewhat, setting the studies side-by-side shows similarities in the methodology and data used; even the results are comparable.

Both studies have same definition of flight efficiency and propose similar metrics, with some differences in the original route references used. EEC based the study on 2 weeks of traffic (compared to FAA's 2 days), but the incompleteness of the radar data resulted in a smaller sample of the total traffic.

The quantity of data available in the US study was greater than that of Europe. Additionally, having a wider geographical coverage allowed the FAA to analyze flight efficiency by Air Traffic Control Center [4]. Results indicated a link between flight efficiency and traffic load in the ACC's. Similar analysis for European ACC's may be of interest.

The results of the FAA study suggest that the aircraft fly around 6 percent – 8 percent excess distance compared to direct routes. Eurocontrol's study quantified an inefficiency of 10.2 percent. Since FAA's study included significantly more long-distance flights, this may explain the lower inefficiency values.

The five categories of flight inefficiency identified for the US NAS [4] are not all as relevant to the European situation. Routing around severe weather is more common in the US than in Europe. En route sector capacity problems in Europe are usually handled by the Central Flow Management Unit (CFMU) by holding aircraft on the ground, and therefore fewer excess distances are flown. The other three categories (conflict avoidance, terminal congestion, and static network inefficiency), however, are common sources of inefficiency in Europe as well. Furthermore, state-specific route charges applied in Europe can play an additional role to the inefficiency. The exact shares of any of the identified explanatory factors are still to be quantified. FAA has, however, analyzed that between 6 percent and 16 percent of excess distances are inevitable due to conflict avoidance.

The FAA study showed that around 70 percent of the total excess distance flown in the US takes place within terminal airspace and the remaining 30 percent occurs in en route airspace. On a European level, average figures were not possible to calculate but the analysis with three airport pairs supports similar division although the differences between markets can be great.

Both studies addressed the cost of flight inefficiency by converting the excess distances into monetary values and comparing with other studies. Based on the estimate by FAA, the inefficient routes cost US airspace users approximately $700 million per year. EEC's 'minimum cost' scenario quantified the extra cost for the airlines to be around 1000 million Euros per year in Europe.

Clearly, there is a need to better understand the actions both the US and European ATM systems can take to improve efficiencies and save money. With improved data and modeling we will both be able to measure progress and assess the value of future problems.

References

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Key Words

Flight Inefficiency, Performance Indicator, Route Efficiency, Direct Route, Route Charges, Environmental Impact, Airspace Structure, En Route, Benefits Estimation, Free Flight, Sector Capacity, Airspace Structure, Automation Tools, Investment Analysis, FACET.

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