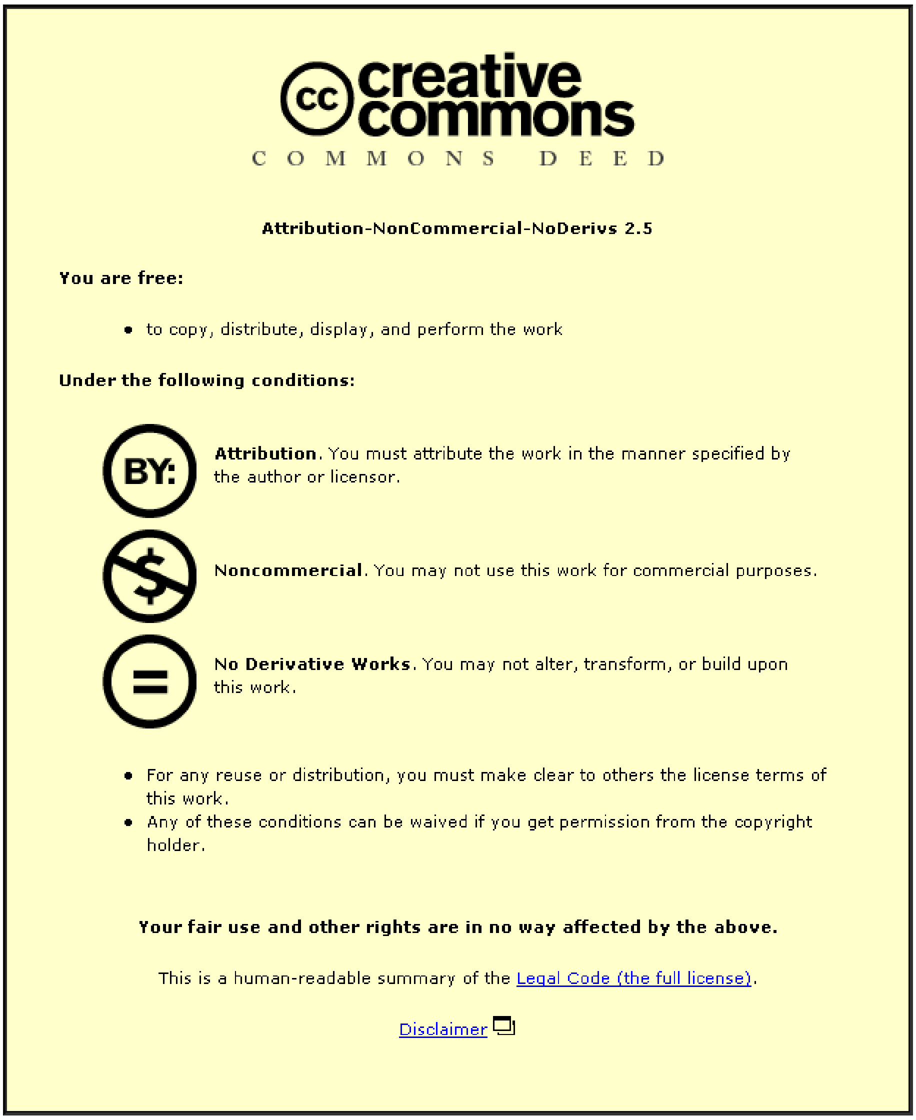

Aviation in a sustainable world Omega

Environmental effects of aircraft operations and airspace charging regimes

Final Report

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About Omega

About Omega
Omega is a one-stop-shop providing impartial world-class academic expertise on the environmental issues facing aviation to the wider aviation sector, Government, NGO's and society as a whole. Its aim is independent knowledge transfer work and innovative solutions for a greener aviation future. Omega's areas of expertise include climate change, local air quality, noise, aircraft systems, aircraft operations, alternative fuels, demand and mitigation policies.

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Executive Summary

Project aim and outline

There has been anecdotal evidence that differences in airspace charging regimes influence airlines' preferred routes and flight plans through European airspace. Routing aircraft over longer distances in order to reduce direct operating costs has a range of fuel burn and greenhouse gas emission consequences that have yet to be adequately quantified.

The aim of this project is to study the environmental costs of different airspace charging regimes in Europe to ascertain whether the level of route charges that are levied for performing a flight affects the route that is flown between specific origin/destination pairs. Through a strategic assessment of a sample of airline flight plans and discussion with stakeholders, the study investigates the drivers of these apparently inefficient flight plans, quantifies the proportion of European routes that are affected (and the additional distances that are travelled) and identifies the greenhouse gas emission (focussing on carbon dioxide) implications of the observed behaviours.

Project benefits

An understanding of the environmental impacts of differential airspace charging regimes within Europe is a component of the wider analysis of the environmental impacts of non-optimal flight profiles being undertaken by the Climate-Related ATM Omega study that is being led by Cambridge University. Together, these studies are crucial for understanding the size of savings that could be achieved through more efficient aircraft routing and/or harmonised airspace charging policies within Europe. The study will ultimately lead to a better understanding of the impact of aircraft routing on environmental metrics and the extent to which inefficiencies can be removed by different stakeholders within the aviation sector.

Key findings

Through a strategic analysis of a sample of 97 airline flight plans and in-depth discussion with key stakeholders in the airline and ATM sectors, this study has uncovered empirical evidence that airspace charges can play an important role in the choice of flight plans, but there are only a small number of routes where the cost incentive to fly longer distances exists. Of the 14 airport pairs that were analysed, one showed a clear cost incentive for airlines to fly longer routes to take advantage of lower airspace charges. There were also a few other routes where flight plans had the same (or slightly lower) ATM charges but were longer, resulting in higher fuel burn and CO_2 production. The motivation for flying these longer routes was, in the case of the ‘TANGO’ route from the United Kingdom to the Canary Islands, based both on cost and because it was less capacity constrained than alternative (shorter) routes. As a general rule, airlines only accept longer routes to avoid areas of congested airspace or adverse weather conditions (principally strong winds or areas of high convective activity) to maximise schedule adherence and minimise passenger discomfort. Ensuring an on-time arrival is particularly important for low-cost and charter carriers who schedule their aircraft to operate multiple flights a day.

Added value and likely customers for the study outputs

This OMEGA study has demonstrated the value of productive collaboration between ATM researchers and the aviation industry. The combination of a strategic analysis of airline flight plans, computation of airspace charges, fuel burn modelling, and in-depth discussions with key stakeholders has enabled the study team to quantify the likely proportion of intra-European routes that are affected and the additional carbon dioxide that is produced and has added value to an increasingly important area of aircraft operations. A better understanding of the impact of airspace charges on airline behaviour and choice of routes will be invaluable to airspace planners and Air Navigation Service Providers (ANSPs). The study outputs will be of interest to a wide range of customers, not only from within the ATM and airline communities, but also politicians, Government agencies, regulatory and policy making bodies and environmental groups.

Future knowledge needs

This study has presented a preliminary assessment of the environmental impact of current airspace charging regimes within Europe. There is evidently much more work that needs to be done to identify how present inefficiencies could be better quantified and reduced. Specifically, we advocate the following:

- Conduct a time-series analysis of airline flight plans that were filed for a particular airport-pair to see if they respond to changes in Unit Rates
- Quantify the environmental benefits of establishing a common Unit Rate across Europe. One possible way to discourage sub-optimal environmental behaviour would arguably be to charge airlines for the total distance (not merely EUROCONTROL’s Central Route Charges Office (CRCO) distance) their aircraft fly within a given region. A feasibility assessment of such an approach is required

- Maintain and enhance existing research collaborations and work towards overcoming some of the concerns certain stakeholders have about data sharing and data accessibility
- Quantify the environmental effects of bypassing areas of restricted airspace and discuss the potential for new ATM technologies and airspace protocols to overcome their effect
- Obtain data on the flight levels at which individual services were performed to estimate the effect of altitude on emissions and the environmental implications of flying at sub fuel-optimum flight levels
- Investigate the environmental effects of airspace charging of other aircraft pollutants, particularly on levels of nitrous oxides, water vapour, and particulates that are deposited into the troposphere
- Undertake broader analysis of the non-cost induced influences upon additional route mileage and hence fuel burn, e.g. the relationship with scheduling of slots, 'on time' performance, congestion and thus the scope to deliver environmental gains from improved practice and education affecting these drivers for non-optimal routing.

1.0 European airspace

Europe's 6120 square kilometres of airspace contains some of the most complicated and densely trafficked sectors of sky in the world. In 2007, over 8.1 million air traffic movements (the equivalent of 23,000 movements a day on average) were handled and the overall demand for air travel is predicted to increase by 2.7-3.7% per annum until 2025 (EUROCONTROL, 2007). European air traffic control faces a unique challenge in trying to harmonise the continent's fragmented airspace structure and overcome the operational and institutional complexity that has been created as a result of each nation having its own air navigation service provider (ANSPs), each with their own operating systems, computer languages, and working practices (Majumdar and Ochieng 2004). As Oster and Strong (2007) note, the failure to establish a unified air traffic control system within the continent is the result of tensions surrounding national sovereignty over airspace.

The right of individual countries to claim sovereignty over their aerial territory was formally enshrined in Chapter One of the Paris Convention of October 1919 and signed by delegates of 26 Allied and Associated Powers (Veale 1945). Article One stated that 'The high contracting parties recognize that every power has complete and exclusive sovereignty over the air space above its territory... including...both that of the mother country and of the colonies, and the territorial waters adjacent thereto' (cited in Lissitzyn 1942: 366). However, this was on the understanding that '[e]ach contracting State undertakes in time of peace to accord freedom of innocent passage above its territory to aircraft of other contracting States' (Article Two cited in Butler 2001: 9[*]). This condition was further emphasised in Article 15, which guaranteed 'Every aircraft of a contracting state has the right to cross the air space of another state without landing' although, and here was the caveat, '[t]he establishment of international airways shall be subject to the consent of states flown over' (cited in Lissitzyn 1942: 366). This degree of regulation disappointed those delegates who believed aviation had the potential to become a universal globalising force that should not be subject to restrictions imposed by 'selfish' national politicians (Hershey 1943).

By the early 1940s, bureaucratic attention was being directed at developing a system of air traffic control that could efficiently and safety handle predicted post-war volumes of traffic. It was appreciated that the peacetime development of air services required full international cooperation and an important step in formulating the necessary international agreements was taken at a conference in Chicago in 1944 that was attended by the representatives of 52 states (Cole 1950). While the majority of delegates agreed that every Contracting State 'has complete and exclusive sovereignty over the airspace above [their] territory'[†] (cited in Prescott 1987: 26), individual states were not prepared to grant other countries extensive access rights to their airspace, and the US's proposals for 'open skies' across the Atlantic and unrestricted competition, while supported by the Netherlands and Sweden, were flatly rejected by Britain and other European nations who advocated a system of strict bilateral regulation believing there should be 'order in the air' (Pillai 1969: 85). Despite the inherent incompatibility of these two geopolitical strategies and the inevitable stalemate that resulted, the conference produced two important documents in the form of the 'International Air Transport Agreement' and the 'International Air Service Transit Agreement', and created a consensus which directly led to the formation of the 'International Civil Aviation Organisation' (ICAO), a United Nations body that was given responsibility for regulating technical competence and safety standards around the World (Crewe 2002).

The 1944 International Air Transport Agreement was based on Canadian proposals to establish a series of 'freedoms' of the air that would enable states to reciprocally negotiate traffic rights through bi-and multilateral air service agreements (Brittin and Watson 1972; Prescott 1975; Millichap 2000). Unlike ships, it was assumed that aircraft had no automatic right to 'innocent passage' through sovereign airspace and individual access agreements had to be negotiated. The resulting bi- and multilateral air service agreements dictated which routes could be flown, which carriers could operate the service, the fares that could be charged, and the frequency of flights. The exchange or denial of these bilateral navigation agreements had very

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[*] N.B. Pagination refers to the electronic version of this paper.

[†] Including that above all land, territorial waters, colonies, dependencies and mandates.

significant implications on the development of global airline networks, as the lack of overflying rights forced aircraft registered in certain countries to fly lengthy (and costly) circuitous routes to avoid overflying 'unfriendly' countries (Glassner 1996).

1.1 Liberalising European skies

European nations began tentatively discussing the possibility of liberalising the continent's air transport operating environment in the mid-1980s in an attempt to emulate the economic success of the US's 1978 Airline Deregulation Act (Button 1996; Lawton 2002). Increased public dissatisfaction with high airfares combined with the rise of free-market neo-liberal economic ideologies and pressures on public spending, encouraged European Governments to embark on liberalisation and privatisation programmes (Balfour 1994). However, the sheer number of autonomous European states (each possessing its own language, history, and administrative procedures) and the predominance of international services, made the formation of a unified policy highly problematic (Pryke 1991; Williams 1994; Button 1996).

In response, the European Community adopted a coherent policy of aviation liberalisation that took the form of three 'packages' of measures. The first, ratified in December 1987, allowed airlines to increase their capacity shares on a route and sell a limited range of discounted fares. The second, approved in June 1990, removed constraints governing market access, increased fifth freedom flying rights, and allowed airlines to sell discounted fares without governmental approval. The third and final package, ratified in 1993, created a single regulatory structure and granted full freedom flying rights (or cabotage) to all member-registered airlines from 1st April 1997 (see Janic 1997). Cabotage permits any EU-registered airline to treat all EU countries[‡] as a domestic market for the purpose of operating services (Jennings 1990; Trent 1993; Hanlon 1996), thus Ryanair (an Irish carrier) and easyJet (a British airline) can operate domestic flights within other European nations. The creation of this single aviation market was considered 'one of the most important developments in aviation' as it ended the use of traditional bilateral agreements to organise air services within the continent (Kassim 1997: 212).

The newly liberalised operating environment was conducive to increased competition, and European entrepreneurs responded by creating a new genre of low-cost airlines (LCAs), which began frequent flights to a multitude of new destinations, dramatically undercutting the fares charged by incumbent

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[‡] Including European Union members and members of the European Free Trade Association (Iceland, Norway, Switzerland and Liechtenstein).

carriers (Calder 2002), and their formation and rapid expansion has had significant implications for the management of European airspace.

1.2 The structure and regulation of European airspace

European airspace comprises a number of discrete, but interfacing, zones of sovereign control, each of which is subdivided into a number of individual sectors. These sectors are often further subdivided to distinguish between permissible and prohibited (dangerous or otherwise restricted) areas of airspace such as Military air traffic zones (MATZs) which still occupy large areas of sky and oblige commercial flights to route round them. The oft-vaunted 'freedom' of the air is thus largely an illusion, for while (theoretically) airways can be laid anywhere, European political fragmentation has hindered the development of an efficient and coordinated airspace system (Barnford and Robinson 1978). As Majumdar (1994: 168) notes, 'The tortuous air routes caused by following national borders rather than logical routes, coupled with military restrictions, cause the average flight to be 10% longer than it need be', or, the case of Brussels-Zurich, up to 45% longer.

EUROCONTROL, the European Organisation for the safety of air navigation, was founded in 1960 to harmonise the air traffic control procedures of member states to maximise airspace capacity, coordinate pan-European air traffic flows, and fund research and development into new technologies (Dixon 2001; Eurocontrol 2005). In February 2004, EUROCONTROL received formal backing from EU Governments to develop a 'Single European Sky' (SES) to increase capacity and harmonise the continent's fragmented airspace structure (Carstens 2004; Majumdar and Ochieng 2004).

In 1969, EUROCONTROL Member States adopted the principles of a harmonized regional enroute charges system and agreed to implement a common policy for the creation and calculation of a single route charge that would enable Member States to recover the costs they incur by providing air traffic control facilities and services. These route charges, which were first introduced in 1971 and revised in 1998, are computed and administered by EUROCONTROL's Central Route Charges Office (CRCO) in accordance with a common formula.

All users flying within the boundaries of European airspace (either wholly or partially) under Instrument Flight Rules (IFR) are liable to pay route charges, though individual States may also choose to levy route charges on selected Visual Flight Rules (VFR) flights. Route charges are only levied against flights that are actually performed. Any planned flight that does not take off is not charged.

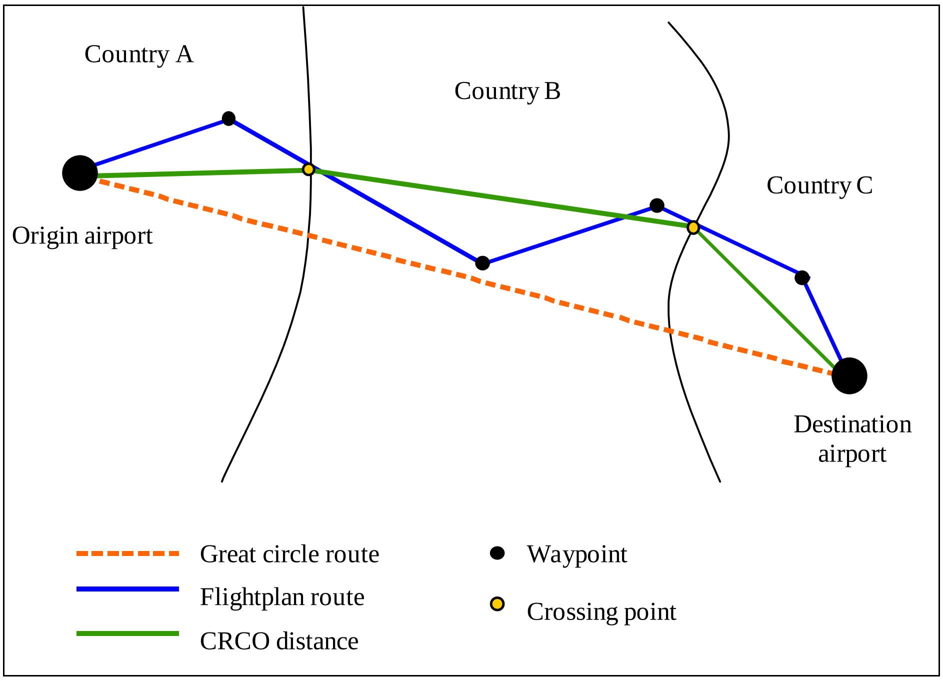
The charges received by Member States are defined by the formula:

$$R_i = T_i \times \frac{D_i}{100} \times \sqrt{\frac{M}{50}}$$

Where T_i is the unit rate of the state *i*, D_i is the distance flown in kilometres in the airspace of State *i*, and M is the Maximum Take Off Weight (in metric tons) of the aircraft.

The distance is calculated as the straight-line distance between the point of entry to, and exit from, different national airspaces (Figure 1). While this regime enables route charges to be calculated relatively easily, airlines are not charged for the actual distance that is flown within a state. Hence, it could be argued that the present charging regime does not necessarily incentivise "good" behaviour.

Figure 1: The difference between the great circle route, the flight plan track, and the CRCO distance



The Unit Rate, expressed in Euros (€), is computed to ensure that revenues equal costs and is made up of two components: the national Unit Rate and the administrative Unit Rate. The national Unit Rate is obtained by dividing the forecast en-route facility cost-base of the State concerned for the reference year by the number of chargeable Service Units (flights) that are likely to be performed in that airspace during the same timeframe. Under or over recovery as a result of a difference between income/revenue and costs is carried over and included in the following year's cost-base.

The administrative Unit Rate, in comparison, recovers the costs of collecting Route Charges and is obtained by dividing the cost base forecast for the year by the number of Service Units estimated in the whole Eurocontrol charging area in that year (Castelli *et al* 2001). The value of the Unit Rate that is charged by each country is updated and published every month and there is considerable variation in the Unit Rates that are set between different charging regions (see Table 1). In October 2008, the Unit Rate for flying through Continental Spanish airspace was over €60 more expensive than that levied on aircraft using Santa Maria airspace to the west of Portugal. Consequently, route charges may play a significant role in defining the routes that are flown by particular airlines as the shortest flight-plannable route may (thanks to higher airspace charges) be more expensive to operate than a longer route through cheaper airspace, even when the additional fuel costs of such a practice are taken into consideration.

Table 1: National Unit Rates, October 2008

State	Unit Rate (€)	State	Unit Rate (€)
Spain - Continent	79.61	Portugal - Lisbon	46.75
Switzerland	71.40	Czech Republic	46.74
Belgium-Luxembourg	69.52	Bulgaria	46.26
UK	67.42	Poland	45.72
Spain - Canaries	67.23	Greece	44.82
Italy	67.07	Albania	44.46
Norway	66.80	Croatia	43.36
Germany	64.93	Romania	41.76
Slovenia	60.84	Finland	40.44
Austria	60.47	Serbia- Montenegro	40.44
Netherlands	59.64	Hungary	35.39
FYROM	59.59	Cyprus	34.02
Denmark	59.33	Bosnia- Herzegovina	29.93
France	58.63	Ireland	28.14
Slovakia	53.99	Malta	26.97
Sweden	50.58	Turkey	26.45
Lithuania	50.15	Portugal-Santa Maria	15.04
Moldova	49.93	**Average Unit Rate**	**50.12**

Source: Eurocontrol, CRCO, October 2008

In addition to varying by state, airspace charges also vary over time and the trend shows Unit Rates are increasing. Between January 2001 and January 2003, Unit Rates for 21 of the 28 CRCO countries increased by anything up to 60% (Castelli *et al* 2004). Between January 2006 and January 2008, the Unit Rate charged by the Netherlands increased from €49.38 to €59.64, while the equivalent rate for Bosnia-Herzegovina dropped from €37.68 to €29.82 over the same time period. The value of the Unit Rate is highly political and it is often used as a tool through which to encourage (or discourage) particular types of traffic. According to a senior director at one European airport operating company, the Unit Rates charged by the Baltic States of Latvia, Lithuania, and Estonia are set intentionally low to encourage traffic and stimulate growth. Airline operators have reportedly responded by altering flight plans to take advantage of this cheaper airspace and are now flying longer routes as a consequence. In comparison, it has been alleged that a Middle Eastern country dramatically increased the charges for using its airspace to discourage airlines from certain countries from flying through it. Both types of pricing behaviour encourage sub-optimal routings resulting in increased fuel burn and emissions.

Political machinations aside, most European airlines have their own preferred route between individual airports. Owing to differences in traffic flow and weather conditions, these preferred routes vary by season, the day of the week and the time of day that the services operate. In most cases, the preferred route corresponds to the shortest theoretical route that can be flown between the origin and destination airports given current airspace configurations, winds and other constraints. However, airlines may also choose to fly a longer route owing to the perceived quality of service they receive from individual ANSPs, experience of operating the route, and differing internal management policies (with charter or low-cost carriers arguably more likely to fly ‘creative’ sub-optimal routes than full-service scheduled carriers) (see Castelli *et al*, 2004).

The ability to choose alternative routes, while making sense from a commercial standpoint, is undesirable from an environmental perspective because longer routes lead to higher fuel consumption and damaging atmospheric emissions. Indeed, it has been suggested that the present airspace charging system in Europe can, in some cases, actively encourage sub-optimal behaviour among airlines as they seek to avoid the most expensive areas of airspace. This study quantifies the proportion of European routes that are affected, calculates the extra distances that are travelled, and discusses the environmental implications of such practices.

2.0 The TANGO controversy

In December 2007, a BBC investigation alleged that at least two UK-based charter airlines were deliberately flying longer routes on services from the UK to the Canary Islands (and back) to avoid flying through the more expensive airspace over mainland Spain and Portugal (BBC, 2007). The report claimed that the 100-mile (160km) diversion, known as the TANGO route (after the waypoint over the Atlantic Ocean of the same name), could result in an extra three tonnes of carbon dioxide being emitted. However, the benefits of lower airspace charges outweighed the additional fuel costs and it was estimated that flying the TANGO route saved the carriers around £100 per flight, a not inconsiderable saving given the frequency with which the routes are operated (BBC, 2007).

3.0 Methodology

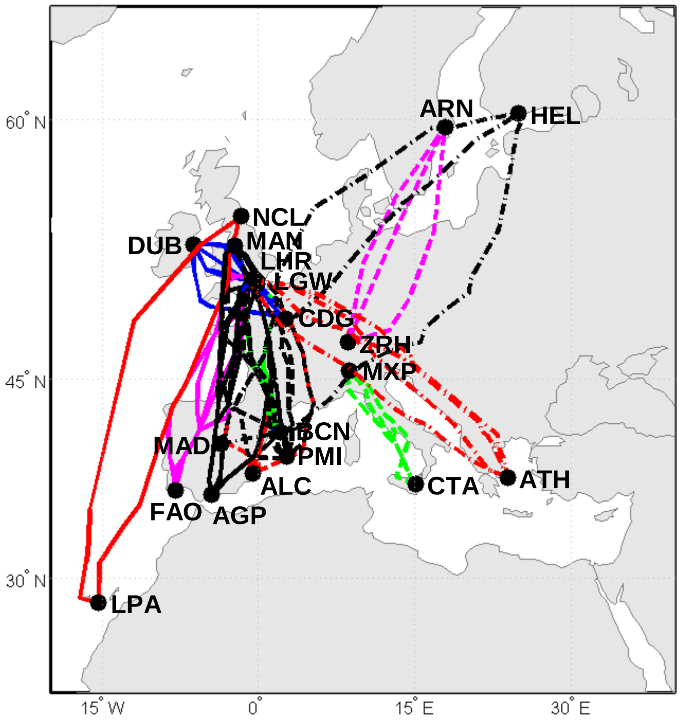
Taking the TANGO controversy as our starting point, the project team aimed to ascertain whether economic incentives existed between other airport pairs within Europe that would have the effect of encouraging sub-optimal environmental route choice behaviour among airlines. The empirical study ultimately involved an economic and environmental analysis of flight plans for 14 frequently flown European airport pairs. The methodology had five key phases:

- Acquire filed flight plans for intra-European services
- Determine relationship between ATM and fuel charges and CO_2 production on each route using EUROCONTROL's RSO route charge calculation software and Base of Aircraft Data (BADA) fuel model
- Indicate environmental impact of observed relationships
- Liase with key stakeholders to understand the rationale behind flying different routes
- Discuss importance of ATM charges on environmental impact at system level

Owing to concerns about data ownership and commercial confidentiality, it was not possible to secure access to flight plans or radar data from 2008 within the time constraints of this project. Individual airlines, while interested in the study, were also unable to supply flight data recorder data owing to concerns from pilot unions about flightcrew confidentiality. Consequently, the study team were only able to access flight plan information from published academic and commercial sources (which attracted a significant fee).

Flight plans for ten frequently flown and delay prone intra-European routes were obtained from Castelli et al's (2004) study (see later this section). Three additional routes, from Madrid to Helsinki, from London/Heathrow to Athens, and from Zurich to Stockholm/Arlanda were also selected for analysis by the study team in order to get wider geographical coverage and because it had been suggested by stakeholders that an investigation into these airport pairs may prove instructive. A cartographic depiction of the routes and the flight plans appears in Figure 2.

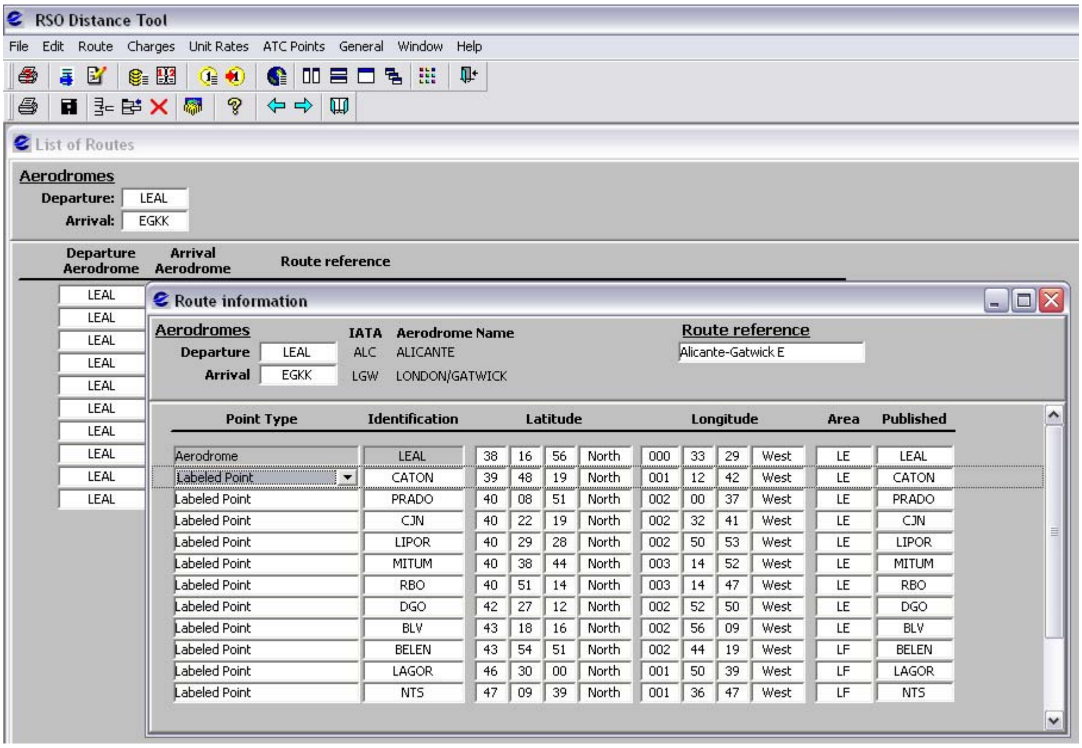
Figure 2: Cartographic depiction of the 14 airport pairs that were selected for analysis



Details of the Zurich-Arlanda routes were derived from actual flight data recorder data that was purchased from Swiss International Airlines by Cambridge University, while the London/Heathrow-Athens and Madrid-Helsinki routes were determined through discussion with stakeholders, reference to high-altitude en-route airspace charts, and expert judgement. Subsequent discussion with stakeholders revealed that our intended flight plans were accurate and likely to be flown in the ‘real world’.

After the flight plans had been collected and quality checked, the airspace charges that would be levied on airlines performing individual flight plan routes was calculated using EUROCONTROL’S RSO (Route per State Overflown) distance tool. This software, which can be freely downloaded from the CRCO section of the EUROCONTROL website, enables users to calculate the approximate charges that will be levied on a flight that is performed wholly or partially within the European Civil Aviation Conference (ECAC) region. Flight plan data, in the form of ICAO four-letter codes for the origin and destination airports and enroute waypoints, is entered, and a spatial profile of the intended route is automatically displayed (see Figure 3). Though the RSO software has an extensive internal database of the geographical coordinates of most waypoints and VOR beacons in European airspace, it was, on occasion, necessary to refer to printed airspace charts to determine the longitude and latitude of particular navigation fixes and enter them manually.

Figure 3: RSO Distance Tool screengrab showing route information for a flight from Alicante to London/Gatwick



Aerodromes
Departure: LEAL
Arrival: EGKK

Departure Aerodrome	Arrival Aerodrome	Route reference
LEAL		
LEAL		
LEAL		
LEAL		
LEAL		
LEAL		
LEAL		
LEAL		
LEAL		
LEAL		

Route information

Aerodromes		IATA	Aerodrome Name
Departure	LEAL	ALC	ALICANTE
Arrival	EGKK	LGW	LONDON/GATWICK

Route reference: Alicante-Gatwick E

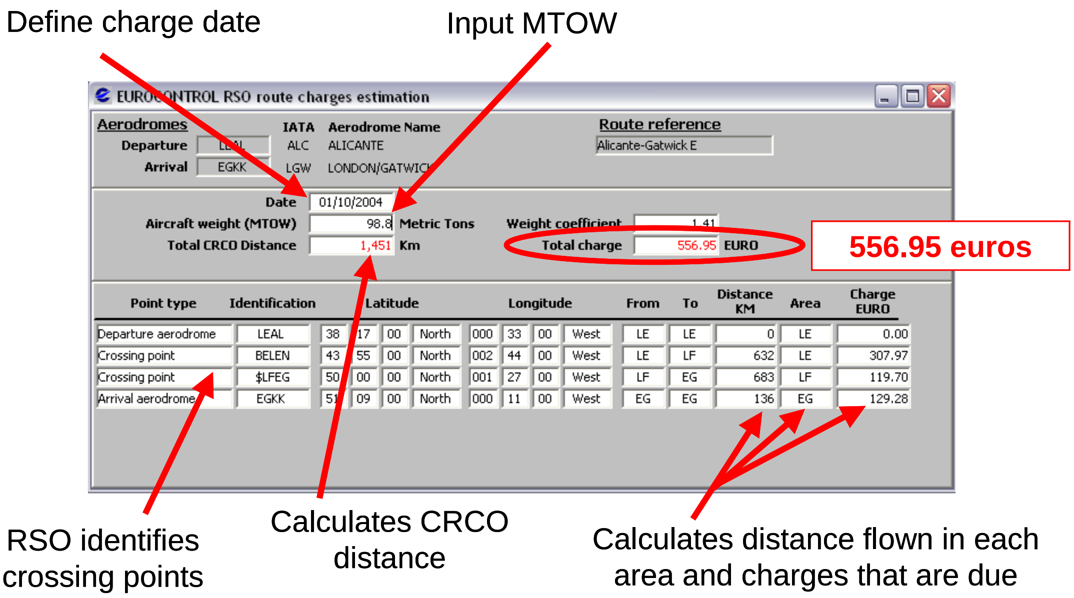
Point Type	Identification	Latitude				Longitude				Area	Published
Aerodrome	LEAL	38	16	56	North	000	33	29	West	LE	LEAL
Labeled Point	CATON	39	48	19	North	001	12	42	West	LE	CATON
Labeled Point	PRADO	40	08	51	North	002	00	37	West	LE	PRADO
Labeled Point	CJN	40	22	19	North	002	32	41	West	LE	CJN
Labeled Point	LIPOR	40	29	28	North	002	50	53	West	LE	LIPOR
Labeled Point	MITUM	40	38	44	North	003	14	52	West	LE	MITUM
Labeled Point	RBO	40	51	14	North	003	14	47	West	LE	RBO
Labeled Point	DGO	42	27	12	North	002	52	50	West	LE	DGO
Labeled Point	BLV	43	18	16	North	002	56	09	West	LE	BLV
Labeled Point	BELEN	43	54	51	North	002	44	19	West	LF	BELEN
Labeled Point	LAGOR	46	30	00	North	001	50	39	West	LF	LAGOR
Labeled Point	NTS	47	09	39	North	001	36	47	West	LF	NTS

The RSO tool also helps users identify the location of the so-called ‘crossing points’ between national airspaces and calculates the total Route Charge that would be levied on any particular flight plan as a function of distance flown, the weight factor of the operating aircraft, and the monthly Unit Rate (as defined and uploaded into the tool by the user). Given the routes under investigation and the likely fleet mix of the airlines that would operate them, the project team chose to calculate airspace charges that would be levied on an operator flying a Boeing 757-200 aircraft (with an assumed maximum take off weight 98.8 tonnes) and an Airbus A320 (with an assumed MTOW of 73.5 tonnes) aircraft. A screengrab showing the RSO output appears in Figure 4 overleaf.

While the RSO tool has its limitations, it does enable consistent comparisons to be made between the total enroute charges different flight plans and aircraft types attract. After the Loughborough team had identified the flight plans and calculated the spatial profile and airspace charges for almost 100 separate flight plans (each of which contained anything up to 25 navigation fixes), colleagues at Cambridge University used Eurocontrol’s BADA (Base of

Aircraft Data) to calculate the quantity of fuel (in kg) a Boeing 757-200 and an Airbus A320 would need to fly the individual routes. The resulting CO_2 emissions were calculated by multiplying the fuel burn by a constant factor of 3.16 (1kg of fuel is known to produce 3.16kg of carbon dioxide). The fuel costs associated with performing each flight were calculated by multiplying the BADA fuel burn with the average price of hedged JET A1 that was paid by four major European carriers in 2004.

Figure 4: RSO route charges estimation screen showing the stages involved in calculating the total charge that would be levied on a B757-200 flying one particular route between Alicante and London/Gatwick


Define charge date

Input MTOW

EUROCONTROL RSO route charges estimation

Aerodromes

		IATA	Aerodrome Name
Departure	LEAL	ALC	ALICANTE
Arrival	EGKK	LGW	LONDON/GATWICK

Route reference: Alicante-Gatwick E

Date: 01/10/2004

Aircraft weight (MTOW): 98.8 Metric Tons

Total CRCO Distance: 1,451 Km

Weight coefficient: 1.41

Total charge: 556.95 EURO

556.95 euros

Point type	Identification	Latitude				Longitude				From	To	Distance KM	Area	Charge EURO
Departure aerodrome	LEAL	38	17	00	North	000	33	00	West	LE	LE	0	LE	0.00
Crossing point	BELEN	43	55	00	North	002	44	00	West	LE	LF	632	LE	307.97
Crossing point	$LFEG	50	00	00	North	001	27	00	West	LF	EG	683	LF	119.70
Arrival aerodrome	EGKK	51	09	00	North	000	11	00	West	EG	EG	136	EG	129.28

RSO identifies crossing points

Calculates CRCO distance

Calculates distance flown in each area and charges that are due

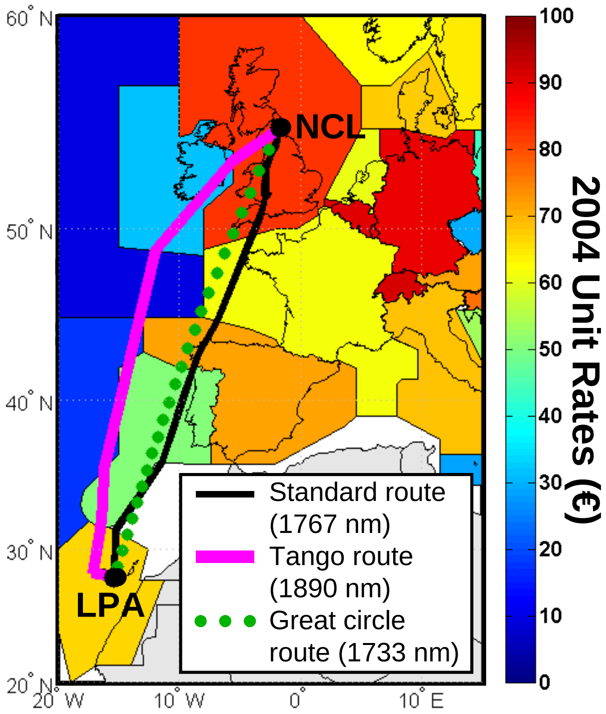
4.0 Strategic analysis of airline flight plans

In order to assess the validity of the BBC's claim about the TANGO route, and quality assure our own methodology, we compared flight plan data for the standard (shortest) route from Newcastle, UK, to Las Palmas in Gran Canaria, with that of the TANGO route. According to our calculations, the TANGO route is 123nm longer than the standard route and a Boeing 757-200 passenger aircraft (assuming a 90% load factor cruising at 35,000ft) would burn an additional 990kg (7%) of fuel (see Table 2). This extra fuel burn would result 3100kg more carbon dioxide being released into the atmosphere, a figure that concurs with the BBC (2007) report. However, even allowing for the additional fuel costs, the TANGO route would still save a B757-200 operator €471 per flight owing to the lower enroute charges. Indeed, the TANGO route actively avoids the relatively expensive airspace of France and Spain by routing aircraft further to the west over cheaper Irish, oceanic, and Santa Maria airspace (Figure 5).

Table 2: Tango route analysis

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO2 (kg)	ATM (€)	Fuel (kg)	CO2 (kg)
Standard	1767	2405	10419	32924	2803	13913	43965
Tango	1890	1482	11144	35215	1727	14896	47071
GC	1733	2113	10226	32314	2463	13649	43131

Figure 5: Depiction of the standard route and the TANGO route from Newcastle, UK, to Las Palmas, Gran Canaria. The warmer colours indicate areas of higher airspace charges.



For this airport pair, our calculations show that a cost incentive exists for airlines to fly further, though any inducement to fly the longer route will be reduced as fuel price goes up and airspace charging differences between neighbouring airspace go down. Crucially, if airspace charges stay the same, fuel costs would have to rise to $1350/tonne (€1,076/tonne) before the TANGO route would be more expensive to operate than the standard (shorter) route.

Having completed the analysis of the TANGO route, the project team examined the routes that were flown between a further 13 European city pairs. Given issues of data ownership and corporate confidentiality, published flight plan data for 10 of the routes was obtained from Castelli *et al* (2004). This study, published in 2004, identified the European airport pairs that attracted the highest average delay per movement and, as several senior flight planners revealed that airspace congestion was one of the main reasons why airlines may accept longer routes, these airport pairs were used as the basis of the subsequent empirical investigation. Eight of the routes were services between the United Kingdom and the Iberian peninsula, one was an internal flight between Milan/Malpensa and Catania/Sicily in Italy, and the tenth was Dublin to Paris/Charles de Gaulle (see Table 3).

Table 3: The ten O/D city pairs most affected by ATM delays

ECGG (Manchester, UK) to LEPA (Palma de Mallorca, Spain)
EGKK (London/Gatwick, UK) to LEMG (Malaga, Spain)
EIDW (Dublin, Ireland) to LFPG (Paris/Charles de Gaulle, France)
LEAL (Alicante, Spain) to EGKK (London/Gatwick, UK)
LEBL (Barcelona, Spain) to EGLL (London/Heathrow, UK)
LEMG (Malaga, Spain) to EGKK (London/Gatwick, UK)
LEPA (Palma de Mallorca, Spain) to EGCC (Manchester, UK)
LEPA (Palma de Mallorca, Spain) to EGKK (London/Gatwick, UK)
LIMC (Milan/Malpensa, Italy) to LICC (Catania/Fontanarossa, Sicily, Italy)
LPFR (Faro, Portugal) to EGKK (London/Gatwick, UK)

Details of the individual flight plans appear in Appendix A while summary findings of our empirical analyses of these routes are presented in the following subsections.

Route 1: LEAL (Alicante) to EGKK (London/Gatwick)

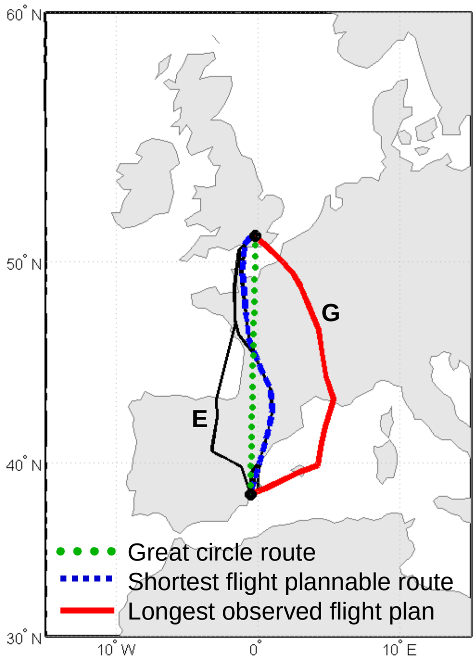
This route is popular with leisure travellers and is flown by both charter and low-cost carriers. Over the course of a week, seven distinct flight plans were filed. Details of the distance, the route charges, the fuel burn, and the CO_2 emissions for each flight plan and aircraft type appear in Table 4.

While the majority of the flight plans are close to the Great Circle route, two (Routes E and G) deviated significantly from it (see Figure 6). In both cases, airspace congestion in the notoriously busy Barcelona, Bordeaux, and Marseilles Flight Information Regions (FIRs), as well as adverse weather conditions over western France, were offered as possible reasons why the airlines would accept these longer routes.

Table 4: Airspace charges, fuel burn, and CO_2 emissions for the B757 and A320 for the seven flight plans vis-à-vis the great circle distance between Alicante and London/Gatwick.

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	831	1173	5040	15926	1367	6620	20919
B	835	1181	5063	15999	1376	6650	21014
C	817	1193	4965	15689	1367	6512	20578
D	821	1193	4988	15762	1367	6543	20676
E	862	1193	5218	16489	1390	6858	21671
F	845	1181	5120	16179	1376	6727	21257
G	990	1336	5937	18761	1556	7827	24733
GC	773	1122	4718	14909	1307	6186	19548

Figure 6: Flight plan routes between Alicante and London/Gatwick



The longest route (Route G) was over 170nm longer and ATM costs almost €150 higher than the shortest and cheapest routes. A B757 flying Route G as opposed to the shortest route (Route C) would result in an extra four tonnes of carbon dioxide being produced. Significantly, when the airspace charges and the fuel costs for operating Route G were combined, it offered airlines no cost incentive but may have enabled them to avoid bad weather or congestion and arrive in London on time.

Route 2: LEMG (Malaga) to EGKK (London/Gatwick)

Over the course of the study week, six distinct flight plans were filed (Figure 7) and subsequently analysed (Table 5).

Figure 7: Flight plan routes between Malaga and London/Gatwick

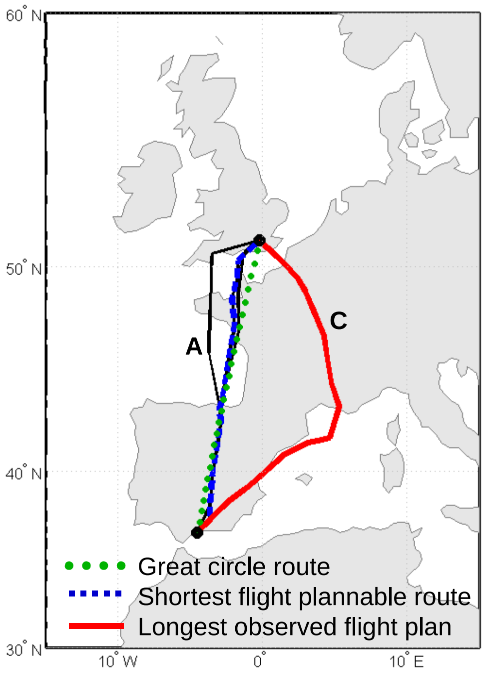


Table 5: Details of the airspace charges, fuel burn, and CO_2 emissions for the six flight plans and the great circle route between Malaga and London/Gatwick

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	979	1437	5878	18574	1674	7742	24465
B	908	1337	5473	17295	1558	7203	22761
C	1164	1666	6928	21892	1942	9172	28984
D	916	1337	5519	17440	1558	7265	22957
E	910	1337	5484	17329	1558	7219	22812
F	908	1337	5473	17295	1558	7203	22761
GC	888	1320	5362	16944	1538	7047	22269

Routes B and F (both at 908nm) were the shortest, cheapest and most frequently used. Route C (at 1164nm) was the longest observed flight plan and would require a B757 aircraft to burn nearly 2000kg more fuel, which would result in an additional 6000kg of carbon dioxide being emitted. Airline sources have indicated that this route would only be used in exceptional circumstances such as severe airspace congestion or bad weather over western France.

Route 3: LEBL (Barcelona) to EGLL (London / Heathrow)

Three different flight plans were filed (see Figure 8) and analysed (Table 6).

Figure 8: Flight plan routes between Barcelona and London/Heathrow

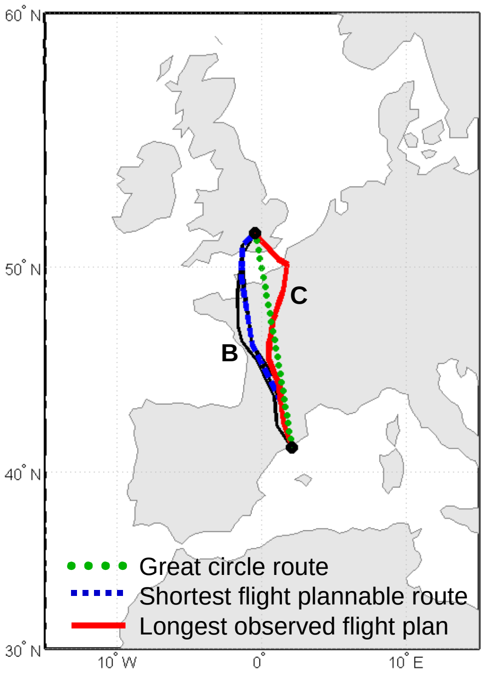


Table 6: Details of the airspace charges, fuel burn, and CO_2 emissions for the three flight plans and the great circle route between Barcelona and London/Heathrow

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	651	905	4039	12763	1054	5267	16644
B	664	919	4108	12981	1071	5365	16953
C	665	899	4113	12997	1048	5372	16976

GC	620	875	3864	12210	1020	5040	15926

Route A (at 651nm) was the shortest, while Route B was the most used and Route C was the cheapest. However, there was no significant variation in ATM charges and no cost incentive for airlines to fly a longer route.

Route 4 EIDW (Dublin) to LPFG (Paris/Charles de Gaulle)

Eight flight plan routes were identified and analysed (see Figure 9 and Table 7).

Figure 9: Routes between Dublin and Paris CDG

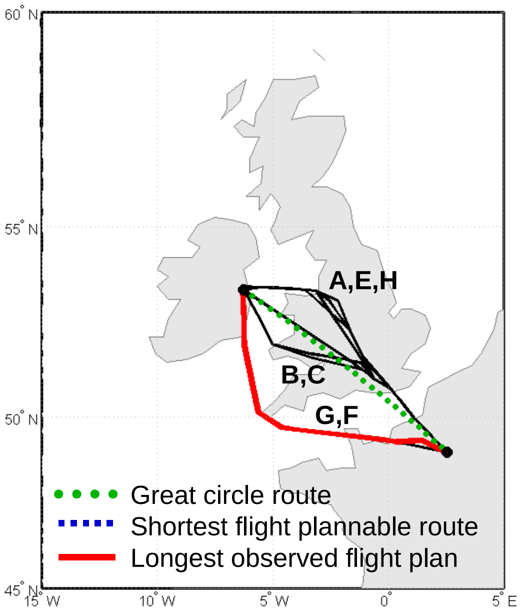


Table 7: Details of the airspace charges, fuel burn, and CO_2 emissions for the eight flight plans vis-à-vis the great circle distance between Dublin and Paris/Charles de Gaulle

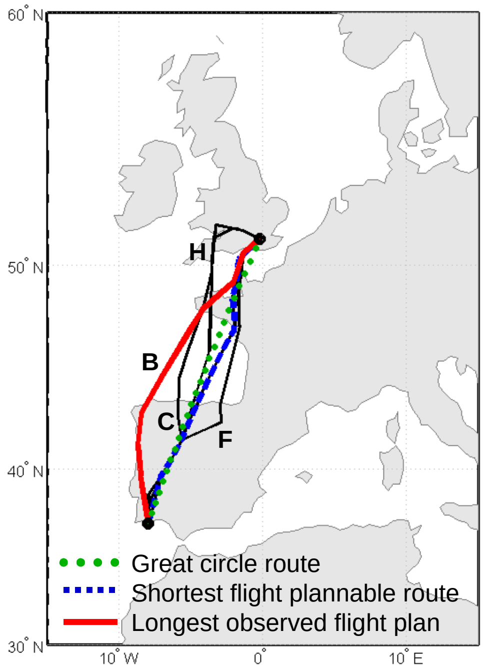
Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	460	698	3038	9600	813	3920	12387
B	451	665	2987	9439	775	3851	12169
C	447	665	2964	9366	775	3820	12071
D	426	679	2843	8984	792	3659	11562
E	461	698	3041	9610	813	3922	12394
F	539	700	3491	11032	816	4521	14286
G	542	700	3434	10851	816	4459	14090
H	460	698	3081	9736	813	3976	12564
GC	424	673	2831	8946	784	3644	11515

Unlike some of the other origin/destination (O/D) pairs, this route shows considerable variation in the spatial profile of the flight plans that were filed. Airline sources have indicated that this variation is to be expected as it is almost certainly the result of military activity over mid Wales that restricts the availability of the optimum routes at certain times of the day and week. The shortest route (Route D) was over 110nm shorter than the longest two routes (Routes F and G) that require aircraft to fly south from Dublin before turning east over southwest England. These longer routes result in almost two tonnes more carbon dioxide being emitted, but there is no cost incentive for airlines to fly these flight plans and they would only do so to avoid congestion and maintain their schedules.

Route 5: LPFR (Faro) to EGKK (London/Gatwick)

Ten different routes were identified (Figure 10) and analysed (Table 8 overleaf).

Figure 10: Flight plans between Faro and London/Gatwick



Congestion in the London FIR (principally at waypoints TERKU and BARLU) and in the Madrid FIR (at ZAMORA) resulted in rerouting and deviation from preferred flight plans. Whereas the shortest route (Route I) is only 29nm longer than the Great Circle distance, the longest route (Route B) is over 200nm longer than the shortest theoretical distance between the two airports. If operated by an A320, Route B produces over three and a half tonnes more carbon dioxide than the shortest (Great Circle) route. However, when fuel and

ATM costs are taken into consideration, there is no cost incentive for airlines to fly further on this O/D pair.

Table 8: Details of the airspace charges, fuel burn, and CO_2 emissions for the ten flight plans and the great circle route between Faro and London/Gatwick

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	949	1313	5704	18025	1530	7509	23728
B	1118	1291	6664	21058	1504	8807	27830
C	1047	1382	6261	19785	1611	8264	26114
D	949	1313	5704	18025	1530	7509	23728
E	944	1313	5675	17933	1530	7482	23643
F	985	1345	5907	18666	1568	7789	24613
G	965	1291	5796	18315	1504	7633	24120
H	1056	1391	6314	19952	1621	8335	26339
I	940	1315	5658	17879	1532	7451	23545
J	1020	1392	6110	19308	1622	8055	25454
GC	911	1309	5490	17348	1526	7226	22834

Route 6 EGKK (London/Gatwick) to LEMG (Malaga)

Nine routes were identified (Figure 11) and analysed (Table 9).

Figure 11: Routes from London/Gatwick to Malaga

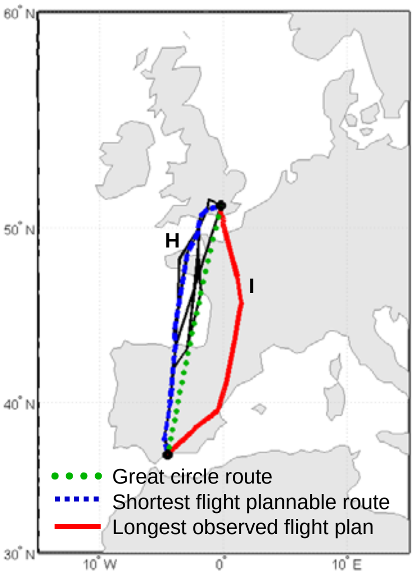


Table 9: Details of the airspace charges, fuel burn, and CO_2 emissions for the nine flight plans and the great circle route between London/Gatwick and Malaga

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	929	1358	5594	17677	1582	7365	23273
B	930	1362	5600	17696	1587	7373	23299
C	897	1330	5415	17111	1549	7118	22493
D	930	1362	5600	17696	1587	7373	23299
E	933	1362	5617	17750	1587	7696	24319
F	934	1362	5623	17769	1587	7404	23397
G	933	1362	5617	17750	1587	7396	23371
H	962	1362	5779	18262	1587	7610	24048
I	974	1383	5849	18483	1612	7703	24341
GC	888	1320	5362	16944	1538	7047	22269

The majority of routes correspond closely with the shortest great circle distance. Overall, Route C (at 897nm) was both the shortest and the cheapest in terms of ATM + fuel charges, but Route B was the most frequently filed route. Route I, which takes aircraft further to the east over France before reaching the southeast coast of Spain was the longest observed flight plan at 974nm. This route would require a B757 to burn over 300kg more fuel and produce over 600kg of additional carbon dioxide.

Route 7: EGCC (Manchester) to LEPA (Palma)

This O/D pair had the highest number of different flight plans of any of the airport pairs we analysed. 17 separate routes were filed (Figure 12) and analysed (Table 10). Routes B, C, D, F, H, I, L, N, O, though exhibiting subtle variations, were the shortest (at 860nm) and the cheapest to operate. Of these, Route L was the most commonly flown. Route E was the longest at 983nm and would result in a B757 producing almost three tonnes more carbon dioxide. Airline sources suggested that this route might have been filed to avoid congestion at the HONILEY and DEAUVILLE waypoints in UK and French airspace respectively.

Figure 12: Routes from Manchester to Palma de Mallorca

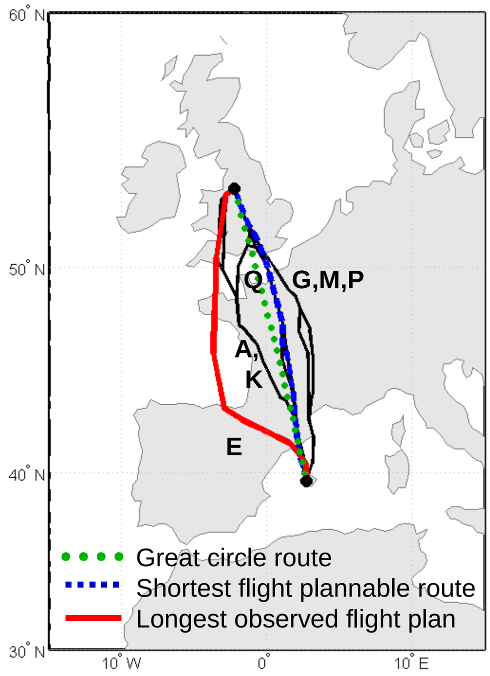


Table 10: Details of the airspace charges, fuel burn, and CO_2 emissions for the 17 flight plans and the great circle route between London/Gatwick and Palma

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	910	1319	5484	17329	1537	7219	22812
B	860	1286	5207	16454	1499	6482	20483
C	862	1286	5218	16489	1499	6858	21671
D	860	1286	5207	16454	1499	6842	21621
E	983	1451	5895	18628	1691	7773	24563
F	860	1286	5207	16454	1499	6842	21621
G	888	1297	5362	16944	1511	7047	22269
H	876	1286	5293	16726	1499	6955	21978
I	862	1286	5218	16489	1499	6568	20755
J	904	1319	5450	17222	1537	7172	22664
K	913	1319	5501	17383	1537	7242	22885
L	860	1286	5207	16454	1499	6842	21621
M	887	1297	5356	16925	1511	7040	22246
N	863	1286	5224	16508	1499	6866	21697
O	859	1286	5374	16982	1499	6835	21599
P	890	1297	5374	16982	1511	7064	22322
Q	895	1287	5403	17073	1499	7103	22445
GC	854	1281	5172	16344	1493	6796	21475

Route 8 LIMC (Milan/Malpensa) to LICC (Catania/Fontanarossa)

Unlike all the other routes, this O/D pair was performed within the airspace of one European country. Three different flight plans were filed (see Figure 13) and analysed (Table 11).

Figure 13: Routes from Milan/Malpensa to Catania

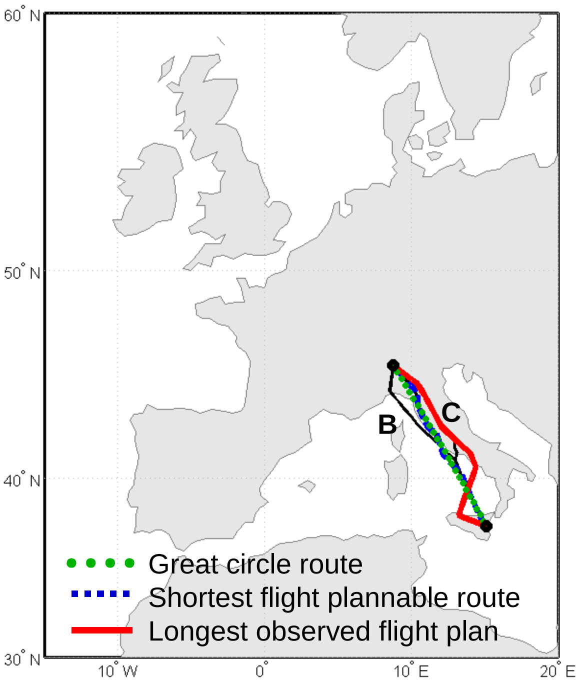


Table 11: Details of the airspace charges, fuel burn, and CO_2 emissions for the three flight plans and the great circle route between Milan/Malpensa and Catania/Sicily

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	586	837	3676	11616	975	4784	15117
B	592	837	3710	11724	975	4829	15260
C	656	837	4067	12852	975	5305	16764
GC	567	837	3573	11291	975	4646	14681

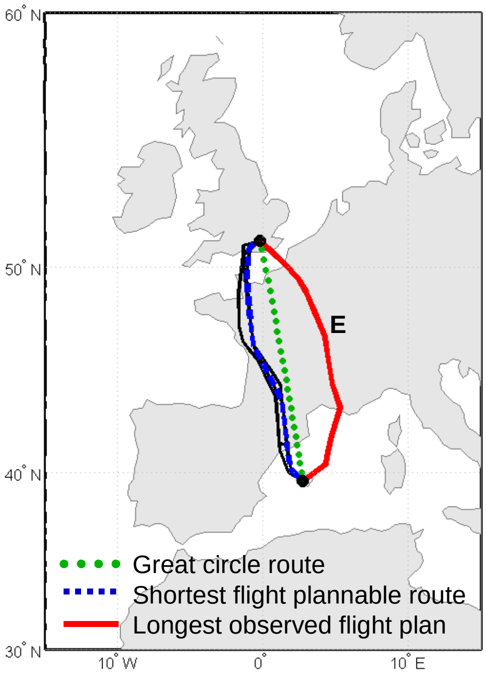
Route C (the longest at 656nm) was reportedly the result of routine radar maintenance at Catania airport that forced arrivals to fly a revised approach. As this is a domestic flight, all the CRCO distances and route charges were the same, however the *actual* flight distances varied by 60nm causing a variation in carbon dioxide emissions between the longest and shortest routes of over

1600kg. These findings suggest that enroute charges based on CRCO distance alone are, in isolation, not a good way of preventing sub-optimal behaviour or the prolongation of routes. Ideally, charging should be a function of both CRCO distance and emissions and further research is required into the feasibility of such an approach which would have the effect of providing a further cost incentive to fly the shortest route.

Route 9 LEPA (Palma de Mallorca) to EGKK (London/Gatwick)

Eight routes were observed (Figure 14) and analysed (Table 12).

Figure 14: Routes between Palma de Mallorca and London/Gatwick



Route F was the shortest (at 759nm) and the joint cheapest. Route E was the longest (at 803nm), but there was little variation in CRCO distances flown as the variation in total route length typically occurred within the airspace of one state. Route E would result in over a tonne more carbon dioxide being released into the atmosphere than Route F.

Table 12: Details of the airspace charges, fuel burn, and CO_2 emissions for the eight flight plans and the great circle route between Palma and London/Gatwick

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	776	1068	4735	14963	1245	6209	19620
B	778	1062	4747	15001	1238	6224	19668
C	790	1068	4810	15200	1245	6306	19927
D	762	1061	4655	14710	1236	6101	19279
E	803	1081	4884	15433	1260	6405	20240
F	759	1054	4638	14656	1229	6078	19206
G	761	1054	4649	14691	1229	6093	19254
H	780	1068	4758	15035	1245	6239	19715
GC	707	1006	4347	13737	1173	5690	17980

Route 10 LEPA (Palma) to EGCC (Manchester)

14 routes were identified (Figure 15) and analysed (Table 13).

Figure 15: Routes between Palma and Manchester

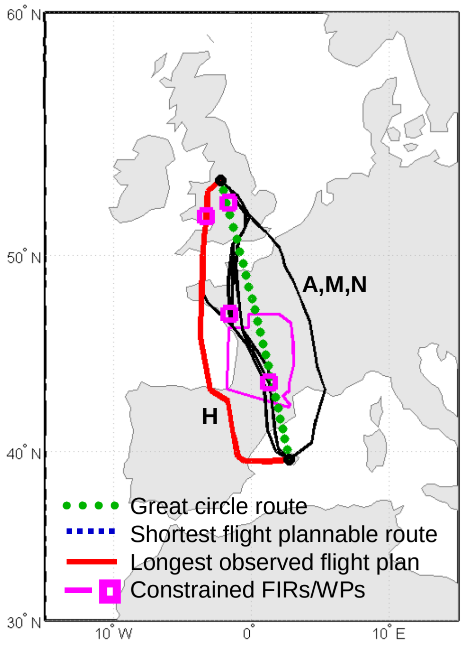


Table 13: Details of the airspace charges, fuel burn, and CO_2 emissions for the 14 flight plans and the great circle route between Palma and Manchester

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	958	1373	5756	18189	1599	7579	23950
B	937	1343	5641	17826	1565	7427	23469
C	923	1291	5559	17566	1504	7319	23128
D	909	1291	5479	17314	1504	7211	22787
E	933	1291	5617	17750	1504	7396	23371
F	906	1285	5461	17257	1498	7188	22714
G	921	1291	5547	17529	1504	7304	23081
H	1047	1451	6261	19785	1691	8264	26114
I	923	1291	5559	17566	1504	7319	23128
J	916	1285	5519	17440	1498	7265	22957
K	919	1291	5536	17494	1504	7288	23030
L	906	1285	5461	17257	1498	7188	22714
M	958	1373	5756	18189	1599	7579	23950
N	957	1373	5750	18170	1599	7571	23924
GC	854	1281	5172	16344	1493	6796	21475

Routes F, J, and L were the shortest (at 916nm) and the cheapest. Route H, which routed aircraft to the west of the coast of France and out over the Bay of Biscay was the longest at 1047nm and was the result of airspace congestion in the London and Marseilles FIRs. It has been suggested that Routes A and M were flown to avoid military activity in the English Channel. Whatever the cause, Route H would require a A320 to burn over 2000kg more fuel which would, in turn, create over 6000kg of CO_2.

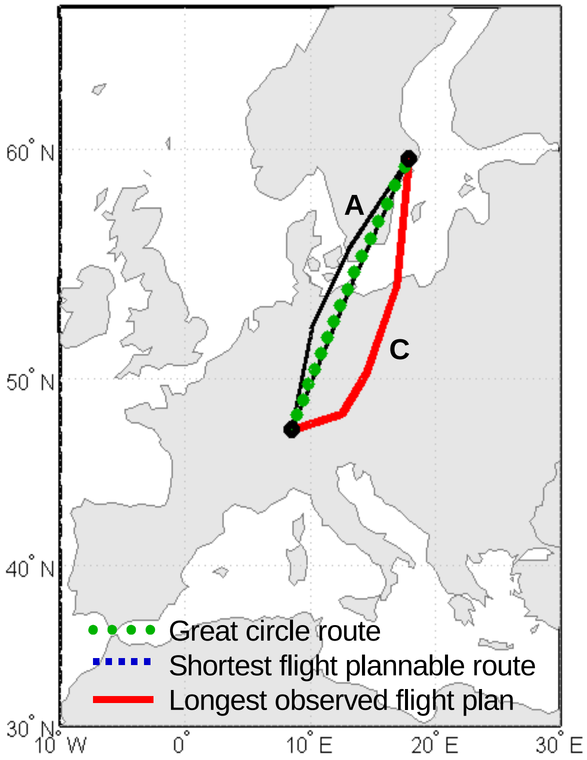
4.1 Additional routes

In addition to analysing the effects of airspace charges on fuel burn and CO_2 emissions of the ten most delay-prone routes within Europe, we also investigated three other routes; Zurich/Kloten to Stockholm/Arlanda, London/Heathrow to Athens, and Madrid/Barajas to Helsinki/Vantaa as it was thought that variation in Unit Rates between neighbouring European countries could provide an incentive for airlines to fly longer routes. In total, 7 flight plans and three actual flight tracks that were flown by Swiss International Airlines were analysed.

Route 11: LSZH (Zurich/Kloten) to ESSB (Stockholm/Arlanda)

On this route, we compared three routes that were flown by Swiss International Airlines' short-haul aircraft between their base at Zurich/Kloten and Stockholm's main airport at Arlanda (see Figure 16).

Figure 16: Routes between Zurich/Kloten and Stockholm/Arlanda



Whereas Route A takes aircraft up through the relatively more expensive airspace of Germany, route C takes aircraft further east and up through the Czech Republic and Poland where airspace charges are considerably lower. Consequently, the costs of flying this route, even allowing for the additional fuel costs, provide an incentive for airlines to fly the longer route (Table 14).

Table 14: Details of the airspace charges, fuel burn, and CO_2 emissions for the three flightpaths flown by Swiss International Airlines' aircraft between Zurich/Kloten and Stockholm/Arlanda

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	810	1384	4926	15566	1613	6462	20420
B	803	1400	4882	15427	1631	6402	20230
C	893	1126	5389	17029	1312	7083	22382
GC	803	1397	4881	15424	1628	6401	20227

However, while the longer Route C is cheaper for the airlines to operate, it does result in a B757 producing over 1100kg more carbon dioxide. However, unless a tax is applied to fuel or CO_2 emissions, there is no financial incentive for airlines to fly the shorter and more expensive routes.

Route 12: LEMD (Madrid/Barajas) to EFHK (Helsinki/Vantaa)

Three routes were identified. One followed the Great Circle route up across France, northern Germany and southern Sweden, the second (Route B) took aircraft further to the north over cheaper Danish and Norwegian airspace, while the third route (Route C) routed aircraft much further to the south across southern France, northern Italy, though Eastern Europe and up through the Baltic States (Figure 17). Details of the distance, ATM charges, fuel burn and associated emissions are displayed in Table 15.

Figure 17: Routes from Madrid/Barajas to Helsinki/Vantaa

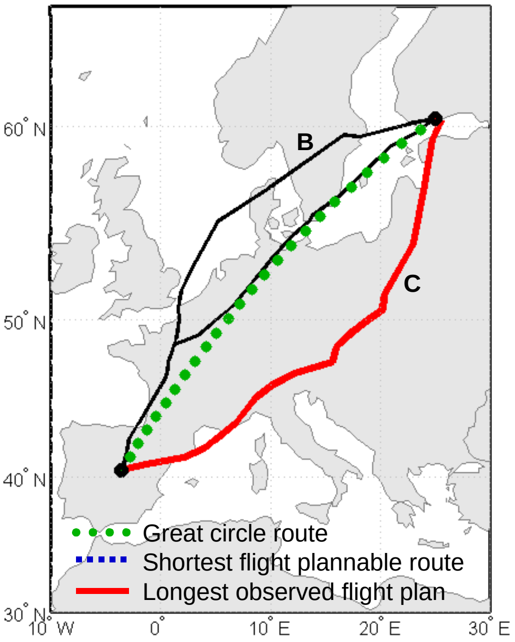


Table 15: Details of the airspace charges, fuel burn, and CO_2 emissions for the three routes from Madrid/Barajas to Helsinki/Vantaa

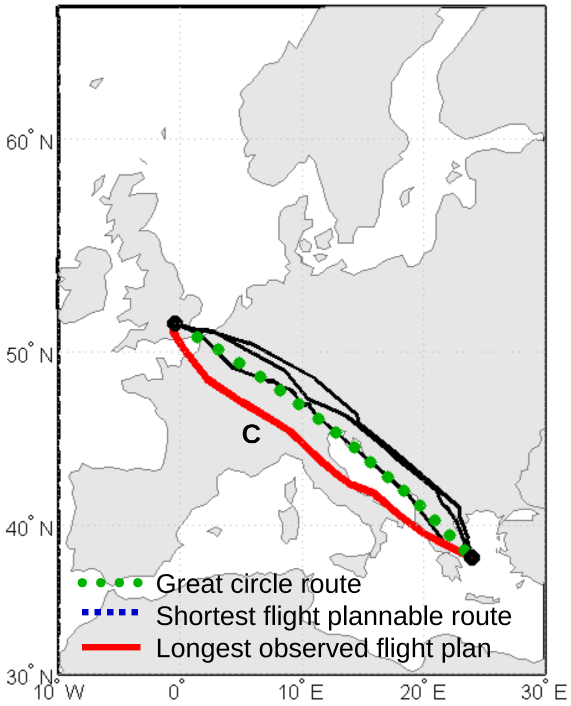
Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	1630	2426	9619	30396	2826	12819	40508
B	1679	2417	9905	31300	2816	13200	41712
C	1866	1954	11004	34773	2277	14715	46499
GC	1591	2380	9391	29676	2774	12515	39547

The opening up of the airspace above the Baltic States of Estonia, Latvia, and Lithuania after the break up of the Soviet Union enabled airlines to easily access this airspace for the first time. It has been suggested that these countries deliberately set their airspace charges at a lower rate to encourage the growth of air traffic in the region.

Route 13: EGLL (London/Heathrow) to LGAV (Athens)

In order to see whether flying through the cheaper airspace of Eastern Europe and the Balkan states would provide an incentive for airlines to fly further, we compared four possible flight plans between London/Heathrow and Athens (Figure 18). Details of the distance, ATM charges, fuel burn and associated emissions are displayed in Table 16.

Figure 18: Routes from London/Heathrow to Athens



As with the Madrid-Helsinki route, we were interested to see whether flying through the relatively cheaper airspace of Eastern Europe and the Balkans would provide a cost incentive for airlines to fly further. However the higher fuel burn associated with flying the longer route negated any savings that were made by flying through the cheaper airspace.

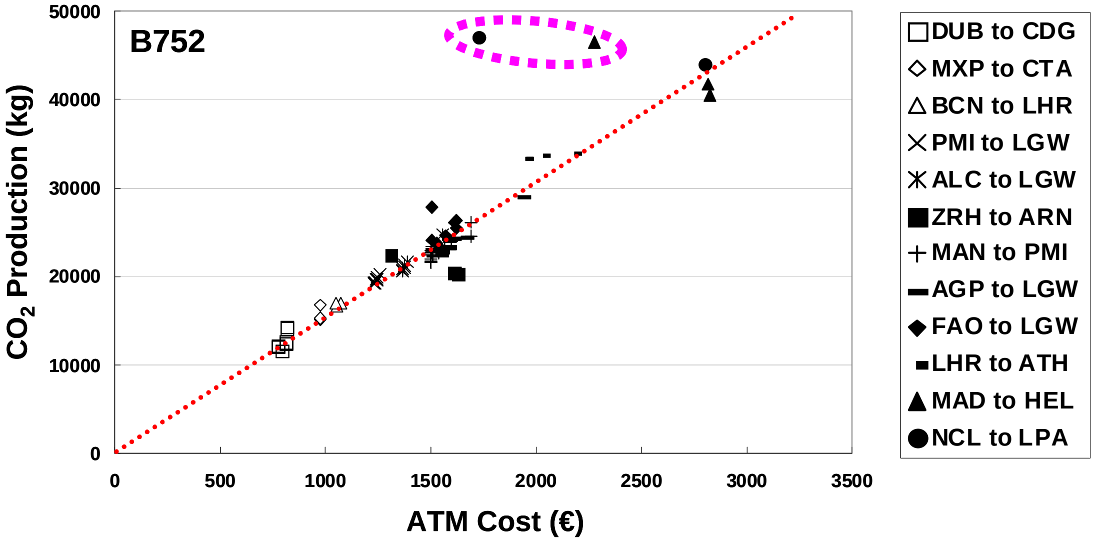
Table 16: Details of the airspace charges, fuel burn, and CO_2 emissions for the three routes from London/Heathrow to Athens

Route	Dist (nm)	A320			B757		
		ATM (€)	Fuel (kg)	CO_2 (kg)	ATM (€)	Fuel (kg)	CO_2 (kg)
A	1344	1677	7958	25147	1954	10563	33379
B	1358	1744	8042	25413	2033	10675	33733
C	1364	1875	8077	25523	2185	10723	33885
D	1342	1673	7946	25109	1950	10547	33329
GC	1311	1676	7768	24547	1953	10301	32551

5.0 Statistical analysis of ATM and fuel costs

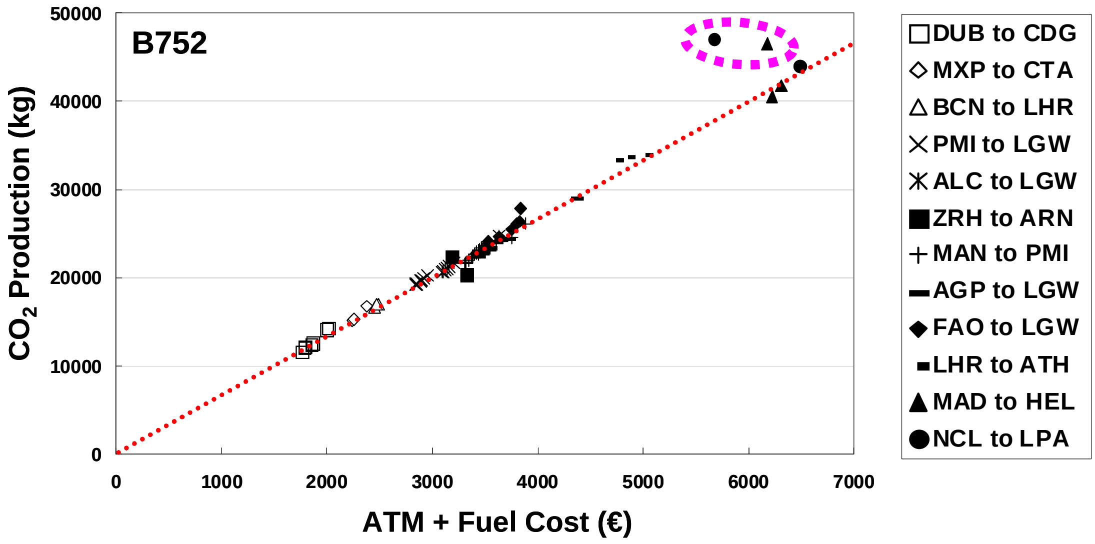
Our calculations show that in high-density routes, ATM cost generally scales with route length (and hence fuel and CO_2 emissions), but two routes (Newcastle to Las Palmas and Madrid to Helsinki) show different behaviour (Figure 19).

Figure 19: ATM costs versus CO_2 production, B757-200.



When ATM and fuel costs are combined, both of these routes still provide a cost incentive for airlines to fly further (Figure 20), however we acknowledge that there will inevitably be other costs associated with the longer flight times that are not dealt with in this study (such as increased crew cost associated with longer duty times on longer routes).

Figure 20: ATM and fuel costs v CO_2 production, B757-200



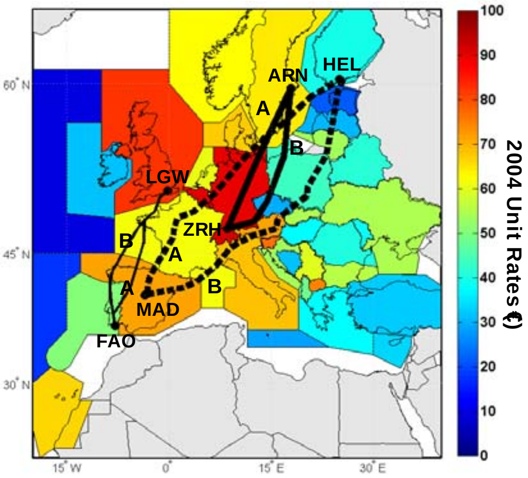
In each case the dotted straight line represents the general behaviour expected of a route where the CO_2 production is proportional to the en route or en route plus fuel costs and, hence, there is little or no cost incentive to fly a route that has higher emissions. For the majority of the routes analyzed, this is the case, i.e. airspace charging is not having a major influence on the route definition. But a small number of the routes lie off this line and hence do show a cost incentive to fly further due to the presence of much lower cost airspace in immediately neighbouring airspace compared to the most direct route, as discussed in the preceding section for each route.

Most significantly, perhaps, fuel costs would have to rise to $1350/tonne (from an average hedge price of $323/tonne in 2004) in order for the TANGO and the standard route from Newcastle to Las Palmas to break even. This is the equivalent to a CO_2 tax of $470/tonne (€390/tonne).

6.0 Summary Findings

Of the 97 flight plans that were analysed, only one route (the TANGO route to the Canary Islands) had a major cost incentive that may encourage airlines to fly a longer route. There were a few other routes where flight plans had the same (or slightly lower) ATM charges but were longer, resulting in higher fuel burn and CO_2 production (Figure 21).

Figure 21 For services between three city pairs in our dataset, longer routes proved cheaper to operate that the shorter routes owing to lower to lower airspace charges



Market	Rte	Dist (nm)	ATM (€)	ATM + Fuel (€)	CO_2 (kg)
MAD to HEL	A	1630	2826	6221	40,508
	B	1866	2277	6174	46,499
ZRH to ARN	A	803	1631	3327	20,230
	B	893	1312	3188	22,382
FAO to LGW	A	949	1530	3519	23,728
	B	1118	1504	3837	27,830

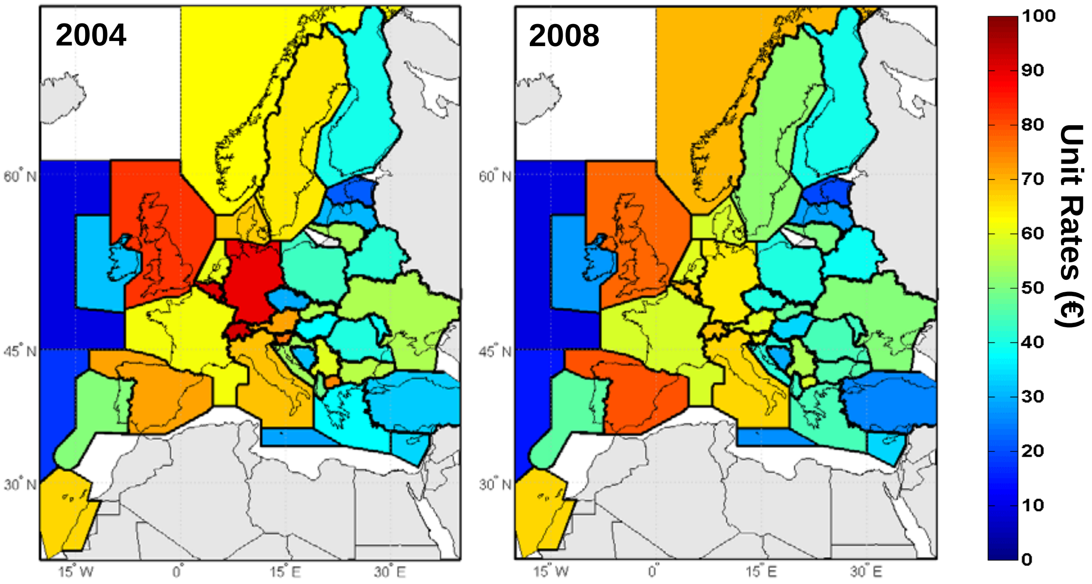
This study has uncovered empirical evidence that more expensive routes can have lower carbon dioxide effects. From an environmental perspective, the best solution to reducing emissions would be flying the Great Circle route as these were an average of 26nm shorter, €54 cheaper, and produced 470kg less CO_2 than the shortest observed flight plan route and were 37nm shorter, €71 cheaper, and produced 647kg less CO_2 than the most commonly flown route. In other words, the great circle route would be cheaper for the airlines and have fewer CO_2 emissions (i.e. a “win-win” option) if only the air traffic management system could accommodate them more easily.

7.0 Future research directions

Through an in-depth analysis of airline flight plans and discussion with industry stakeholders, this study has shown that route charges can play a role in the routes that are flown by individual carriers and that longer routes may occasionally prove attractive to airlines because of their lower overall flight costs. The findings of the study raise a number of questions that need to be addressed.

One possible way to discourage sub-optimal environmental behaviour would be to charge airlines for the total distance (not just the CRCO distance) their aircraft fly within European airspace or take steps to harmonise airspace across the continent to remove the financial incentive to fly longer routes. In recognition that airspace charges are dynamic and vary every month it would be instructive to analyse time-series data of airline flight plans on a specific number of intra-European services to see whether they vary in response to changing Unit Rates. Figure 22 shows the difference in average Unit Rates between 2004 and 2008. Certain airspace regions, including Continental Spain, Norway, and Sweden have become more expensive, while the Rates charged by Germany, Switzerland, and Belgium have dropped. Interestingly, rates in Eastern Europe have not changed significantly over this time period.

Figure 22: The variation in Unit Rates between 2004 and 2008



Further work needs to explore the effects of airspace charges on the production and deposition of other aircraft pollutants in the atmosphere as well as explore how often aircraft are able to cruise at their fuel-optimum flight level. ATM researchers need to engage with politicians at both the national and supranational levels in order to assess the feasibility of changing the existing charging regime from a set Unit Rate to the 'polluter pays' principle or establishing a common Unit Rate for the whole of the continent. Of course, we recognise that any such change would have to overcome significant political and logistical challenges. We would like to see ATM researchers and the airline industry agree a protocol for data sharing and data accessibility that will overcome concerns about commercial confidentiality to enable research to be conducted that will not only benefit the aviation community but global society as a whole.

A conclusion of this report is that, aside from the limited effect of differential airspace use charging upon route mileage and fuel burn, there are several other factors that do play a part in the non-optimal routes flown by airlines. Some are attributable to unavoidable factors such as meteorological conditions but others will be influenced by airline, airport and ATM practices, conventions and rules. It would be appropriate to understand how factors such as scheduling, slot availability and valuation, 'on-time' performance and congestion specifically add to route distance. Unpacking these environmental inefficiency sources would help to inform the development of effective strategies, linked to cost/benefit analysis, to sharpen practice that will ease excess route mileage and deliver environmental improvement.

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Appendix A Declared/Derived Flight plans

The following tables provide details of the O/D airports and the waypoints/VOR beacons that were contained in the flight plans.

Route 1: LEAL (Alicante) to EGKK (London/Gatwick)

Route A	**Route B**	**Route C**	**Route D**	**Route E**	**Route F**	**Route G**
LEAL	LEAL	LEAL	LEAL	LEAL	LEAL	LEAL
MITOS	VLC	CASIM	VLC	CATON	MITOS	MITOS
COMPI	CASIM	DORMI	CASIM	PRADO	COMPI	BRUNO
CASIM	DORMI	BALDE	DORMI	CJN	CASIM	MJV
DORMI	BALDE	VILAR	BALDE	LIPOR	DORMI	BASSO
BALDE	VILAR	LRD	VILAR	MITUM	BALDE	MHN
VILAR	LRD	MECKI	LRD	RBO	VILAR	MEROS
LRD	MECKI	GEMAS	MECKI	DGO	LRD	CHELY
MECKI	GEMAS	BARBO	GEMAS	BLV	MECKI	LUMAS
GEMAS	BARBO	GIROM	BARBO	BELEN	GEMAS	SOSUR
BARBO	GIROM	AGN	GIROM	LAGOR	BARBO	SOFFY
GIROM	AGN	SECHE	AGN	NTS	GIROM	MRM
AGN	SECHE	VELIN	SECHE	BAKUL	AGN	MTL
SECHE	VELIN	CGC	VELIN	KOKOS	SECHE	ETREK
VELIN	CGC	TUPAR	CGC	KATHY	VELIN	MADOT
CGC	ADILU	ANG	TUPAR	EGKK	CGC	ATN
TUPAR	MANAK	SENLO	ANG		ADILU	OKRIX
ANG	TIRAV	KATHY	SENLO		MANAK	CLM
SENLO	NTS	EGKK	KATHY		TIRAV	UTELA
KATHY	BAKUL		EGKK		NTS	KOPOR
EGKK	KOKOS				BAKUL	KOMEL
	KATHY				KOKOS	ABSUD
	EGKK				KATHY	GUBAR
					EGKK	GURLU
						EGKK

Route 2: LEMG (Malaga) to EGKK (London/Gatwick)

Route A	Route B	Route C	Route D	Route E	Route F
LEMG	LEMG	LEMG	LEMG	LEMG	LEMG
LOJAS	LOJAS	VIBAS	VIBAS	LOJAS	LOJAS
BLN	BLN	BAZAS	BLN	BLN	BLN
MORAL	MORAL	YES	MORAL	MORAL	MORAL
VTB	VTB	ASTRO	VTB	VTB	VTB
RBO	RBO	VLC	RBO	RBO	RBO
DGO	DGO	EBROX	DGO	DGO	DGO
BLV	BLV	PEXOT	BLV	BLV	BLV
TUROP	BELEN	SALON	BELEN	BELEN	BELEN
NOVAN	LAGOR	AGENA	LAGOR	LAGOR	LAGOR
POMTA	NTS	MAROT	NTS	NTS	NTS
TERKU	BAKUL	LUMAS	BAKUL	BAKUL	BAKUL
ARE	KOKOS	SOSUR	KOKOS	KOKOS	KOKOS
MUREL	KATHY	SOFFY	KATHY	KATHY	KATHY
SALCO	EGKK	MRM	EGKK	LUCCO	EGKK
BHD		MTL		AVANT	
DAWLY		ETREK		MID	
GIBSO		MADOT		EGKK	
EGKK		ATN			
		AVLON			
		OKRIX			
		CLM			
		UTELA			
		KOPOR			
		KOMEL			
		ABSUD			
		GUBAR			
		GURLU			
		EGKK			

Route 3: LEBL (Barcelona) to EGLL (London/Heathrow)

Route A	Route B	Route C
LEBL	LEBL	LEBL
OKABI	MOPAS	OKABI
TOU	GIROM	TOU
FISTO	AGN	FISTO
POKET	SECHE	FOUCO
TUPAR	VELIN	ADABI
ANG	CGC	BOKNO
SENLO	ADILU	DEVRO
KATHY	MANAK	VANAD
EGLL	TIRAV	VADOM
	NTS	BAMES
	BAKUL	PODEM
	KOKOS	ABUDA
	KATHY	GUBAR
	EGLL	GURLU
		EGLL

Route 4: EIDW (Dublin) to LFPG (Paris/Charles de Gaulle)

Route A	Route B	Route C	Route D	Route E	Route F	Route G	Route H
EIDW	EIDW	EIDW	EIDW	EIDW	EIDW	EIDW	EIDW
DUB	VATRY	VATRY	BASET	DUB	DUB	DUB	DUB
LIFFY	STU	STU	INLAK	LIFFY	BEPAN	BEPAN	LIFFY
GINIS	AMMAN	NUMPO	NIGIT	GINIS	DIMUS	DIMUS	GINIS
NATKO	BCN	NIGIT	VAPID	NATKO	BANBA	BANBA	NATKO
LYNAS	ALVIN	VAPID	MID	LYNAS	PAVLO	PAVLO	LYNAS
ROLEX	BADIM	MID	SFD	ROLEX	LND	LND	ROLEX
WAL	WOTAN	SFD	WAFFU	WAL	NAKID	NAKID	WAL
NANTI	MALBY	WAFFU	HARDY	KIDLI	ANNET	ANNET	LISTO
STAFA	BASET	HARDY	XIDIL	LINDY	INGOR	INGOR	HON
HON	MIMBI	XIDIL	DPE	MID	DVL	DVL	COWLY
BEREK	KENET	DPE	LFPG	SFD	LFPG	SOKMU	MID
COWLY	CPT	LFPG		WAFFU		LFPG	SFD
SFD	MID			HARDY			WAFFU
WAFFU	SFD			XIDIL			HARDY
HARDY	WAFFU			DPE			XIDIL
XIDIL	HARDY			LFPG			DPE
DPE	XIDIL						LFPG
LFPG	DPE						
	LFPG						

Route 5: LPFR (Faro) to EGKK (London/Gatwick)

Route A	**Route B**	**Route C**	**Route D**	**Route E**	**Route F**
LPFR	LPFR	LPFR	LPFR	LPFR	LPFR
SOTEX	SOTEX	ALAGU	SOTEX	XAPAS	XAPAS
EVURA	VFA	ELVAR	EVURA	ELDUK	ELDUK
BIRBA	MAGUM	RODAP	BIRBA	BEJ	BEJ
PORTA	FTM	BABOV	PORTA	EVURA	EVURA
RODAP	PRT	BARDI	RODAP	BIRBA	BIRBA
BABOV	TURON	ZMR	BABOV	PORTA	PORTA
BARDI	STG	VEDER	BARDI	RODAP	RODAP
ZMR	KORUL	LOTEE	ZMR	BABOV	BABOV
TUROP	KOLEK	ERWAN	TUROP	BARDI	BARDI
NOVAN	COQUE	QPR	NOVAN	ZMR	ZMR
POMTA	KEREB	BERAD	POMTA	TUROP	NEA
TERKU	QPR	RUSIB	TERKU	NOVAN	DGO
ARE	ARE	SALCO	ARE	POMTA	BLV
BADUR	BADUR	BHD	JSY	TERKU	BELEN
JSY	JSY	DAWLY	KATHY	ARE	LAGOR
KATHY	KATHY	TINAN	EGKK	BADUR	NTS
EGKK	EGKK	TIVER		JSY	BAKUL
		EXMOR		KATHY	KOKOS
		NUMPO		EGKK	KATHY
		BCN			
		DIKAS			
		WOTAN			
		MALBY			
		BASET			
		KENET			
		EGKK			
Route G	**Route H**	**Route I**	**Route J**		
LPFR	LPFR	LPFR	LPFR		
XAPAS	SOTEX	XAPAS	XAPAS		
ELDUK	EVURA	ELDUK	ELDUK		
BEJ	BIRBA	BEJ	BEJ		
MAGUM	PORTA	ELVAR	ELVAR		
FTM	RODAP	RODAP	RODAP		
PRT	BABOV	BABOV	BABOV		
TURON	BARDI	BARDI	BARDI		
STG	ZMR	ZMR	ZMR		
KORUL	TUROP	TUROP	TUROP		
KOLEK	NOVAN	NOVAN	NOVAN		
COQUE	POMTA	POMTA	POMTA		
KEREB	TERKU	TERKU	TERKU		
QPR	ARE	ARE	ARE		

ARE	MUREL	BADUR	MUREL		
BADUR	SALCO	JSY	SALCO		
JSY	BHD	KATHY	BHD		
KATHY	DAWLY	EGKK	DAWLY		
EGKK	TINAN		TINAN		
	TIVER		TIVER		
	EXMOR		EXMOR		
	NUMPO		MALBY		
	BCN		BASET		
	DIKAS		KENET		
	WOTAN		EGKK		
	MALBY				
	BASET				
	KENET				
	EGKK				

Route 6: EGKK (London/Gatwick) to LEMG (Malaga)

Route A	**Route B**	**Route C**	**Route D**	**Route E**	**Route F**	**Route G**	**Route H**	**Route I**
EGKK	EGKK	EGKK	EGKK	EGKK	EGKK	EGKK	EGKK	EGKK
SAM	SAM	SNR	SAM	SAM	SAM	SAM	CPT	BOGNA
ASPEN	ASPEN	RATAS	ASPEN	ASPEN	ASPEN	ASPEN	SAM	BENBO
ORTAC	ORTAC	NEA	ORTAC	ORTAC	ORTAC	ORTAC	ASPEN	DRAKE
DIN	GUR	ORBIS	GUR	DIN	GUR	DIN	ORTAC	SITET
ERIGA	ARE	DISKO	ARE	GODAN	ARE	GODAN	GUR	ETRAT
POPUL	TERKU	TLD	TERKU	TERPO	TERKU	TERPO	ARE	DVL
BLV	POMTA	MONTO	POMTA	LAGOR	POMTA	LAGOR	TERKU	LGL
NEA	NOVAN	CRISA	NOVAN	BELEN	NOVAN	BARIK	POMTA	AMB
ORBIS	TUROP	VULPE	TUROP	BLV	TUROP	BELEN	NOVAN	BEBIX
DISKO	SNR	LEMG	SNR	NEA	SNR	BLV	TUROP	MAKOX
TLD	RATAS		RATAS	ORBIS	RATAS	NEA	SNR	AGN
MONTO	NEA		NEA	DISKO	NEA	ORBIS	RATAS	GONUP
CRISA	ORBIS		ORBIS	TLD	ORBIS	DISKO	NEA	ANETO
VULPE	DISKO		DISKO	MONTO	DISKO	TLD	ORBIS	GRAUS
LEMG	TLD		TLD	VULPE	TLD	MONTO	DISKO	LOBAR
	MONTO		MONTO	LEMG	MONTO	CRISA	TLD	SEROX
	CRISA		VULPE		CRISA	VULPE	MONTO	CASPE
	VULPE		LEMG		VULPE	LEMG	CRISA	MLA
	LEMG				MGA		VULPE	CRETA
					LEMG		LEMG	SAURA
								PLANA
								VLC
								ASTRO
								YES
								BAZAS
								VIBAS
								MGA
								LEMG

Route 7: EGCC (Manchester) to LEPA (Palma de Mallorca)

Route A	**Route B**	**Route C**	**Route D**	**Route E**	**Route F**
EGCC	EGCC	EGCC	EGCC	EGCC	EGCC
NOKIN	LISTO	HON	LISTO	NOKIN	HON
KARNO	HON	KIDLI	HON	KARNO	KIDLI
BHD	KIDLI	CPT	KIDLI	BHD	LINDY
SKESO	CPT	VAPID	CPT	SALCO	MID
DIN	VAPID	GWC	VAPID	MUREL	DRAKE
GODAN	GWC	SITET	GWC	ARE	SITET
TERPO	SITET	ETRAT	SITET	TERKU	ETRAT
NTS	ETRAT	DVL	ETRAT	POMTA	DVL
LUGEN	DVL	LGL	DVL	NOVAN	LGL
TUPAR	LGL	AMB	LGL	TUROP	AMB
CGC	AMB	BALAN	AMB	BLV	BEBIX
VELIN	BEBIX	LMG	BEBIX	PPN	TUGLI
SECHE	TUGLI	MAKOX	TUGLI	RONKO	BALPI
AGN	BALPI	BRIVE	BALPI	SURCO	NARAK
TOU	NARAK	AULON	NARAK	MARIO	GAI
ROCAN	GAI	GAI	GAI	POSSY	ROCAN
PUMAL	ROCAN	ROCAN	ROCAN	GRAUS	PUMAL
LORES	PUMAL	PUMAL	PUMAL	GEMAS	LORES
LEPA	LORES	LORES	LORES	REBUL	LEPA
	LEPA	LEPA	LEPA	VIBOK	
				CAVES	
				LORES	
				LEPA	
Route G	**Route H**	**Route I**	**Route J**	**Route K**	**Route L**
EGCC	EGCC	EGCC	EGCC	EGCC	EGCC
HON	HON	HON	NOKIN	MONTY	HON
KIDLI	KIDLI	KIDLI	KARNO	NITON	KIDLI
LINDY	CPT	CPT	SKESO	DIKAS	CPT
MID	PEPIS	VAPID	DIN	BCN	VAPID
BOGNA	SAM	GWC	GODAN	NUMPO	GWC
BENBO	GWC	SITET	TERPO	EXMOR	SITET
HAWKE	SITET	ETRAT	NTS	TIVER	ETRAT
XAMAB	ETRAT	DVL	LUGEN	TINAN	DVL
VEULE	DVL	LGL	TUPAR	DAWLY	LGL
BAMES	LGL	SORAP	CGC	BHD	AMB
RBT	AMB	BENAR	VELIN	SKERY	BEBIX
PTV	BALAN	VANAD	SECHE	SKESO	TUGLI
VEROS	LMG	AMB	AGN	DIN	BALPI
KUSOS	MAKOX	BALAN	TOU	GODAN	NARAK
VALKU	BRIVE	LMG	ROCAN	TERPO	GAI
ADATU	AULON	MAKOX	PUMAL	NTS	ROCAN

OLRAK	GAI	BRIVE	LORES	LUGEN	PUMAL
GONIM	ROCAN	AULON	LEPA	TUPAR	LORES
DEGOL	PUMAL	GAI		CGC	LEPA
LAPRO	LORES	ROCAN		VELIN	
PPG	LEPA	PUMAL		SECHE	
KANIG		LORES		AGN	
BGR		LEPA		TOU	
FEVIK				ROCAN	
SALON				PUMAL	
SADEM				LORES	
DUNES				LEPA	
SISMO					
KENAS					
LEPA					
Route M	**Route N**	**Route O**	**Route P**	**Route Q**	
EGCC	EGCC	EGCC	EGCC	EGCC	
HON	HON	HON	HON	HON	
COWLY	KIDLI	KIDLI	KIDLI	KIDLI	
MID	CPT	CPT	LINDY	CPT	
BOGNA	VAPID	VAPID	MID	PEPIS	
BENBO	GWC	GWC	BOGNA	SAM	
HAWKE	DRAKE	SITET	BENBO	ASPEN	
XAMAB	SITET	ETRAT	HAWKE	ORTAC	
VEULE	ETRAT	DVL	XAMAB	DIN	
BAMES	DVL	LGL	VEULE	GODAN	
RBT	LGL	AMB	BAMES	TERPO	
PTV	SORAP	BEBIX	RBT	NTS	
VEROS	BENAR	TUGLI	PTV	LUGEN	
KUSOS	VANAD	BALPI	NEV	TUPAR	
VALKU	AMB	NARAK	CFA	CGC	
ADATU	BALAN	GAI	MALEB	VELIN	
OLRAK	LMG	ROCAN	MOKDI	SECHE	
GONIM	MAKOX	PUMAL	MEN	AGN	
LAPRO	BRIVE	LEPA	AMLIR	TOU	
PPG	AULON		BADAM	ROCAN	
KANIG	GAI		NEKTA	PUMAL	
BGR	ROCAN		SIJAN	LEPA	
FEVIK	PUMAL		PPG		
SALON	LORES		KANIG		
SADEM	LEPA		BGR		
DUNES			FEVIK		
SISMO			SALON		
KENAS			SADEM		
LEPA			DUNES		
			SISMO		

			KENAS		
			LEPA		

Route 8: LIMC (Milan/Malpensa) to LICC (Catania/Sicily)

Route A	Route B	Route C
LIMC	LIMC	LIMC
PAR	LAGEN	PAR
LUPOS	ANAKI	LUPOS
FRZ	IXITO	FRZ
AMTEL	UNITA	AMTEL
BOL	KAFEE	BOL
PEMAR	KONER	PEMAR
LAT	MAURO	ALAXI
CIRCE	ELB	TEA
PNZ	GILIO	SOR
TAGEL	MEDAL	DELER
AMANO	TORLI	AMANO
VAKOR	PNZ	ROSAS
PELEN	TAGEL	PAL
COBBA	AMANO	INTER
LICC	VAKOR	LIBRO
	PELEN	LICC
	COBBA	
	LICC	

Route 9: LEPA (Palma de Mallorca) to EGCC (Manchester)

Route A	Route B	Route C	Route D	Route E	Route F	Route G	Route H
LEPA	LEPA	LEPA	LEPA	LEPA	LEPA	LEPA	LEPA
DRAGO	DRAGO	DRAGO	DRAGO	MEROS	GALAT	GALAT	GALAT
RES	RES	RES	RES	CHELY	ANTON	ANTON	ANTON
SELVA	SELVA	SELVA	SELVA	LUMAS	BISES	BISES	BISES
KARES	KARES	KARES	KARES	SOSUR	SADUR	SADUR	SADUR
ARBEK	ARBEK	ARBEK	ARBEK	SOFFY	CAVES	CAVES	ARBEK
REBUL	REBUL	REBUL	REBUL	MRM	ALIGA	ALIGA	REBUL
USKAR	USKAR	USKAR	USKAR	MTL	OKABI	OKABI	USKAR
MOPAS	MOPAS	MOPAS	MOPAS	ETREK	TOU	TOU	MOPAS
GIROM	GIROM	GIROM	GIROM	MADOT	FISTO	FISTO	GIROM
AGN	AGN	AGN	AGN	ATN	POKET	POKET	AGN
SECHE	SECHE	SECHE	SECHE	AVLON	TUPAR	TUPAR	SECHE
VELIN	VELIN	VELIN	VELIN	OKRIX	ANG	ANG	VELIN
CGC	CGC	CGC	CGC	CLM	SENLO	SENLO	CGC
ADILU	ADILU	ADILU	TUPAR	UTELA	KATHY	KATHY	MANAK
MANAK	MANAK	MANAK	ANG	KOPOR	EGKK	LUCCO	TIRAV
TIRAV	TIRAV	TIRAV	SENLO	KOMEL		AVANT	NTS
NTS	NTS	NTS	KATHY	ABSUD		MID	BAKUL
BAKUL	BAKUL	BAKUL	EGKK	GUBAR		EGKK	KOKOS
KOKOS	KOKOS	KOKOS		GURLU			KATHY
KATHY	KATHY	KATHY		EGKK			EGKK
EGKK	LUCCO	ELDER					
	AVANT	SAM					
	MID	EGKK					
	EGKK						

Route 10: LEPA (Palma de Mallorca) to EGCC (Manchester)

Route A	**Route B**	**Route C**	**Route D**	**Route E**	**Route F**	**Route G**
LEPA	LEPA	LEPA	LEPA	LEPA	LEPA	LEPA
MEROS	DRAGO	DRAGO	DRAGO	DRAGO	GALAT	DRAGO
CHELY	RES	RES	RES	RES	ANTON	RES
LUMAS	SELVA	SELVA	SELVA	SELVA	BISES	SELVA
SOSUR	KARES	KARES	KARES	KARES	SADUR	KARES
SOFFY	ARBEK	ARBEK	ARBEK	ARBEK	CAVES	ARBEK
MRM	REBUL	REBUL	REBUL	REBUL	OKABI	REBUL
MTL	USKAR	USKAR	USKAR	USKAR	TOU	USKAR
ETREK	MOPAS	MOPAS	MOPAS	MOPAS	FISTO	MOPAS
MADOT	GIROM	GIROM	GIROM	GIROM	POKET	GIROM
ATN	AGN	AGN	AGN	AGN	TUPAR	AGN
AVLON	SECHE	SECHE	SECHE	SECHE	ANG	SECHE
OKRIX	VELIN	VELIN	VELIN	VELIN	SENLO	VELIN
CLM	CGC	CGC	CGC	CGC	KATHY	CGC
UTELA	ADILU	ADILU	TUPAR	ADILU	AVANT	ADILU
KOPOR	MANAK	MANAK	ANG	MANAK	MID	MANAK
SOMIL	TIRAV	TIRAV	SENLO	TIRAV	OCK	TIRAV
NITAR	DEGEX	NTS	KATHY	NTS	HEMEL	KATHY
VESAN	ARE	KOKOS	LUCCO	BAKUL	BUZAD	LUCCO
RATUK	MUREL	KATHY	AVANT	KOKOS	WELIN	AVANT
SOVAT	SALCO	LUCCO	MID	KATHY	TNT	MID
SANDY	BHD	AVANT	OCK	LUCCO	EGCC	OCK
DET	DAWLY	MID	HEMEL	AVANT		HEMEL
BPK	TINAN	OCK	BUZAD	MID		BUZAD
POTON	TIVER	HEMEL	WELIN	OCK		WELIN
BEDFO	EXMOR	BUZAD	TNT	BPK		TNT
LESTA	NUMPO	WELIN	EGCC	POTON		EGCC
TNT	BCN	TNT		BEDFO		
EGCC	DIKAS	EGCC		LESTA		
	NITON			TNT		
	MONTY			EGCC		
	EGCC					
Route H	**Route I**	**Route J**	**Route K**	**Route L**	**Route M**	**Route N**
LEPA	LEPA	LEPA	LEPA	LEPA	LEPA	LEPA
TURIA	DRAGO	GALAT	DRAGO	GALAT	MEROS	MEROS
RIKOS	RES	BARUS	RES	BARUS	CHELY	CHELY
VLC	SELVA	ANTON	SELVA	ANTON	LUMAS	LUMAS
CLS	KARES	BISES	KARES	BISES	SOSUR	SOSUR
CMA	ARBEK	SADUR	ARBEK	SADUR	SOFFY	SOFFY
PPN	REBUL	CAVES	REBUL	CAVES	MRM	MRM
BLV	USKAR	OKABI	USKAR	OKABI	MTL	MTL

TUROP	MOPAS	TOU	MOPAS	TOU	ETREK	ETREK
NOVAN	GIROM	FISTO	GIROM	FISTO	MADOT	MADOT
POMTA	AGN	POKET	AGN	POKET	ATN	ATN
TERKU	SECHE	TUPAR	SECHE	TUPAR	AVLON	AVLON
ARE	VELIN	ANG	VELIN	ANG	OKRIX	OKRIX
MUREL	CGC	SENLO	CGC	SENLO	CLM	CLM
SALCO	ADILU	KATHY	TUPAR	KATHY	UTELA	UTELA
BHD	MANAK	LUCCO	ANG	LUCCO	KOPOR	KOPOR
DAWLY	TIRAV	AVANT	SENLO	AVANT	SOMIL	SOMIL
TINAN	NTS	MID	KATHY	MID	NITAR	NITAR
TIVER	BAKUL	OCK	LUCCO	OCK	VESAN	VESAN
EXMOR	KOKOS	BPK	AVANT	HEMEL	RATUK	RATUK
NUMPO	KATHY	POTON	MID	BUZAD	SOVAT	SOVAT
BCN	LUCCO	BEDFO	OCK	WELIN	SANDY	SANDY
DIKAS	AVANT	LESTA	BPK	TNT	WIZAD	LAM
NITON	MID	TNT	POTON	EGCC	DET	WELIN
MONTY	OCK	EGCC	BEDFO		BAKER	TNT
EGCC	HEMEL		LESTA		BPK	EGCC
	BUZAD		TNT		POTON	
	WELIN		EGCC		BEDFO	
	TNT				LESTA	
	EGCC				TNT	
					EGCC	

Route 11: ESSB (Stockholm/Arlanda) to LSZH (Zurich/Kloten)

Route A	**Route B**	**Route C**
ESSB	ESSB	TRS
DKR	NOSLI	PENOR
KOPIM	TONSA	KRT
LBE	REMKO	DEKUT
OSN	MIC	GUDIN
DOM	WRB	OKX
NOR	BOMBI	AGNAV
ARCKY	KRH	RUDNO
DIK	NATOR	MAMOR
GTQ	TRA	MAH
MIRGU	LSZH	KONIN
BLM		KPT
HOC		TRA
LSZH		LSZH

Route 12: LEMD (Madrid/Barajas) to EFHK (Helsinki/Vantaa)

Route A	**Route B**	**Route C**
LEMD	LEMD	LEMD
RBO	GASMO	CMA
GASMO	DGO	BCN
DGO	SOMOS	PIVUS
ABRIX	ADABI	SOSUR
ADABI	DEVRO	KOLON
BOKNO	BAMES	EVANO
DEVRO	ABUDA	LUSIL
VANAD	RATUK	BZO
VADOM	ODROB	DETSA
TSU	BUKUT	PUBEG
CTL	GOLUM	STO
ARDEN	AAL	HLV
LENDO	ARS	TUSIN
NOR	TEB	JED
USISI	SUNAS	DEDOL
OSDIK	EFHK	SUW
MOBSA		BOKSU
KEGAB		RIA
MABAS		SOKVA
KOKOR		TLL
KOSMO		PVO
MOSAT		EFHK
MALIV		
ALM		
PERRY		
KOTAM		
LAGIS		
KAL		
ALAMI		
RAMIM		
PEXEN		
EFHK		

Route 13: EGLL (London/Heathrow) to LGAV (Athens)

Route A	Route B	Route C	Route D
EGLL	EGLL	EGLL	EGLL
DVR	DVR	MID	BIG
KONAN	KONAN	XAMAB	SANDY
KOK	KOK	RESMI	ING
DIK	SPI	DJL	RANUX
PITES	WLD	PONSA	OBORN
KRH	MUN	ARLES	LUPEN
LAMGO	KFT	SRN	NATOR
ALGOI	DOL	PAR	USETI
MOGTI	BOSNA	VALEN	NEDOV
LIZUM	DISOR	VERNA	GARMO
ARNOS	FSK	PREKI	NEGRA
GILIN	TSL	PES	BAMUR
NEMEK	SKP	VIE	VEBEG
TUPUS	ATV	BRD	KUSAM
MONID	LGAV	KRK	SISDU
IDASI		VARDI	PITAR
SOLGU		ATV	BZO
GILUK		LGAV	NIVAS
GORAV			PUL
MODRA			SPL
KOGAT			KOFER
BUREK			YNN
PEP			ATV
TALAS			LGAV
ELPIS			
ABLON			
LGAV			