# Flight Trajectory Selection Impact on the Flight Cost

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***Abstract* — Airlines that exploit controlled airspace of EUROCONTROL Member States pay for the air traffic services they use. They are charged per flight, irrespective of the overflown States number. EUROCONTROL's Central Route Charges Office (CRCO) is responsible for collecting charges from the airspace users on behalf of the Member States. The CRCO calculates route charges based on the Member States imposed rates, taking into account provided services, collects them from the airspace users and distributes income to the States concerned. En-route charges are regulated at the EU level; however, each Member State has different overflight rates. Hence, a flight between two European cities can be less, or more expensive to the airline, depending on the chosen trajectory. The goal of this article is to perform an analysis of the flight trajectory impact on the total flight cost, from the airlines' perspective.**

## I. Introduction

Currently, we are living in a society where we hear about saving money, costs reduction everywhere; and aviation is not an exception. Hence, by this article, the authors intend to emphasize how proper flight planning can positively impact total flight cost and consequently, reduce expenses for the airlines. Overflying the different EUROCONTROL Member States means different route charges, thus, the analysis comparing 2 flights between the same airports but via different countries with an impact on the flight cost is part of this article. The analysis in this article does not include the unavoidable situations, e.g. the ATC strikes, weather conditions; this will be a subject of the further analysis to be included in a dissertation work dealing with the safety and civil route network optimization.

## II. EUROCONTROL Central Route Charges Office (CRCO) [5]

The EUROCONTROL CRCO is located at EUROCONTROL's headquarters in Brussels. CRCO operates a cost-recovery system of air traffic management (ATM) services, available to airspace users. The CRCO was established in 1971 with a purpose to operate a centralised system for the collection of route charges. At that time, there were 7 EUROCONTROL Member States that decided to adopt a common policy for en-route charging; later on, they created a joint system for the establishment, billing, and collection of en-route charges, and used EUROCONTROL principles for these purposes.

The decision-making body governing en-route charges is the enlarged Commission for Route Charges; this Commission consists of the Ministers of Transport of the Member States or their alternates. It determines the principles for recovering the costs incurred by States in respect of en-route services and also determines the common rules for calculating route charges. The enlarged Committee for the Route Charges, consisting of Member States' representatives at senior level, it is the executive body supervising the operation of the system and preparing the decisions of the enlarged Commission.

The unit rates are approved by the enlarged Commission. The CRCO of EUROCONTROL has the responsibility to operate the common route charges system on behalf of the EUROCONTROL Member States.

### *A. Route Charges System*

The costs of air traffic management (ATM) services in Europe are funded through air navigation charges. ATM services are funded on the "user pays principle". All States' Air Service Navigation Providers (ANSPs) who are participating in the Route Charges System recover the cost for facilities and services provided to airspace users by means of route charges. Route charges are collected for each flight, performed in the airspace under the responsibility of the Contracting States.

The airspace is divided into charging zones; this division depends on individual states. The cost-base for route charges and the calculation of the unit rates of their charging zones are established following the EUROCONTROL principles. These costs form the basis of route charges. A unit rate established for each charging zone is expressed in euro and consists of two parts:

- the unit rate, obtained by dividing the en-route facility forecast cost-base of the charging zone concerned for the reference year by the forecast number of service units to be generated in the airspace of that charging zone during the same year;

- the administrative unit rate, whose purpose is to recover the costs of collecting route charges (CRCO costs). It is obtained by dividing these costs by the number of service units generated in the EUROCONTROL charging area as a whole. The component of the unit rate representing the CRCO costs is therefore identical in all charging zones.

The unit rates are applicable as from the 1$^{st}$ January of each year.

Aircraft operators (AO) are charged a single amount per flight while the number of States overflown is not taken into account. The bills for AOs are issued by the CRCO; CRCO is using flight messages sent by the Contracting States' Route Charges Offices

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(RCOs) and additional flight information made available via the EUROCONTROL Network Manager Directorate (NMD). The CRCO bills aircraft operators monthly, collects charges and distributes the amounts collected to the States and service providers at their request, or every week. Financial and operational reporting is permanently available.

## III. FLIGHT COST CALCULATION

For route charge calculation, the authors have used 3 basic elements: 0

### *A. Distance Factor (X)*

This factor is obtained by the following equation:

*X = Kilometres between the aerodrome of departure (or entry point of the charging zone) and the aerodrome of arrival (or exit point of the charging zone) /100* (1)

This equation is applied to each charging zone overflown.

### *B. Aircraft Weight Factor (Y)*

This factor is determined by dividing the maximum take-off weight (MTOW) of the aircraft by 50 and subsequently, taking the square root of the result rounded to the second decimal.

$$Y = \sqrt{\frac{MTOW}{50}} \tag{2}$$

In this article, the authors use Airbus A320 as an example. MTOW of this aircraft is 77 metrical tonnes. This number will be used in further calculations.

### *C. Unit Rate of Charge*

The unit rate of charge is the charge in euro applied in a charging zone to a flight operated by an aircraft of 50 metric tonnes and for a distance factor of 1.00. The unit charges are applicable as from the 1st of January of each year. The unit rate of charge is different for each State. The individual charges for each EUROCONTROL Member State are available on the following website:

***https://www.eurocontrol.int/services/monthly-adjusted-unit-rates***

It is important to mention that these charges are updated on a monthly basis; during the analysis, the charges for March 2019 were taken into account.

The result obtained when multiplying these 3 elements gives us the route charge per charging zone. This operation must be repeated for each charging zone overflown.

## IV. ANALYSIS OF FLIGHT TRAJECTORIES

This paper provides an analysis of 2 flight trajectories impact on the total flight cost by using the equations/information as provided in *Chapter III*. For the analysis the authors have decided to compare the following trajectories:

1. **Flight Athens – Munich**
- Departure aerodrome: Athens LGAV
- Arrival aerodrome: Munich EDDM
- Date: 27th of March
2. **Flight Munich – Athens**
- Departure aerodrome: Munich EDDM
- Arrival aerodrome: Athens LGAV
- Date: 27th of March

Both flights are operated between the same 2 city airports; the difference between the flights is that they are crossing different countries. This will allow authors to compare how the route charges applied in different States impact the price of the flight.

### *A. Flight 1: LGAV-EDDM (crossing Italian airspace)*

This flight (depicted in Figure *1* below) took place on 27th of March 2019 and crossed the following States:

*Greece, Albania, Croatia, Slovenia, Italy, Austria and Germany*

The route according to the Flight Plan was as follows:

N0459F400 PIKAD UL53 GARTA UV60 YNN UL611 TUMBO DCT RODON DCT DETSA DCT BRENO M726 KOGOL

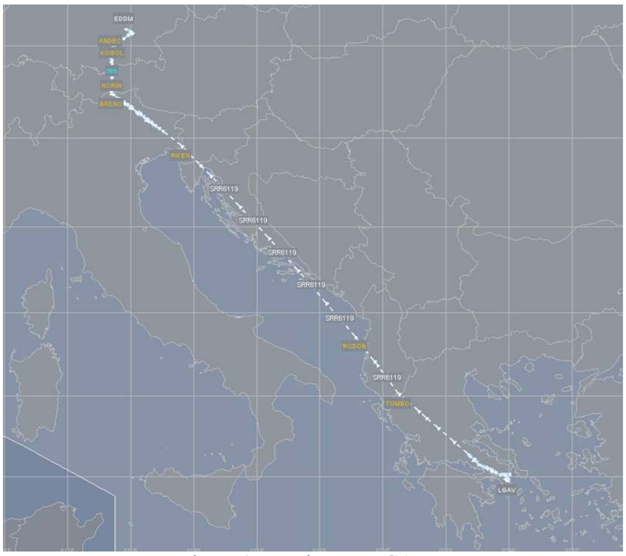

Figure 1. Trajectory LGAV-EDDM

Based on the route described above, for further calculations, the authors used the defined points in ICAO Flight Plan and summarized them into the table below together with their coordinates and Free Route Airspace (FRA) [1]relevance. FRA relevance of all points was added since this flight penetrated some FRA airspaces; these calculations will be also used in future dissertation work.

[1] *Free route airspace (FRA) is a specified airspace within which users can freely plan a route between a defined entry point and a defined exit point, with the possibility of routing via intermediate (published or unpublished) waypoints, without reference to the air traffic services (ATS) route network, subject of course to availability. Within such airspace, flights remain subject to air traffic control. [2]*

TABLE I.
Flight 1 Route: Points - ICAO Codes, Coordinates and FRA Relevance

| ICAO Code | Coordinates | FRA Relevance[2] |
|---|---|---|
| LGAV | 37° 56′ 11″ N | N/A |
| | 23° 56′ 40″ E | |
| PIKAD | 38° 03′ 41″ N | |
| | 22° 41′ 52″ E | N/A |
| GARTA | 20° 58′ 06″ E | N/A |
| | 20° 58′ 06″ E | |
| TUMBO | 40° 04′ 02″ N | N/A |
| | 20° 28′ 22″ E | |
| RODON | 41° 27′ 30″ N | F (EX) |
| | 19° 06′ 00″ E | |
| RIFEN | 45° 51′ 04″ N | FRA (EXAD) |
| | 13° 35′ 23″ E | |
| DETSA | 19° 06′ 00″ E | FRA (E) |
| | 12° 16′ 52″ E | |
| BRENO | 46° 58′ 48″ N | FRA (EX) |
| | 11° 22′ 36″ E | |
| NORIN | 47° 23′ 11.77″ N | N/A |
| | 11° 24′ 08.27″ E | |
| KOGOL | 47° 37′ 20″ N | FRA (I) |
| | 11° 23′ 59″ E | |
| EDDM | 48° 21′ 14″ N | N/A |
| | 11° 47′ 10″ E | |

Based on the coordinates, the authors calculated the approximate distances that were overflown over individual States. By knowing the distances over each State, we could use the formula for calculation of the distance factor (X). The distances and distance factors are summarized in *TABLE II.* below.

TABLE II.
Flight 1 Route: Distance Factor

| | | | |
|---|---|---|---|
| Greece | 382,2 KM | Distance Factor | 3,82 |
| Albania | 193,1 KM | Distance Factor | 1,93 |
| Croatia | 659,3 KM | Distance Factor | 6,593 |
| Italy | 211 KM | Distance Factor | 2,11 |
| Austria | 45,25 KM | Distance Factor | 0,4525 |
| Germany | 111,3 KM | Distance Factor | 1,113 |

Now when the distance factors are known, to finalize the calculations, the only needed information is to find out the route charges per each State. The MTOW of the aircraft was 77 metric tonnes (as defined above).

The Route Charge for each zone overflown is calculated as a multiplication of 3 elements (distance factor, MTOW, unit rate of charge):

*Greece:* 3,82 x 1,24 x 30,45 = 144,236 EUR
*Albania:* 1,93 x 1,24 x 49,05 = 117,386 EUR
*Croatia:* 6,593 x 1,24 x 42,26 = 354,489 EUR
*Italy:* 2,11 x 1,24 x 77,96 = 203,975 EUR
*Austria*: 0,4525 x 1,24 x 67,74 = 38,010 EUR
*Germany:* 1,113 x 1,24 x 63,63 = 87,817 EUR

**The total price:** 945,913 EUR

*B. Flight 2: EDDM- LGAV (not crossing Italian airspace)*

This flight (depicted in *Figure 2* below) was operated on 27th of March 2019 and crossed the following States:

*Germany, Austria, Slovenia, Croatia, Bosnia and Hercegovina, Montenegro, North Macedonia and Greece*

The route according to the Flight Plan was as follows:
N0455F390 VAVOR M867 VAROB DCT NEMEK DCT MEDUX UM867 KOGAT DCT TALAS UM749 SKP B1 ABLON

[2] *FRA Relevance of the significant points is published in the States' AIP by the following letters and published within brackets:[1]*
*(E), for "FRA Horizontal Entry Point"*
*(X), for "FRA Horizontal Exit Point"*
*(I), for "FRA Intermediate Point"*
*(A), for "FRA Arrival Connecting Point"*
*(D), for "FRA Departure Connecting Point"*


Figure 2. Trajectory EDDM-LGAV

For the calculations, the authors used the same methodology as in the previous example.

TABLE III.
Flight 2 Route: Points - ICAO Codes, Coordinates and FRA Relevance

| ICAO Code | Coordinates | FRA Relevance |
|---|---|---|
| EDDM | 48° 21′ 14″ N | N/A |
| | 11° 47′ 10″ E | |
| VAVOR | 47° 56′ 03″ E | |
| | 12° 09′ 16″ E | N/A |
| VAROB | 47° 37′ 34.63″ N | FRA (EX) |
| | 12° 32′ 19.05″ E | |
| BERTA | 46° 26′ 58.95″ N | FRA (IAD) |
| | 14° 37′ 30.85″ E | |
| NEMEK | 45° 34′ 29″ N | F (I) |
| | 15° 17′ 53″ E | |
| MEDUX | 42° 44′ 51″ N | FRA (X) |
| | 20° 01′ 19″ E | |
| KOGAT | 42° 06′ 45″ N | N/A |
| | 21° 03′ 20″ E | |
| TALAS | 41° 04′ 36″ N | N/A |
| | 21° 55′ 00″ E | |
| ABLON | 38° 10′ 10″ N | N/A |
| | 23° 44′ 08″ E | |
| LGAV | 37° 56′ 11″ N | N/A |
| | 23° 56′ 40″ E | |

The distances and distance factors are summarized in the *TABLE IV.* below.

TABLE IV.
Flight 2 Route: Distance Factor

| | | | |
|---|---|---|---|
| Germany | 98,04 KM | Distance Factor | 0,9804 |
| Austria | 205,2 KM | Distance Factor | 2,052 |
| Slovenia | 110 KM | Distance Factor | 1,10 |
| Croatia | 122,65 KM | Distance Factor | 1,2265 |
| Bosnia and Hercegovina | 245,3 KM | Distance Factor | 2,453 |
| Montenegro | 122,65 KM | Distance Factor | 1,2265 |
| North Macedonia | 135,6 KM | Distance Factor | 1,356 |
| Greece | 394 KM | Distance Factor | 3,94 |

To finalize the calculations, the only needed information was to find the route charges per each State. The MTOW of the aircraft was 77 metric tonnes (as defined above).

The Route Charge for each zone overflown is calculated as a multiplication of 3 elements (distance factor, MTOW, unit rate of charge):

*Germany:* 0,9804 x 1,24 x 63,63 = 77,355 EUR
*Austria:* 2,052 x 1,24 x 67,74 = 172,363 EUR
*Slovenia:* 1,10 x 1,24 x 59,51 = 81,172 EUR
*Croatia:* 1,2265 x 1,24 x 42,26 = 64,272 EUR
*Bosnia and Hercegovina:* 2,453 x 1,24 x 34,61 = 105,274 EUR
*Montenegro:* 1,2265 x 1,24 x 29,36 = 44,652 EUR
*North Macedonia:* 1,356 x 1,24 x 45,02 = 75,699 EUR
*Greece:* 3,94 x 1,24 x 30,45 = 148,767 EUR

**The total price:** 769,554 EUR

## V. CONCLUSIONS

As mentioned above, each State can define its route charge. In March 2019, Italy was the country with the highest route charges in Europe, namely 77,96 EUR. Hence, the authors were intentionally focusing on the trajectory that crosses Italy to be able to compare the impact of these charges on the flight costs. The results of the analysis show that the flight cost for the first flight (overflying Italy) was 945,913 EUR while the flight cost for the second flight was 769,554 EUR.

From the analysis of the first flight, it can be concluded that the part that was overflown over Italy had a significant impact on the total flight cost; an aircraft overflew approximately 211 km over Italy which costed airline 203,975 EUR while overflying Greece costed 144,236 EUR although a distance was much bigger, i.e. 382,2 km.

Hence, if the distance and price per distance are compared, it is visible that they are not mutually proportional and, route charges applied in different countries have a significant impact on flight costs.

From the analysis of the second flight (which was not operated over Italy), it can be concluded that also the distances and prices for these distances are not proportional. It is visible that a price is lower due to avoiding Italian airspace but e.g. a distance overflown in Greece 394 km cost 148 EUR while distance overflown in Austria 205 km cost 172 EUR.
Therefore, from authors' point of view it is very important to plan the route well in advance and to consider different trajectories if the goal of the airlines/aircraft operators is to reduce the costs.
This paper provided an analysis of flight trajectory selection impact on the flight cost however, the situations when the flights are deviated due to reasons such as ATC strikes, permanently closed airspaces, bad weather, etc. are not included. Recently the amount of these unavoidable situations is growing which consequently causes delays, leads to higher fuel consumption and results in growing costs for the airlines. The analysis of flight deviations due to the weather conditions or strikes would require further investigation of real cases and examples from practice. The further plan would be to analyze the deviations as mentioned above and their impact, to include the results into a dissertation work which will raise the subject of a safety and civil route network optimization.


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