ICAO Carbon Emissions Calculator
Version 5
June 2012

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1 Introduction

This document presents a general methodology developed for estimating the amount of carbon emissions (CO_2) generated by a passenger in a flight, for use in carbon offsetting programmes.

It provides information on the methodological approach and details the assumptions underlying the generic factors employed by the ICAO Carbon Emissions calculator. The methodology is provided in an open source format facilitating individual air carriers that may wish to customize it with their own data.

The document includes a general description of the method adopted by ICAO in order to estimate the CO_2 emissions of a flight (Item 2); the detailed calculation process implemented by the ICAO Calculator (Item 3); a description and analysis of the data inputs used (Item 4); a demonstration of the data coverage and sensitivity (Items 5 and 6); and the steps needed to be taken by a company wishing to customize the calculator with its own data set (Item 7).

2 Methodological Approach

The ICAO methodology employs a distance-based approach to estimate an individual's aviation emissions using data currently available on a range of aircraft types. In order to implement this methodology, ICAO uses the best publicly available data regarding fuel consumption and it is committed to continuously monitor and seek improvements in the data used, in order to obtain better emissions estimation.

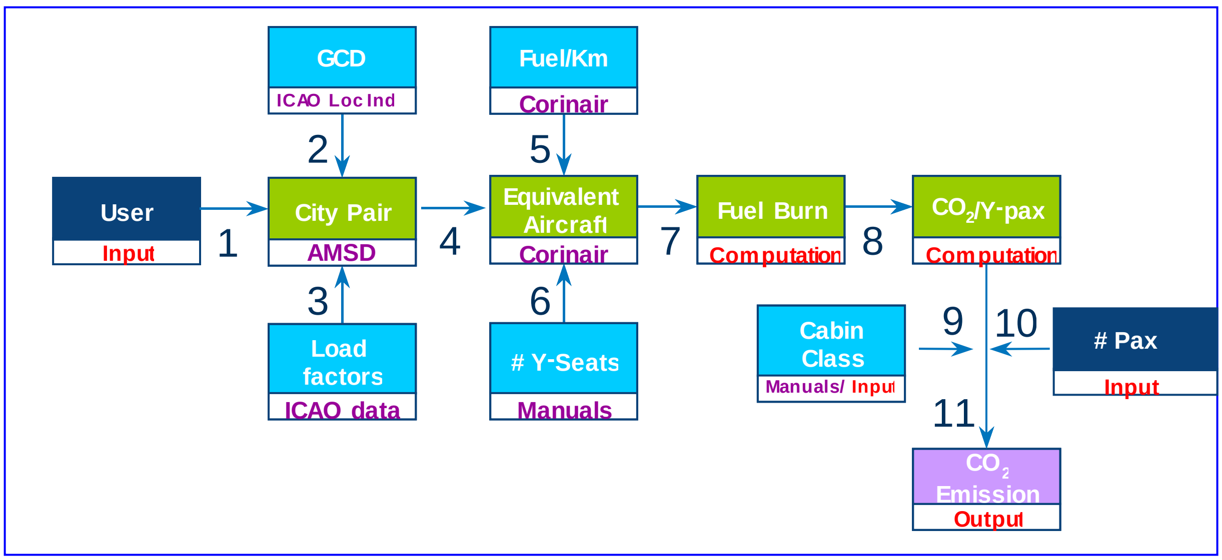
The ICAO methodology has been designed to require a minimum amount of input information from the user regarding the particulars of the flight concerned. It employs industry averages for the various factors which contribute to the calculation of the emissions associated with the individual passenger's air travel. As passengers' aviation emissions are affected by continuously changing variables specific to each flight, it is necessary to develop average factors to account for the effect of these flight parameters. While these factors cannot be captured on a flight-specific basis, this methodology considers them for the purpose of developing a more robust estimation of flight emissions and educating the public and the industry as to how these factors affect an individual passengers' emission intensity.

2.1 General Description of the Methodology

The ICAO Carbon Emission Calculator requires that the user input the airports of origin and destination for a direct through flight (i.e. a flight which does not have a change of the flight number). This is then compared with the published scheduled flights to obtain the aircraft types used to serve the two airports concerned and the number of departures per aircraft. Each aircraft is then mapped into one of the fifty equivalent aircraft types in order to calculate the fuel consumption for the trip based on the great circle distance between the airports involved in the journey. The passenger load factors, and passenger to cargo ratios, obtained from traffic and operational data collected by ICAO, are then applied to obtain the proportion of total fuel used which can be attributed to the passengers carried. The system then calculates the average fuel consumption for the journey weighted by the frequency of departure of each equivalent aircraft type. This is then divided by the total number of economy class equivalent passengers, giving an average fuel burn per economy class passenger. The result is then multiplied by 3.157 in order to obtain the amount of CO_2 footprint attributed to each passenger travelling between those two airports.

3 Calculation Procedure

ICAO used this methodology to develop a Carbon Emissions Calculator using a database constructed from several data sources. From the diagram below, we identify the following information used as input to the calculator:



City Pair: Obtained from the airlines multilateral schedules database (AMSD). The flight schedule data are based on the latest available information and are updated annually.

GCD (Great Circle Distance): The distance between origin and destination airports is derived from latitude and longitude coordinates originally obtained from ICAO Location Indicators database.

Load Factors: The average generic factors considered for the purpose of this calculation are sourced from the Traffic by Flight Stage database (TFS) which collects air carrier city-pair specific traffic data by aircraft type produced on an annual basis, and domestic traffic and operational data, both collected by ICAO, as well as data based on the flight schedules published by the air carriers.

Fuel/Km: This information, per equivalent aircraft model, is obtained from the CORINAIR database, and expanded by ICAO to reflect the fuel consumption of regional jets.

Y-seats: This is the number of economy seats that can be fit inside the equivalent aircraft. ICAO made use of a standard cabin layout (in terms of location of galleys, toilets and exits) for each reference aircraft. This fixed space was then fitted with an all-economy seating using a pitch of about 31/32 inches (79/81 cm). This seating configuration was then compared with a mixed configuration involving business and/or first class row/seat combinations where, for the large wide bodied aircraft, business class seats have a 38 inch pitch, and those in first class have a 60 inch pitch. Examples of these layouts were obtained from the Manual on Airplane Characteristics for Airport Planning published on the Web by the aircraft manufacturers.

In simple terms, the general methodology used by the ICAO calculator can be described with the following steps, with references to the diagram above:

User input (1) – The user enters the origin and destination airports. The database is searched for all flights, direct or non-direct, serving that city-pair. However, the tool does not compute total emissions for journeys with different flight numbers (connecting flights). To do this, the user can choose to build a total by calculating each of the journey legs separately and adding them up.

Code share flights are treated as a single flight. This avoids a possible double counting of flight departures that would otherwise affect the calculations.

The origin and destination database includes individual routings for single flight numbers with multiple stops. Hence the passenger does not need to know, nor input the full itinerary of the flight.

Trip distance (2) – The ICAO Location Indicators database contains the longitude and latitude coordinates for the airports. From these coordinates the Great Circle Distance (GCD)[1] is then calculated and corrected by a factor depending on the distance between the two airports concerned (see section 4.2).

Traffic data (3) – A passenger load factor is assigned to the user-defined city-pair, based on the passenger load factor for the corresponding route groups. Load factor information is obtained from the database, based on 17 international route groups plus 5 domestic areas (see **Appendix A**).

Aircraft mapping (4) – From the scheduled flights database, the scheduled aircraft is identified and linked to the aircraft fuel consumption database EMEP/CORINAIR. When the scheduled aircraft is not in the database, the aircraft is mapped into one of the fifty equivalent aircraft types existing in the aircraft fuel consumption database. **Appendix B** provides details of how this mapping was done. This allows estimation of the total fuel use on each route serving the user-defined city-pair.

Fuel burn data (5) – The fuel burn to flight distance relationship is extrapolated from the Emissions Inventory Guidebook (EIG) prepared by EMEP/CORINAIR. The factors considered include passenger load factor, flight distance, the proportion of the overall payload represented by passenger traffic, cabin class flown, and type of equivalent aircraft

[1] The Great Circle Distance it is the shortest path betw een tw o points on the surface of a sphere

flown. The amount of fuel used on a route is the weighted average of total fuel burnt based on the frequencies of the scheduled aircraft types flown.

Economy Class (Y) seat capacity (6) – From cabin floor plans obtained from the "Manual on Airplane Characteristics for Airport Planning", which is developed by manufacturers to provide necessary data to airport operators and airlines for airport facilities planning, the maximum number of Y-seats that can be fitted per equivalent aircraft is determined. This "virtual" all economy configuration later allows the computation of cabin class factors (steps 9 & 10).

CO_2 per economy passenger (7 and 8) – Using the trip distance, equivalent aircraft fuel consumption, passenger to seat load factor and passenger to freight load factor for the route group, and the number of Y-seats, the methodology calculates the CO_2 associated to each passenger, as follows:

CO_2 per pax = 3.157 * (total fuel * pax-to-freight factor)/(number of y-seats * pax load factor)

Where:

Total fuel = The weighted average of the fuel used by all flights departed from the origin airport in order to reach the destination airport. The weighting factor is the ratio of number of departures for each equivalent aircraft type, to the total number of departures.

Pax-to-freight factor = is the ratio calculated from ICAO statistical database based on the number of passengers and the tonnage of mail and freight, transported in a given route group.

Number of Y-seats = the total number of economy equivalent seats available on all flights serving the given city pair.

Pax load factor = the ratio calculated from ICAO statistical database based on number of passengers transported and the number of seats available in a given route group.

3.157 = constant representing the number of tonnes of CO_2 produced by *burning* a tonne of aviation fuel.

Cabin class (9 and 10) – Depending on user selection, a multiplicative cabin class factor is applied to adjust the CO_2 per Y-passenger, on those routes where multiple class passenger services are available.

Passenger CO_2 output (11) – The estimated quantity for the carbon emission.

4 Data Sources

This methodology seeks to distribute the emissions between the passengers travelling in different cabin classes, and between passengers and cargo, in an equitable manner. This section details how the various contributing factors come together to accomplish this result.

4.1 Fuel Data

In keeping with the latest recommendations of the IPCC contained in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, a modified Tier 3A method is used which is based on actual movement data. The 2006 Guidelines suggest the EMEP/CORINAIR Emission Inventory Guidebook[2] (EIG) as the base of commercial aviation fuel burn and emission information. The Guidebook includes an accompanying workbook which details fuel burn and emissions associated with discrete mission distances for 44 equivalent aircraft types. CORINAIR fuel database uses modelled data derived from the aircraft performance model PIANO[3]. It uses equivalent aircraft types and, due to the age of the study, lacks fuel data for the more recent aircraft types and their derivatives.

In order to implement the methodology, the database used by ICAO takes the fuel burn to distance flown data provided by CORINAIR and extends some aircraft ranges by extrapolation using a linear regression. This approach was chosen since the fuel consumption curve approaches a linear relationship to distance when considering medium and long haul flights. ICAO also expanded the data by adding fuel burn information, provided by the manufacturers, for 6 regional jets.

While the main objective of CORINAIR is to support the development of National GHG Inventories, this methodology seeks to allocate a proportion of emissions associated with a given equivalent aircraft type operating between given city pairs to individual passengers. In this context, it is considered appropriate to use CORINAIR data as long as the CO_2 calculation is performed on an average fleet basis per city pair and not on an individual aircraft basis, and noting that in many cases the calculation is near ±10%. This variation in data is largely due to the aircraft models currently included in CORINAIR and mapping these aircraft to the actual operating aircraft models not included in CORINAIR[4].

While it is well known that most air carriers have detailed information in regards to their fuel consumption and fuel efficiency, this information is not publicly available. At present, it was not possible to identify any suitable public alternative data source, making CORINAIR the best publicly available data source for the purpose of the ICAO methodology.

The dataset obtained from the modified CORINAIR, listing the 50 equivalent aircraft data, is included in **Appendix C** of this document.

[2] EMEP/CORINAIR Emission Inventory Guidebook (http://reports.eea.europa.eu/EMEPCORINAIR4/en/page002.html)
[3] http://www.lissys.demon.co.uk/.
[4] For example, to model a B737, CORINAIR contains two choices of older models, the B737-100 and B737-400. For some city pairs this may adequately model the specific aircraft servicing the city pair. However, on other city pair routes that operate mainly newer more fuel-efficient B737 models (B737-600/700/800/900) CORINAIR would overestimate the fuel burn and CO2 production

4.2 Trip distance

The methodology proposes the use of the Great Circle Distance (GCD) between the input airports, in order to get the fuel used, and thus estimate the CO2 emissions.

GCD is by definition the shortest distance between two points on the surface of a sphere. This distance can be calculated by using the geographical coordinates of the two points concerned. The coordinates for the airports involved are obtained from the ICAO Location Indicators database. Once the GCD is calculated, it is then corrected by a factor depending on the distance between the two airports concerned.

The correction factor is needed in order to include the emissions of distance flown in excess of the GCD, stacking, traffic and weather-driven corrections. According to EIG, the actual distance flown compared with GCD that is given in the scheduled flights timetable may vary up to 11% in Europe (ANCAT/EC2 1998).

Stopovers, connecting flights and refuelling stops impact on the overall flight distance as they divert from the straight line representing the GCD. The implementation of the ICAO methodology, carried by ICAO to calculate the trip distance takes into account the additional mileage resulting from stopovers and refuelling stops associated with a sequence of flights identified by a single flight number. However, for a sequence of flights with different flight numbers (connecting flights) the trip distance is calculated separately for each individual flight segment.

The table below shows the GCD correction factor used.

GCD	Correction to GCD
Less than 550 Km	+ 50 Km
Between 550 Km and 5500 Km	+ 100 Km
Above 5500 Km	+ 125 Km

4.3 Aircraft type

The CO_2 emission is calculated from the fuel burned by the aircrafts serving a given route. The scheduled aircraft is identified from the scheduled flights database, and mapped into one of the fifty equivalent aircraft types existing in the aircraft fuel consumption database (**Appendix C** provides details of how this mapping was done). The aircraft types, that cannot be mapped, are excluded from the calculations. Leaving out aircraft types or variants that are not in the database would at present only have a minor influence on the final result.

4.4 Passenger Load Factors and Passenger to Cargo Factor

As this methodology is intended to assess the passenger's aviation emissions it is necessary to deduct the flight emissions associated with the freight and mail carried on the flight from the total. This calculation will be performed on a revenue mass basis using historic freight and mail numbers specific to the city-pair being considered.

The data are sourced from the ICAO TFS dataset which contains totals of number of seats and passengers, tonnes of freight, and tonnes of mail carried. In order to develop an average freight allocation an average passenger mass with baggage is assumed as 100 Kg, plus a 50 Kg add-on to account of the onboard equipment and infrastructure associated with passenger use (for example, the weight of seats, toilets, galleys and crew). The total mass is then established as:

[((No. Passengers*100Kg) + (No. of seats * 50 Kg))/1000] (tonnes) + Freight (tonnes) + Mail (tonnes)

Based on the historical traffic data it is then possible to establish the proportion of freight and mail mass in relation to the total mass calculated by the formula above. The resulting proportion is the fraction of the flight emissions for which the passengers should not be held accountable for. The TFS data is updated annually by ICAO for each one of the 17 international route groups (see **Appendix A**).

4.5 Cabin class

The cabin class correction factor is used only on equivalent aircraft types that support such differentiation, and on flights of more than 3,000 Km. It is based on the principle that premium seats occupy a larger space than that of an economy seat; therefore the same cabin configured with premium seat arrangements carries fewer passengers than an all-economy layout.

In order to define the cabin class correction factor, each representative aircraft has been assigned a standard all-economy class layout so that the reduced capacity resulting from the larger space occupied by premium seating and the associated increase in per-passenger emissions is accounted for. This cabin class correction factor is based on the principle that premium seats occupy a larger footprint than that of an economy seat; therefore the same cabin configured with premium seat arrangements carries fewer passengers than an all-economy layout. While it is not possible to account for all possible configurations of a given aircraft the cabin class correction factor serves to educate the user as to the environmental effect of their travel decisions. For this reason generic cabin class factors have been estimated.

The methodology employs a simplified approach by using two cabin class factors (“economy” and “premium”) when allocating emissions to passengers, with a ratio of 1:2.

5 Discussion of Sensitivities

In any modelling exercise the desire for accuracy is moderated by the level of complexity the analyst is willing to accommodate. In the case of the ICAO methodology, an attempt has been made to account for the principal factors which define an individual’s aviation carbon emission footprint while assessing each at a level which recognizes the inherent uncertainty underlying many of the assumptions embedded in this approach.

Great Circle Distance – while it is understood that air travel does not occur in a straight line between two points, actual flown distance to be collected from the air carriers, or from a more accurate trip distance database showed to be not feasible for the time being.

Representative Aircraft – as aircraft typically share similar performance characteristics, if designed for similar operation, the adoption of a representative aircraft approach is both necessary and reasonable given the level of detail available. It is recognized that the CORINAIR data lacks representation for several aircraft types. It is also recognized that there are considerable differences in fuel consumption between aircraft belonging to the same aircraft type variant, dependent on many factors such as age and airline specific configuration, including engines. However, at present, it was not possible to identify any suitable public alternative data source making CORINAIR the best publicly available data source for the purpose of the ICAO methodology.

Cabin Class Factor – this recognizes that several seat configurations can be offered, and the different classes of service among air carriers. The ICAO Carbon Emissions calculator does not use a specific aircraft configuration; instead, it uses the equivalent aircraft approach that represents the actual equipment in use. Due to the general nature of this methodology, it was decided to use a simplified approach, restricting the cabin classes to two: one representing the economy class, and the other representing the premium classes (premium-economy, business, and first).

Passenger Load Factor – average passenger load factors are calculated on a route group basis for international flights and on a regional basis for domestic flights. The data are obtained from the reported data sent by States to ICAO, and it tends to change with every annual update.

Passenger to Cargo Factor – average cargo factors on passenger aircraft are calculated on a route group basis for international flights and on a regional basis for domestic flights. The data is obtained from the reported data sent by States to ICAO, and it tends to change with every annual update.

Fuel consumption per aircraft type – throughout the design of this tool, the intention was to default to the best publicly available information. While it is well known that most air carriers have detailed information in regards to their fuel consumption and fuel efficiency, this information is not publicly available. At present, it was not possible to identify any suitable public alternative data source making CORINAIR the best publicly available data source for the purpose of the ICAO methodology.

6 Maintenance Requirements of the ICAO Methodology

In order to support the continued improvement and adoption of the ICAO methodology various data components will require a regular update by ICAO and be provided to users seeking to implement the ICAO methodology. These include:

ICAO traffic data – to be analyzed and updated on an annual basis.

Air carriers scheduled data – In order to calculate the composite city emissions city-pairs data are to be updated on an annual basis to reflect the schedules operated by the air carriers during the period.

Generic Aircraft Mapping – To account for changes in the equipment operating in the industry ICAO will complete a review of the aircraft types listed in the scheduled flights database and the TFS and publish a reference document showing the corresponding mapping to representative aircraft type for all in service aircraft type.

Aircraft Fuel consumption – In order to keep up to date information about new aircrafts types and technology improvements adopted by the industry, ICAO will update the fuel per kilometre information for the several aircraft equivalent models, as soon as new information is made available by aircraft manufacturers and air carriers.

7 Options for Carrier Specific Accuracy Improvements

As ICAO recognizes the additional benefits, which more detailed air carrier specific data can provide, the ICAO methodology is intended to be open source for carriers that are considering their own offset programmes and able to receive enhancements to the quality of data employed for the calculations. Possible carrier specific improvements include:

Fuel Burn – Given the air carriers flight planning requirements in terms of efficiency and safety it is anticipated that air carriers will be interested in employing more robust data to the fuel consumed on their operated flights.

Cargo Carried – An air carrier may use its own cargo factor so long as the level of aggregation is provided in accompanying documentation.

Passenger Load Factor – An air carrier may use their own passenger load factor so long as the level of aggregation is clear in accompanying documentation.

Aircraft Configuration – On account of the generic nature of this methodology an air carrier may wish to implement fleet specific data on the aircraft operated in its service.

Appendix A

Factors per Route Group

Version 5 data are based on traffic during calendar year 2010.

Route Groups		Pax Load Factors		Pax to Freight Factors	
		Wide Body	**Narrow Body**	**Wide Body**	**Narrow Body**
1	Between North America and Central America/Caribbean (NC)	81.72%	77.82%	91.64%	99.05%
2	Between and within Central America and the Caribbean (LC)	65.56%	76.30%	89.37%	99.54%
3	Between Bermuda, Canada, Mexico and the United States (LNM)	73.44%	76.16%	93.69%	99.38%
4	Between North Am/Central Am/Caribbean & South America (NCS)	79.74%	73.38%	84.72%	98.13%
5	Local South America (LS)	68.80%	74.30%	98.06%	98.51%
6	Local Europe (LE)	69.07%	73.96%	88.72%	99.00%
7	Local Middle East (LM)	66.69%	61.41%	83.66%	97.71%
8	Local Africa (LA)	56.81%	66.14%	87.03%	94.91%
9	Between Europe and Middle East (EM)	72.96%	70.75%	75.73%	97.76%
10	Between Europe /Middle East and Africa	76.18%	73.98%	79.68%	98.98%
11	North Atlantic	82.89%	83.55%	81.32%	98.12%
12	Mid Atlantic	81.42%	81.03%	89.03%	88.58%
13	South Atlantic	84.03%	77.70%	85.93%	88.38%
14	Local Asia	68.98%	69.25%	81.37%	95.87%
15	Between Europe/Middle East/Africa and Asia	75.91%	69.25%	76.95%	98.94%
16	North & Mid Pacific	83.69%	78.30%	84.53%	83.92%
17	South Pacific	82.49%	75.09%	94.70%	98.01%

Appendix B - Equivalent Aircraft Mapping (based on aircraft currently flown)

AIRCRAFT	EQVT
100	100
141	146
142	146
143	146
146	146
310	310
313	310
318	320
319	320
320	320
321	320
32S	320
330	330
332	330
333	330
340	340
342	340
343	340
345	340
346	340
380	ND
717	100
721	727
722	727
727	727
72A	727
72M	727
72S	727
732	732
733	734
734	734
735	734
736	734
737	732
738	734
739	734
73A	732
73C	734
73G	734
73H	734
73J	734

AIRCRAFT	EQVT
73M	732
73Q	734
73S	732
73W	734
741	747
742	747
743	747
744	744
747	747
74D	747
74E	744
74L	747
74M	747
752	757
753	757
757	757
75W	757
762	767
763	767
764	767
767	767
772	777
773	777
777	777
77L	777
77W	777
A28	AN6
A40	F50
AB3	767
AB4	767
AB6	767
ACD	ND
AGH	ND
AN4	AN6
AN6	AN6
AR1	146
AR7	146
AR8	146
ARJ	146
AT3	AT4

AIRCRAFT	EQVT
AT4	AT4
AT5	AT4
AT7	AT7
ATP	DH8
ATR	AT4
B11	B11
B350	B350
BE1	BES
BE2	ND
BE20	BE20
BE9	F406
BEC	ND
BEH	BES
BES	BES
BET	BE20
BH2	ND
BNI	ND
BNT	ND
CNA	ND
CNC	CNC
CR1	CR2
CR2	CR2
CR7	CR7
CR9	CR9
CRA	CR7
CRJ	CR2
CS2	SC7
CS5	DH8
CV5	AN6
D10	D10
D1C	D10
D28	SWM
D38	D38
D93	DC9
D95	DC9
D9S	DC9
DC9	DC9
DH1	DH8
DH2	DH8
DH3	DH8

AIRCRAFT	EQVT
DH4	DH8
DH7	DH7
DH8	DH8
DHB	CNC
DHC	ND
DHL	DHO
DHO	DHO
DHP	ND
DHS	ND
DHT	SC7
E70	CR9
E75	CR9
E90	100
E95	100
EM2	J41
EMB	EMB
EMJ	CR9
ER3	CR2
ER4	CR2
ERD	CR2
ERJ	CR2
F24	B11
F27	F27
F28	F28
F406	F406
F50	F50
F70	CR9
FK7	F27
FRJ	CR2
GRS	SWM
HS7	F27
I14	S20
IL8	LOF
ILW	747
J31	J31
J32	J31
J41	J41
JST	J31

AIRCRAFT	EQVT
L10	D10
L11	D10
L15	D10
L4T	EMB
LOF	LOF
LOH	LOH
M11	D10
M80	M80
M81	M80
M82	M80
M83	M80
M87	M80
M88	M80
M90	M80
ND	ND
ND2	SH3
NDE	ND
PA2	ND
PAG	ND
PL2	DHO
PN6	BE20
S20	S20
S61	ND
S76	ND
SC7	SC7
SF3	SF3
SH3	SH3
SH6	SH6
SWM	SWM
T20	757
TU3	F28
TU5	727
YK2	DC9
YK4	CR9
YN2	SC7
YN7	AN6
YS1	AN6

Appendix C

Modified CORINAIR fuel consumption table (regional jets added)

Eqvt Aircraft Code	Flight Distance(nm)															
	125	250	500	750	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500
310	2810.56	3899.47	5990.37	8081.27	10172.16	14532.58	18981.64	23699.35	28675.28	33763.82						
320	1644.39	2497.29	3660.61	4705.01	6027.23	8332.01	10865.90	13441.26								
330	4093.66	5862.43	8615.45	11359.97	14121.50	19790.45	25634.21	31714.79	38043.52	44311.94	51005.69					
340	3832.91	5669.09	8482.38	11310.86	14201.21	20133.18	26279.80	32695.54	39114.82	45873.85	52895.18	60079.36	67669.69	75568.29	83691.99	
B11	1393.85	2082.41	3110.10	4194.78	5279.46	7641.61	10160.03									
146	1245.09	1860.53	3124.55	4374.54	5652.57	8270.11										
727	2716.78	3754.67	5660.16	7493.22	9471.16	13544.24	17872.26	22238.06								
732	1799.99	2495.27	3727.09	4949.72	6190.73	8721.79	11438.03									
734	1603.13	2267.96	3612.83	4960.32	6302.56	9187.67	12167.63									
747	6564.83	9419.78	14308.04	19196.29	24084.55	34170.53	44418.98	55255.17	66562.31	77909.24	90362.10	103265.90	116703.31	130411.02		
744	6330.86	9058.26	13404.56	17750.86	22097.16	30921.57	40266.67	49480.22	59576.88	69888.28	80789.24	91986.50	103611.40	115553.02	128170.81	141254.25
767	3030.31	4305.22	6485.18	8665.13	10845.09	15408.59	20086.57	24804.39	29909.40	35239.06	40630.93	46313.67	52208.00			
757	2422.90	3410.18	5070.35	6724.43	8390.71	11845.75	15407.03	19025.89								
777	4819.58	7035.14	10130.36	13226.45	16363.80	22576.41	29225.68	36026.67	43143.25	50294.63	57904.29	65763.50	73655.15	82067.40	90693.23	
DC9	1743.86	2477.97	3815.30	5067.12	6489.97	9354.91	12353.90									
D10	4727.67	6804.37	10487.46	14170.55	17853.63	25476.23	33218.58	41492.33	50361.34	59452.39	69037.90	79034.06	89397.99			
F28	1357.45	1889.25	2984.46	3985.73	5174.88	7318.91										
100	1467.59	2078.75	3212.39	4285.75	5479.66	7796.27										
M80	2102.90	3110.99	4563.92	5913.09	7469.77	10523.32	13738.70									
SWM	147.20	246.10	444.00	641.90	839.80											
SC7	188.00	361.50	706.50	1048.20	1385.40											
SH6	285.00	465.30	826.10	1187.00	1548.30											
SH3	247.90	408.50	730.00	1051.60	1373.40											
SF3	259.60	428.90	767.80	1107.30	1447.40	2130.50										
S20	476.10	814.10	1490.10	2166.20	2842.30	4194.50										
F406	113.40	186.30	332.10	477.90	623.60	914.40										
LOF	943.70	1598.40	2907.80	4217.10	5526.40	8144.40	10761.10	13375.10	15982.30	18570.50	21061.40					
LOH	1101.00	1960.70	3680.50	5400.60	7121.00	10563.00	14006.60	17452.20	20900.20	24351.00	27805.30					
F50	427.80	681.60	1189.50	1697.90	2206.80	3226.30										
F27	374.60	606.80	1070.80	1534.40	1997.60	2921.80	3841.50									
EMB	154.20	273.60	512.10	750.20												
D38	308.10	480.20	824.40	1168.60	1512.80	2201.40										
DHO	100.70	173.40	318.80	464.10	609.40	899.60										
DH7	385.30	629.90	1119.30	1608.60	2097.80	3075.80										
DH8	625.20	1006.60	1769.60	2532.70	3295.70	4821.80	6348.10									
CNC	92.50	163.90	306.80	449.70	592.60	887.90	1174.90									
B350	167.00	269.40	474.20	679.20	884.30	1294.80	1706.10									
BE20	150.50	241.30	423.00	604.90	787.10	1152.60										
BES	186.00	296.40	517.40	738.80	960.60	1406.30	1856.00									
J41	228.20	398.50	739.00	1079.60	1420.30											
J31	174.50	290.30	522.00	754.10	986.50											
AT7	351.60	567.30	998.60	1429.70	1860.70	2721.80	3581.30	4438.20								
AT4	333.60	528.90	919.30	1309.60	1699.80	2479.60	3258.10									
AN6	488.10	818.40	1479.30	2140.80	2803.00	4130.20	5461.90									
CR2	665.00	961.20	1513.60	2073.80	2643.10	3807.00	5014.50									
CR7	929.00	1323.60	2021.70	2736.50	3482.70	5063.00	6681.90									
CR9	1022.90	1444.20	2206.30	3007.80	3824.20	5485.80	7201.20									
ERJ	572.56	879.35	1422.60	1985.52	2561.00	3751.37										
E70	775.24	1201.12	1962.02	2728.27	3513.90	5164.07	6863.00									
E90	959.77	1496.48	2429.10	3373.64	4328.37	6340.90	8438.00									

Appendix D

Airport codes mapped to City codes

Airport_Code	City_code	Airport_Code	City_code	Airport_Code	City_code	Airport_Code	City_code
ACY	AIY	ERS	WDH	MCI	MKC	SIC	SQD
ADB	IZM	ESB	ANK	MCO	ORL	SIG	SJU
ADJ	AMM	EWR	NYC	MDT	HAR	SMF	SAC
AEP	BUE	EZE	BUE	MDW	CHI	SPB	STT
ANR	BRU	FCO	ROM	MGL	DUS	SSB	STX
AOE	ESK	FLG	GCN	MHP	MSQ	STN	LON
ARN	STO	FOE	TOP	MLH	EAP	SVO	MOW
AVV	MEL	GEA	NOU	MMX	MMA	SXF	BER
AZA	PHX	GIG	RIO	MQP	NLP	SZB	KUL
BBU	BUH	GMP	SEL	MXP	MIL	SZF	SSX
BDL	HFD	GNB	LYS	NAY	BJS	TFN	TCI
BFI	SEA	GNY	SFQ	NBW	GAO	TFS	TCI
BGY	MIL	GRK	ILE	NKM	NGO	THF	BER
BHD	BFS	GRU	SAO	NRN	DUS	TLC	MEX
BJV	BXN	GSE	GOT	NRT	TYO	TRF	OSL
BKA	MOW	GTR	UBS	NSI	YAO	TSA	TPE
BMA	STO	GYD	BAK	NYO	STO	TSF	VCE
BQK	SSI	GYY	CHI	OKD	SPK	TTN	PHL
BSL	EAP	HAH	YVA	ORD	CHI	TXL	BER
BVA	PAR	HBE	ALY	ORY	PAR	UKB	OSA
BWI	WAS	HHN	FRA	OTP	BUH	UVF	SLU
CDG	PAR	HLA	JNB	PAC	PTY	VBS	VRN
CGH	SAO	HLP	JKT	PEK	BJS	VCL	TMK
CGK	JKT	HND	TYO	PGU	YEH	VCP	SAO
CIA	ROM	IAD	WAS	PIB	LUL	VDA	ETH
CIU	SSM	IAH	HOU	PIE	TPA	VKO	MOW
CMN	CAS	ICN	SEL	PIK	GLA	VST	STO
CNF	BHZ	IKA	THR	PLU	BHZ	VVI	SRZ
CRK	NCP	ITM	OSA	PMF	MIL	WIL	NBO
CRL	BRU	JFK	NYC	PSM	BOS	XIY	SIA
CTS	SPK	KBP	IEV	PVG	SHA	XNA	FYV
CWA	AUW	KEF	REK	RFD	CHI	XSP	SIN
CXH	YVR	KIX	OSA	RKV	REK	YEG	YEA
CXR	NHA	LBC	HAM	RMQ	TXG	YEI	BTZ
DAL	DFW	LBG	PAR	ROB	MLW	YHM	YTO
DCA	WAS	LCK	CMH	RSW	FMY	YHU	YMQ
DCF	DOM	LCY	LON	RYG	OSL	YND	YOW
DCN	DRB	LGA	NYC	SAW	IST	YTZ	YTO
DME	MOW	LGW	LON	SBP	CSL	YUL	YMQ
DMK	BKK	LHR	LON	SCK	SAC	YWH	YYJ
DTW	DTT	LIN	MIL	SDU	RIO	YYZ	YTO
EMA	NQT	LSI	SDZ	SDV	TLV	ZNA	YCD
EOH	MDE	LTN	LON	SFB	ORL	ZQW	SCN