

Topic: Which region in the world flying from Boston Logan Airport has the lowest carbon footprint?

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Introduction

Flight travel has been growing over the past couple of decades and the increasing demand from flight travelers caused a boom in the aviation industry. More flights are happening around the world leading to our airspace being crowded. More flight happening also means that more plane fuel is being consumed, resulting in more carbon dioxide being produced into the atmosphere. Areas with crowded airspace will experience a polluted atmosphere. The intergovernmental Panel on Climate Change estimates that global air travel accounts for about 3.5% of all human-caused emissions [1](Parks). It may seem that is a small percentage, however, this is about the equivalent of the total carbon emission in South America [3](Ritchie, Roser, and Rosado). By 2030, aviation fuel is estimated to be doubled possibly resulting in a doubling of today's carbon emission [1](Parks). Not to mention, other areas that contribute to the total human-caused emissions will also be growing in the future. This will have detrimental effects on our environment, but fortunately, there is an increasing awareness of the impact of carbon emissions on the environment.

One way to understand your personal effect on the environment is to measure your carbon footprint. Everything you do in daily life has a carbon footprint, especially air travel. Scientists have agreed that everyone should have a personal carbon allowance, the amount of carbon they are allowed to produce for a year. By calculating the world's budget for carbon and dividing the total population on the planet, each person's annual carbon dioxide emission cannot be greater than about 1 ton of CO₂ [2](Hillman). We can measure the amount of carbon a flight between two destinations produces to keep track of your carbon footprint. Travelers, who are environmentalists, may be interested in knowing what is the carbon footprint of a particular flight. It may be also helpful for travelers to decide which destination has the lowest carbon emission. This paper will examine the carbon footprint of flights from Boston to different regions around the world.

Method

Carbon footprint can be measured in many different ways. This paper will focus on measuring the amount of carbon dioxide produced per person for the entire flight. This can be calculated by dividing the total carbon emission produced by the number of passengers on board. We want to create a conclusion that will be still relevant after the pandemic. As the effect

of the pandemic is only temporary, air travel will eventually reach back to the pre-covid level. Therefore, we will focus on data in 2019 and prior.

The regions we will be examining are the regions used in the monthly report statistics of Boston Logan Airport compiled by Massport [4]. The regions are the Caribbean, Canada, Central America, Europe, Trans-pacific, Middle East, South Africa, and North Africa. We will not be analyzing flights to Australia as there is currently no direct flight between Boston and Australia.

To measure the carbon emission, we need the type of aircraft used and the distance to each region. We will be picking a city to represent each region by selecting the most populous city in each region. Then, we can calculate the distance between Boston and the selected city. For the type of aircraft used, the most common aircraft used flying from Boston to the cities will be used. Since Boston Logan only shows departure flight data for the next 24 hours, we will look at the list of departure flights from April 7, 2022, 12:00 AM to April 7, 2022, 11:59 PM[5]. Due to the pandemic, flights to some cities are not available therefore we cannot determine the type of aircraft based on the list of departure flights. Instead, we will find a similar route with a similar distance, and determine the aircraft used for that flight. If a flight to Boston airport is not available, then we will use New York City JFK airport instead. Since New York is close to Boston, in theory, if there was a flight from Boston to a city in a region, it will be possible to use the same aircraft as the flight from JFK to the city. By obtaining the distance and type of aircraft used, we will use the Master emissions calculator published by European Environment Agency. This will return the total carbon dioxide produced for the entire flight, including the amount of carbon produced during take-off and landing as well as during cruising. The takeoff and landing phase uses the default values set by the International Civil Aviation Organization (ICAO). Each flight is assumed to have the same carbon emission during the takeoff and landing phase.

The number of passengers per flight will be each destination's average number of passengers on past flights. We will be assuming that people in Economy, Business, and First Class, will have the same contribution to the total carbon footprint of the flight. By analyzing each month's total number of passengers and the total number of flights to each region from 2016 to 2019, we can calculate the average number of flights and the average number of passengers. Then, we will divide to determine the average number of passengers per flight.

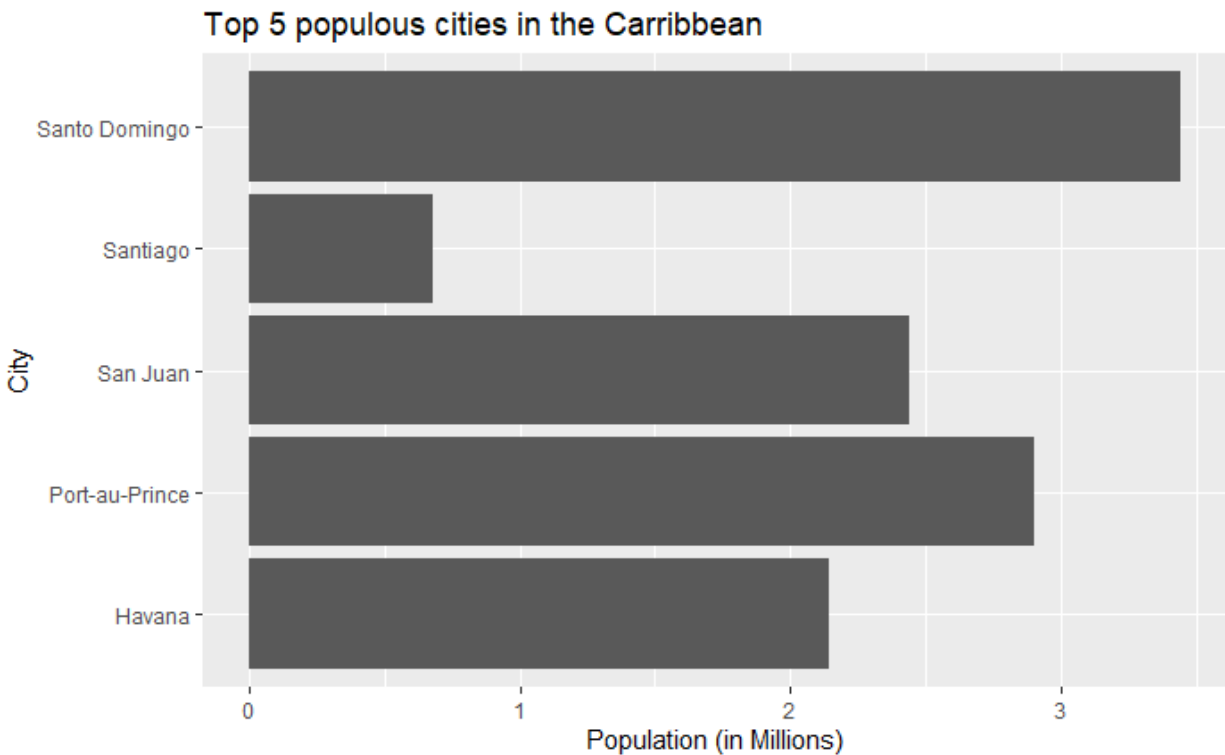
For each region, carbon emission per passenger will be calculated by dividing the total carbon emissions of the flight by the average number of passengers. We will compare which region will have the lowest carbon emissions per passenger and determine which flight has the lowest carbon footprint.

Result

Picking a city to represent each region

Caribbean

According to populationStat, below are the 5 most populous cities in the Caribbean. [7]



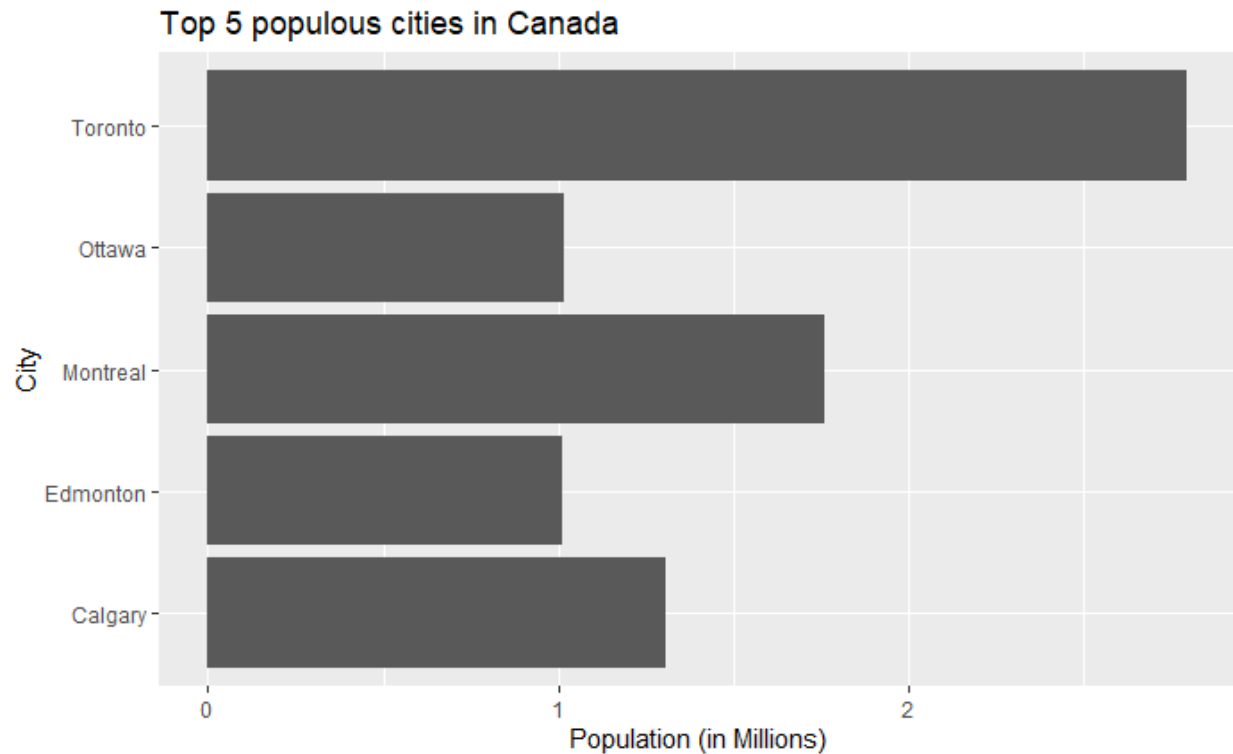
From the bar chart above, we can see that Santo Domingo is the most populous city in the Caribbean region. Therefore Santo Domingo will be used to represent the Caribbean region. We filtered our departing flights to only flights departing to Santo Domingo.

9:17 PM	B61829	Santo Domingo (SDQ)	JetBlue Airways	A321 (N950JT)
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We can see that there is only one flight at 9:17 PM operated by JetBlue Airways. This flight is using the A321 aircraft, thus this aircraft will be representing our flight from Boston to Santo Domingo.

Canada

According to the Population and dwelling counts published by Canada Statistics, below are the top 5 cities in Canada by population count.[8]



We can see that Toronto has the most population out of the other cities in Canada with over 2.5 million people. Therefore, Toronto will be represented Canada.

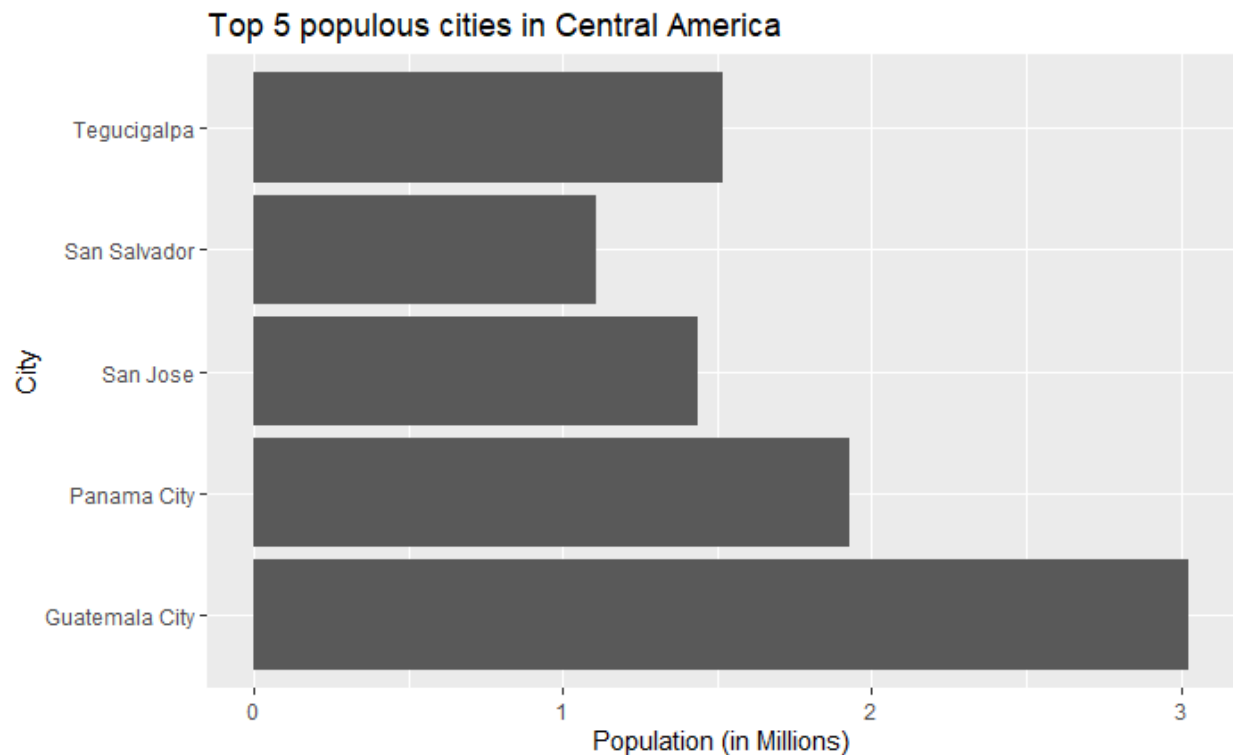
Below are the departing flights filtered to only flights to Toronto.

1:40 PM	PD942	Toronto (YTZ)	Porter Airlines	DH8D (C-GKQE)
7:55 PM	PD948	Toronto (YTZ)	Porter Airlines	DH8D (C-GKQE)
11:30 AM	PD940	Toronto (YTZ)	Porter Airlines	DH8D (C-GLQE)
8:15 AM	PD938	Toronto (YTZ)	Porter Airlines	DH8D (C-GLQR)
7:33 PM	AA4558	Toronto (YYZ)	American Airlines	E75
12:36 PM	AA4556	Toronto (YYZ)	American Eagle	E75L (N442YX)
2:20 PM	AC7509	Toronto (YYZ)	Air Canada Express	E75S (C-FEJC)
6:20 AM	AC7501	Toronto (YYZ)	Air Canada Express	E75S (C-FRQK)
11:20 AM	AC7505	Toronto (YYZ)	Air Canada Express	E75S (C-FRQK)
5:40 PM	AC7513	Toronto (YYZ)	Air Canada Express	E75S (C-FRQM)
7:51 AM	AA4552	Toronto (YYZ)	American Eagle	E75S (N409YX)

We see that there are four flights operated by Porter Airlines flying the DH8D also known as De Havilland Canada DHC-8, while there are 7 flights operated by American Airlines, American Eagle, and Air Canada Express, flying on the E75, E75S, and E75L. Both the E75S and E75L are variants of the E75, which is the Embraer 175 or E175. Since there are more flights using the E175, then we will pick E175 as the aircraft for the flight between Toronto and Boston.

Central America

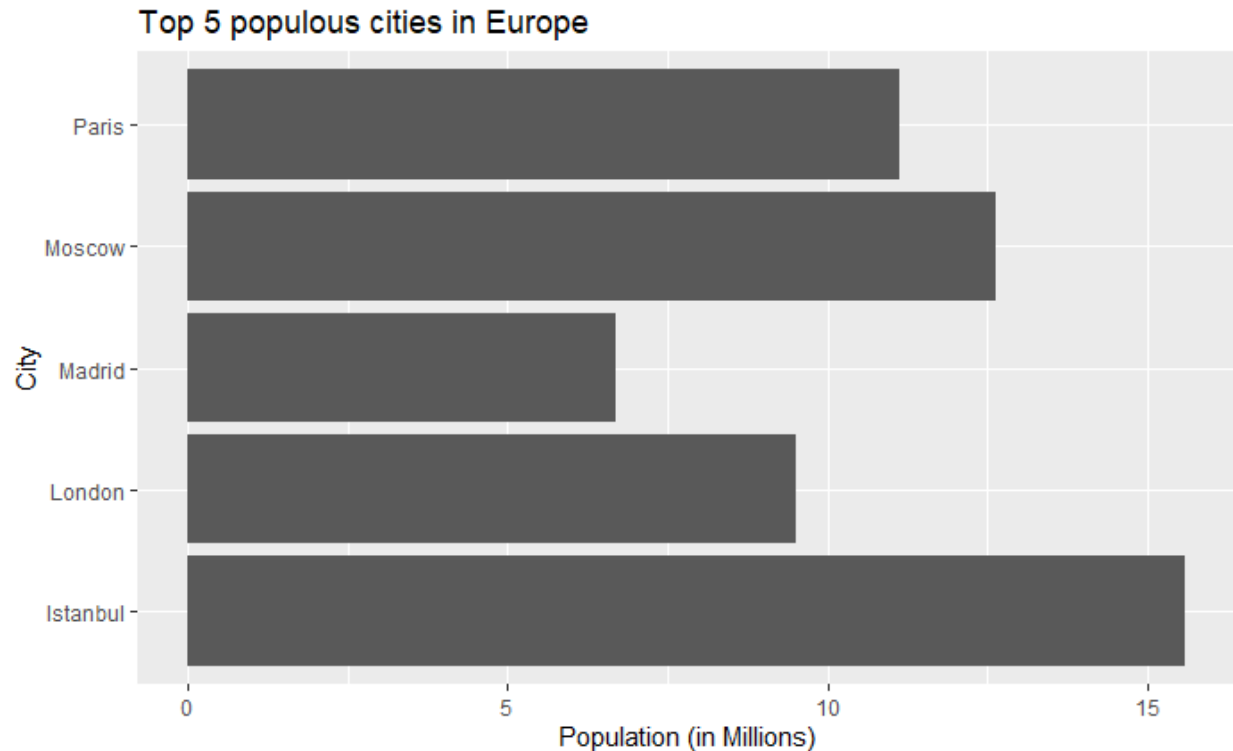
According to populationStat, below is the graph that shows the 5 most populous cities in Central America. [9]



We see that Guatemala City is the most populated city in Central America with around 3 million people. However, in our list of departure flights, we see that there are no flights to Guatemala City. However, looking at FlightAware, there is a flight from Guatemala City to New York City operated by JetBlue flying on an Airbus A321.[10] Since New York City is close to Boston, we will assume that if there was a flight between Boston and Guatemala City, aircraft A321 will be used.

Europe

According to PopulationStat below is the graph that shows the top 5 most populous cities in Europe. [11]



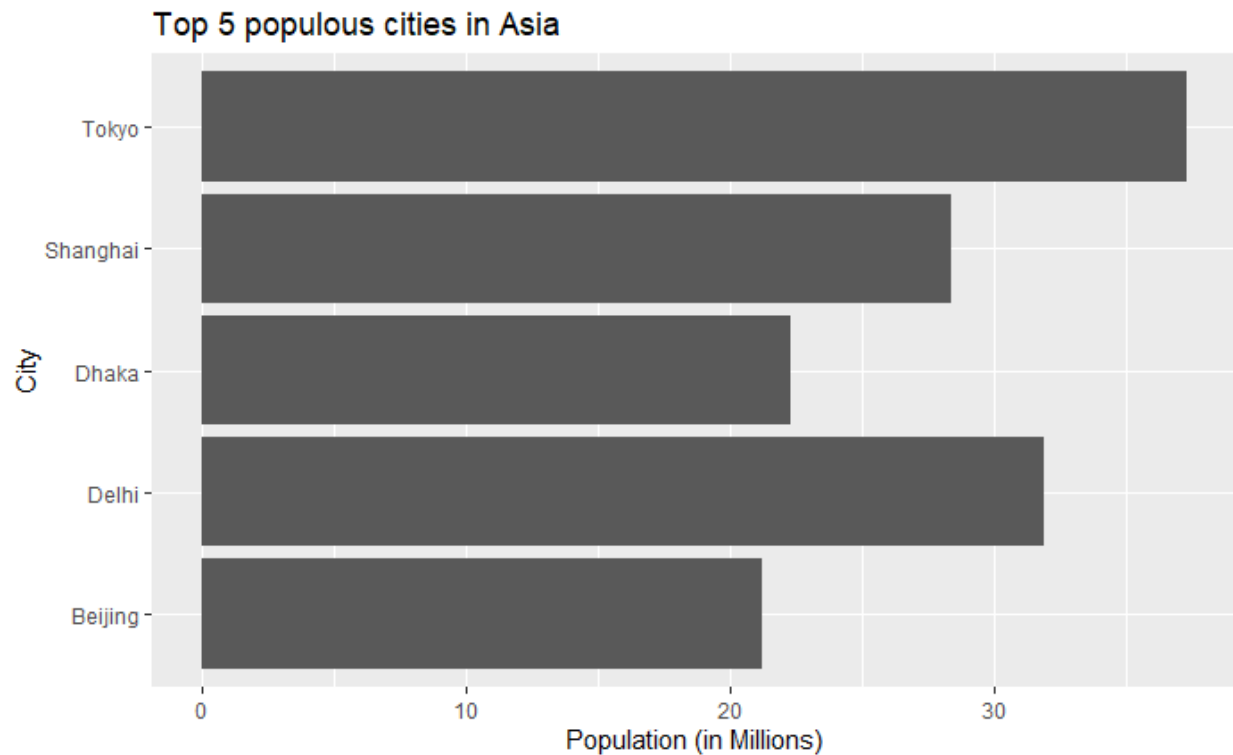
The populous city according to the graph above is Istanbul with over 15 million people. However, Istanbul is located closer to the Middle East rather than the center of Europe and is sometimes considered in the Middle East region. The following largest city is Moscow, the capital of Russia, which is sometimes considered in Asia and also close to the center of Europe. Picking either Istanbul or Moscow will be not representative of Europe as most travelers' image of Europe is mostly in western or central Europe. Therefore, the third-largest city on the list is Paris, France, which is close to the center of Europe. We will pick Paris as the city to represent Europe. Below is our list of departing flights to Paris.

6:55 PM	DL224	Paris (CDG)	Delta Air Lines	A333 (N831NW)
5:25 PM	AF333	Paris (CDG)	Air France	A359

There are two flights heading to Paris, one operated by Delta Air Lines on an A333, the other by Air France on an A359. We will pick the latter one operated by Air France as it is the flag carrier of France. Therefore, we will pick A359 for our flight between Boston and Paris.

Trans-Pacific

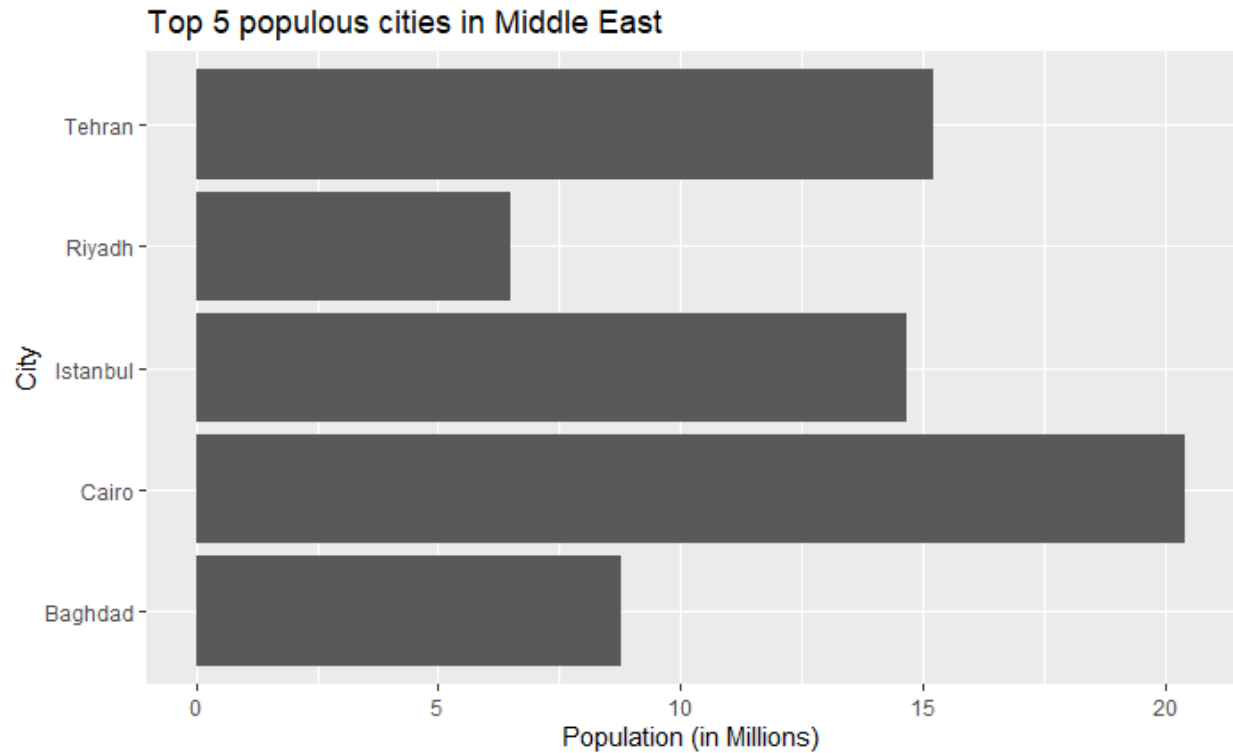
According to PopulationStat below is a graph of the top 5 most populous cities in Asia. [12]



Since Tokyo has the most populated with over 30 million people, Tokyo will represent Asia. There are no direct flights from Boston to Tokyo, however, there are recent flights between New York City and Tokyo. Looking at flight JAL5, operated by Japan Airlines, the flight uses the B77W aircraft or Boeing 777-300ER.[13] Therefore, we will be using the B77W aircraft for our analysis between Boston and Tokyo.

The Middle East

According to WorldAtlas below are the top 5 populous cities in the Middle East[14].



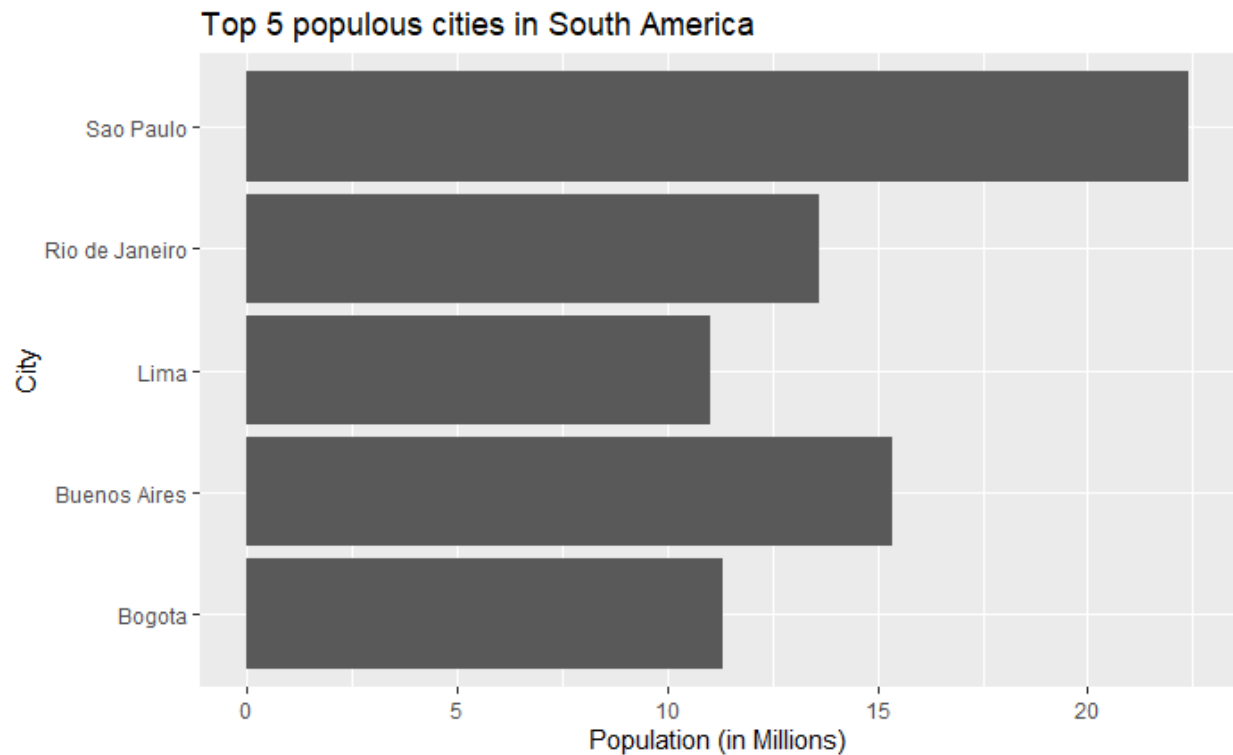
Cairo is the most populous city according to the list with over 20 million people, However, Cairo is located in Egypt, and Egypt is sometimes considered an African country. Tehran is the capital city of Iran and the second most populous city according to the list. However, there is no direct flight between US and Iran as the US has issued a ban on flights to Iran since 2020.[15] Therefore, we will be picking the third most populous city on the list, Istanbul, as it is close to the center region of the Middle East. Below are the flights filtered from our list to Istanbul.

11:30 PM	TK82	Istanbul (IST)	Turkish Airlines	A333
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Since there is only one flight to Istanbul which is using the A333 aircraft, we will be using the A333 to represent our flight between Boston and Istanbul.

South America

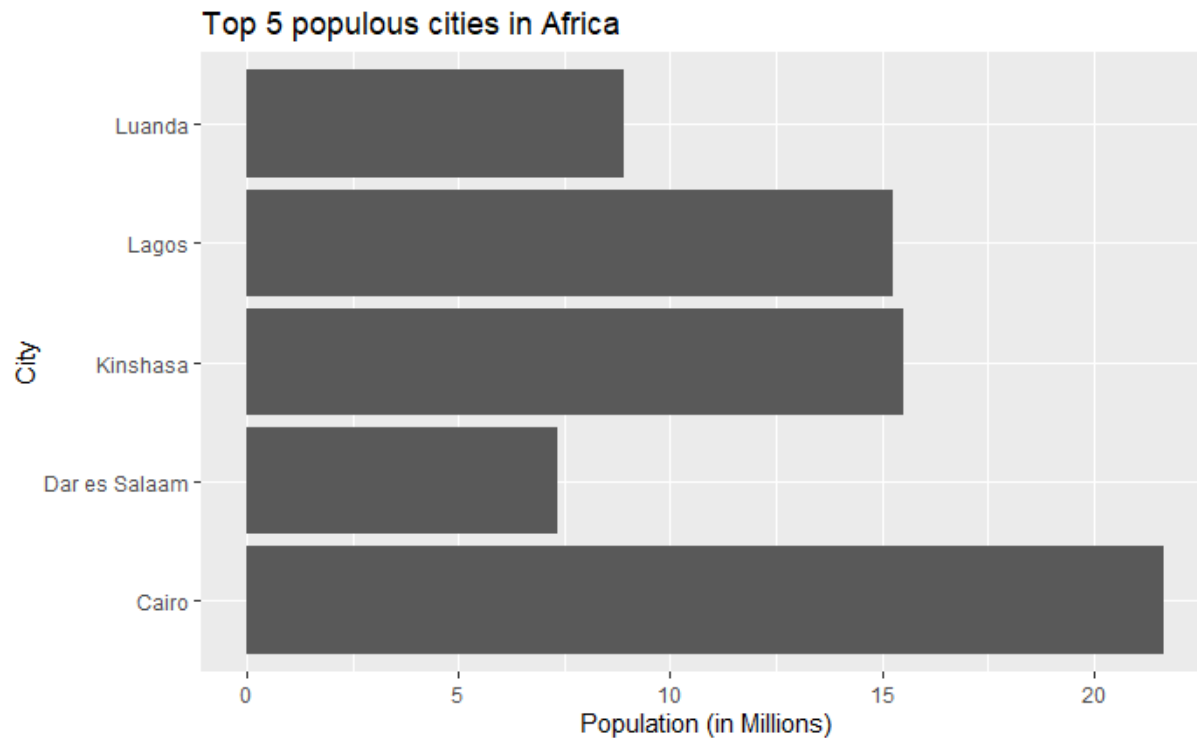
Below is the top 5 most populous cities in South America according to PopulationStat. [16]



Sao Paulo is the most populous city in South America with over 20 million people, therefore Sao Paulo will be picked as the city to represent South America. Because there is no direct flight between Boston and Sao Paulo, therefore we will be looking at a flight between New York City and Sao Paulo. [17] Flight JJ8181 operated by LATAM Brasil Flight uses B789 as the aircraft. Therefore, we will assume that if there was a flight operating between Boston and Sao Paulo, the aircraft of choice will be the B789.

Africa

Below is the top 5 most populous cities in Africa according to PopulationStat. [18]



We see that Cairo is the most populous city in Africa. Cairo is located in Egypt and it is considered a country in the North African region. Therefore, Cairo will be the city to represent Africa. Since there is no direct flight between Boston and Cairo, we will look at a flight between New York City to Cairo.[19] This flight uses the B789 therefore we will be using the B789 to represent our flight between Boston and Cairo.

Distance from Boston

After we have picked a city to represent each region, we can calculate the distance from Boston. We will be using the online tool, distancefromto.net [20], to calculate the distance between cities. This tool is great as it also returns values in nautical miles since the Master Calculator requires distance in nautical miles. We can also include the type of aircraft we will be using for each city. Below is the result: [20a]

Region	City	Aircraft	DistanceKm	DistanceMi	DistanceNMi
Caribbean	Santo Domingo	A321	2658.36	1651.83	1435.4
Canada	Toronto	E175	691.57	429.72	373.42
Central America	Guatemala City	A321	3601.42	2237.82	1944.61
Europe	Paris	A359	5531.18	3436.91	2986.6
Trans-pacific	Tokyo	B77W	10789.54	6704.31	5825.88
Middle East	Istanbul	A333	7763.37	4823.94	4191.89
South America	São Paulo	B789	7745.73	4812.98	4182.36
North Africa	Cairo	B789	8717.35	5416.71	4706.99

We see that Toronto has the shortest distance between Boston with just under 700 kilometers, while Tokyo is the furthest distance from Boston with over 10,000 kilometers. This makes sense as Canada borders the United States and Boston is located in the Northeast. Tokyo is located on the other side of the globe in Asia, therefore it also makes sense that there is a great distance between the two cities.

Calculating Mean Flights and Passengers for Each Region

Calculating the average flights and Passengers for each region will be done by taking the average of all 48 months between 2016 and 2019. This data is taken from the official site of Boston Logan Airport[21].

By importing the data into R, we can calculate the mean value of each column. We can also divide the average number of Passengers by the average number of flights to obtain the average number of passengers per flight. Below, is the result:[22]

Region	DistanceNMI	Aircraft	AverageFlight	AveragePassenger	AveragePassengerPerFlight
Caribbean	1435.40	A321	738.60	94022.40	127.30
Canada	373.42	E175	1517.08	81622.58	53.80
Central America	1944.61	A321	166.02	20919.88	126.01
Europe	2986.60	A359	1499.06	320098.00	213.53
Trans-pacific	5825.88	B77W	217.27	53786.98	247.56
Middle East	4191.89	A333	34.25	4746.65	138.59
South America	4182.36	B789	207.15	42756.02	206.41
North Africa	4706.99	B789	3.35	536.75	160.02

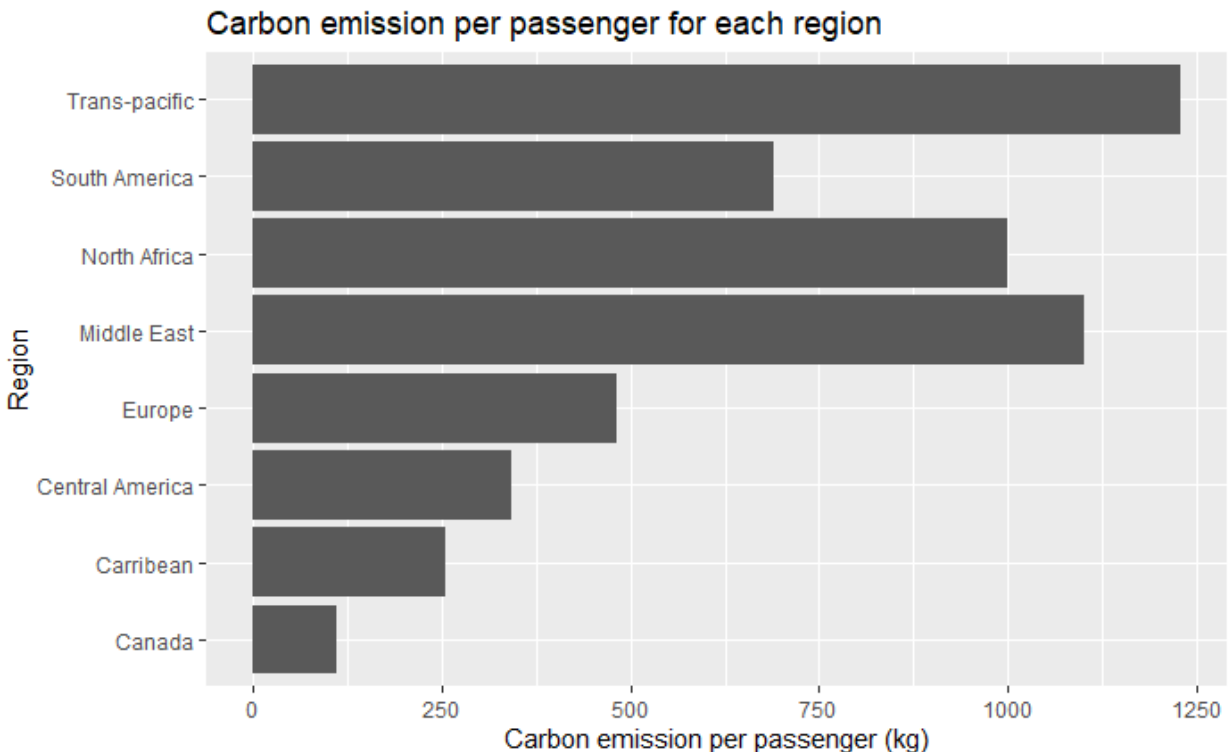
Calculating Carbon Emission with the Master Calculator

Knowing the distance traveled, the type of aircraft used, we can estimate the total carbon emission for a flight. Using that number, we can divide it by the average passenger per flight to return the carbon emission by each passenger. Below is the result:[23]

Region	Distance NMI	Aircraft	Carbon Output (kg)	Average Flight	Average Passenger	Average Passenger Per Flight	Carbon Per Passenger (kg)
Caribbean	1435.40	A321	32614.49	738.60	94022.40	127.30	256.21
Canada	373.42	E175	5952.13	1517.08	81622.58	53.80	110.63
Central America	1944.61	A321	43284.71	166.02	20919.88	126.01	343.51
Europe	2986.60	A359	103020.96	1499.06	320098.00	213.53	482.46
Trans-	5825.88	B77W	304296.70	217.27	53786.98	247.56	1229.20

pacific							
Middle East	4191.89	A333	152705.08	34.25	4746.65	138.59	1101.86
South America	4182.36	B789	142483.91	207.15	42756.02	206.41	690.31
North Africa	4706.99	B789	159974.78	3.35	536.75	160.02	999.69

To visualize it better we can graph the carbon per passenger to see which destination has the lowest carbon footprint.

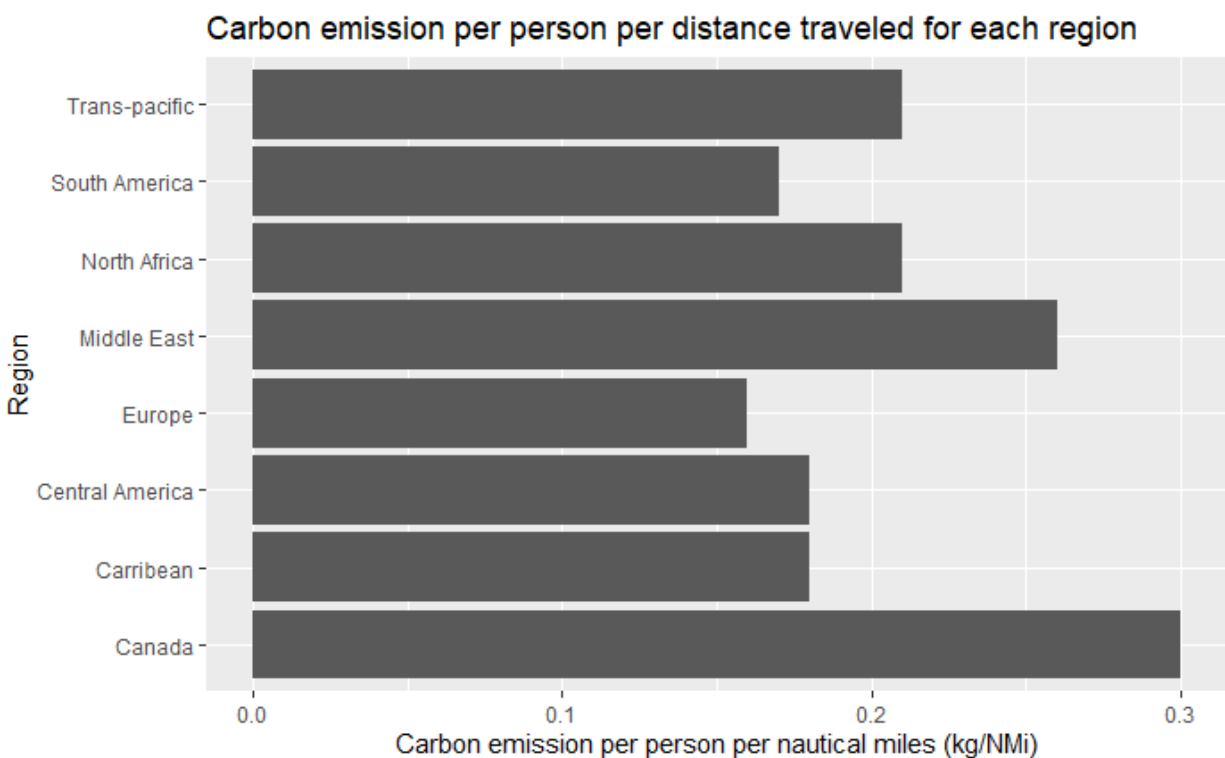


Analyzing the chart above, we can see that flights to trans-pacific have the highest carbon footprint with almost 1250 kilograms of carbon produced per passenger. Flights to Canada have the lowest carbon footprint with under 75 kilograms of carbon produced per passenger. This seems constant with the distance between Boston and the two cities; Tokyo is the furthest from Boston and Toronto is the closest to Boston.

Since we already have the distance traveled and the total carbon output for a flight to each region, we can also calculate the carbon per passenger per nautical mile. This will normalize the carbon emission for all regions as it will represent the about of carbon dioxide produced by each passenger for every nautical mile traveled. We will divide the number we got previously for carbon per passenger by the nautical miles. Below is the results:[23]

City	Distance NMi	Aircraft	Carbon Output (kg)	Average Passenger Per Flight	Carbon Per Passenger (kg)	Carbon Per Passenger Per NMi
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Santo Domingo	1435.40	A321	32614.49	127.30	256.21	0.18
Toronto	373.42	E175	5952.13	53.80	110.63	0.30
Guatemala City	1944.61	A321	43284.71	126.01	343.51	0.18
Paris	2986.60	A359	103020.96	213.53	482.46	0.16
Tokyo	5825.88	B77W	304296.70	247.56	1229.20	0.21
Cairo	4191.89	A333	152705.08	138.59	1101.86	0.26
São Paulo	4182.36	B789	142483.91	206.41	690.31	0.17
Cairo	4706.99	B789	159974.78	160.02	999.69	0.21



Despite Canada being the closest to Boston, flights to Canada has the highest carbon emissions per person for every nautical mile traveled, 0.3 kilograms of carbon for every nautical mile produced by one passenger. Europe is the lowest with 0.16 kilograms of carbon for every nautical mile produced by one passenger.

Discussion

Our findings are very interesting as the flights going to Canada had the lowest carbon emission per passenger out of the other regions. This may be explained by the fact that Canada is physically closer to Boston than any other region, therefore less travel time and less fuel consumed. However, if we look at the carbon emissions for a person by the distance traveled in

nautical miles, we can see that Canada has the highest carbon emission out of the other regions with Europe being the lowest. Although less distance requires less time flying in the air, there is a constant amount of carbon emissions during the landing and takeoff phase. Even if Tokyo is located the furthest away from Boston and has the highest carbon emission per passenger, it only has an average carbon emission per passenger per nautical mile. This can be explained that the majority of the carbon emission is from the landing and takeoff phase and during cruising and it is not using as much fuel compared to the landing/takeoff phase. But, cruising is the time that the aircraft has the highest speed as it is mostly traveling in a straight line. Therefore, we can come to two conclusions.

If a traveler from Boston, who is environmentally concerned, is looking to travel to a region that takes the shortest amount of time to get to, then traveling to Canada will produce the lowest carbon footprint as it has lower carbon emissions per person for that flight. Despite Canada having the highest carbon emission for every nautical mile, it will not be significant due to the short distance. However, if a traveler is looking to travel somewhere else further away from Boston, then traveling to Europe is the best option for the lowest carbon footprint. This is because it has the lowest carbon emission per person per nautical mile and it has a relatively moderate amount of carbon emission per passenger. In addition, travelers should also consider other modes of transportation such as rail or bus, since those methods of transportation have a much smaller carbon impact than flying.

On the other hand, airlines companies can also step in and help reduce carbon emissions. By using more aircraft that more efficiently consumed fuel, it can reduce carbon emissions by a significant amount, especially traveling long distances.

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