Reducing air travel's carbon footprint

Modeling flight efficiency reveals new opportunities for travelers

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1 Problem Statement

Our work focuses on modeling the greenhouse gas emissions of individual flights to improve the accuracy of carbon reporting and identify opportunities to reduce the impact of unavoidable air travel. Applications include identifying aviation industry efficiency trends and leaders, developing company-specific recommendations based on past travel patterns, and adding emissions estimates to online flight search aggregators to enable point of purchase comparisons.

Companies and individual travelers have few tools at their disposal to address the impact of air travel. Although initiatives like the European Union's Emissions Trading System and the International Civil Aviation Organization (ICAO) commitment on climate change aim to reduce the emissions of the aviation industry as a whole, flying less is generally seen as the only way an individual can cut air travel emissions. But this simple prescription ignores the fact that alternate flights serving the same route often vary in efficiency by 50% or more.

2 Model Description

We model flight emissions for an individual passenger as a function of aircraft fuel economy, flight distance, number of seats, load factor, non-passenger freight carried, and seat class. As our model is

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intended for individuals and companies that are unlikely to be able to provide all of these inputs, we rely on a database of historical flight records to estimate any unknown values. We take monthly operating statistics aggregated by airline, aircraft, and city- pair for all certified U.S. carriers and all foreign carriers having at least one point of service in the United States from the US Bureau of Transportation Statistics [1]. We take annual operating statistics aggregated by airline, aircraft, and city-pair for international flights by 215 ICAO member airlines from the ICAO [2].

To estimate unknown values for seats, load factor, and quantity of non-passenger freight we select all records within an appropriate date range that match the input origin, destination, airline, and aircraft. If any of these inputs is omitted we select all possible values for that characteristic. If the combination of inputs does not match any records we recursively drop the least important characteristic until a match is made. We then average across the matched records, weighted by number of passengers for each record.

To calculate flight distance we determine the great circle distance between the origin and destination airports and inflate to account for real-world routing. If either airport is unknown we use the average distance of the matched records, weighted by passengers.

We calculate fuel consumption from flight distance using an aircraft-specific third-order polynomial equation. If the aircraft was not input we average across the aircraft of the matched records, weighted by passengers. For 45 common aircraft we derive the equation from European Environment Agency (EEA) data [3] using a least-squares regression. For an additional 186 aircraft we derive the equation from the 45 reference equations using a correspondence table from the EEA [3] or by averaging across the equations for aircraft with the same body size and type and number of engines, weighted by passengers.

We allocate fuel to passengers (seats times load factor) and freight by weight and then calculate emissions from a single passengers fuel consumption using an emissions factor and adjusting for the additional forcing effects of high-altitude emissions. If seat class was input we adjust based on the relative portion of cabin area occupied by a seat of that class.

3 Applications

We used the model to retrospectively calculate the emissions for 122 million flights within or touching the United States from 2000 through 2010 and 10 million flights outside the United States from 2007 through 2009. Emissions per passenger-kilometre varied by more than a factor of ten overall, and many routes had flights that varied in efficiency by a factor of two or more. Flights within or touching the United States showed a 20% improvement in efficiency from 2000 to 2010 due to increases in average aircraft fuel economy, load factor, and flight distance. Most low-cost carriers scored well on average efficiency while regional feeder airlines performed worst due to older aircraft, lower load factors, and shorter flights.

We also used the model to analyze data on 300,000 flights by employees of two Fortune 500 corporations, where we found that a majority (62% and 97%, respectively) of flights were on routes served by more efficient alternatives. Reduction opportunities across these routes amounted to 14% and 40% of the companies total air travel footprints, respectively.

For experimentation we developed Careplane[1], a free browser plugin that adds emissions estimates to flight search results on the Bing, Hipmunk, Kayak, and Orbitz travel search sites. The plugin helps travelers reduce their footprint by considering climate impact alongside cost and convenience, and could be used to investigate how presenting emissions information at the point of sale influences consumer behavior.

References

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[1] http://careplane.org