Fuel Burn Reduction:
How Airlines Can Shave Costs

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High-Level Airline Statistics

The airline industry is complex and dynamic, with strong interactions between economic drivers and technical constraints.

In the United States, airlines are required to report a wide variety of operating metrics, financial results, and other data points that help describe the current state of the industry.

All data presented here for US airlines only - similar data is unavailable for most international airlines. The source of the data is the MIT Airline Data Project, located at the following URL: http://web.mit.edu/airlinedata/www/default.html

The MIT Airline Data Project aggregates data sources including financial reports from the US Securities and Exchange Commission (SEC) and operational reports from the US Department of Transportation (DOT) Bureau of Transportation Statistics (BTS).

In order to understand the economics of airline fuel costs, it is important to understand some fundamental statistics in the airline industry. Highlight statistics, current as of 2013, include:

- Total fuel consumption by all US airlines in 2013 (Scheduled Services): **13.2 billion US Gallons**
- Total fuel cost to all US airlines in 2013 (Scheduled Services): **$40.5 billion USD**
- Average price per gallon of jet fuel paid by US airlines in 2013: **$3.07 USD**
- Average flight distance for US airlines in 2013: **1,201 Statute Miles**
- Average number of flights per day by each airplane operated by US airlines in 2013: **3.77**
- Percentage of total US airline costs attributed to fuel in 2013: **34%**
- Total number of airplanes operated by US airlines in 2013: **3,434**
- Total number of flights operated by US airlines in 2013: **4.7 million**
- Average amount of fuel used per flight by US airlines in 2013:
    - **2,790 gallons**
    - **$8,575 dollars**
- Average passenger ticket revenue per flight: **$25,700**

Options for Improved Fuel Efficiency

Airlines have a variety of options to reduce fuel consumption in their fleets:

- Buy new aircraft
- Change technology onboard the aircraft
- Change the way the aircraft is flown

Image courtesy Airteam Images

New generations of aircraft and jet engines can provide very large fuel burn savings (on the order of 20% or greater), but the required investment by airlines to purchase new fleets is significant.

This report provides a summary of some of the less-expensive options used by airlines to reduce fuel costs.

Cruise Speed Optimization

The “cruise phase” of flight refers to the segment of every flight after climb and before descent. Airline flights spend significant amounts of time in the cruise phase. In domestic US operations, about **56% of total flight time is spent in cruise**.

Commercial airplanes do not normally operate at a speed that maximizes fuel efficiency. For an airplane carrying some amount of weight, there is one speed that minimized fuel burn. Put another way, if aircraft flew exactly the same path over the ground but sped up or slowed down to an optimal speed, the total fuel consumption for each flight would be lower on each flight.

Average fuel reduction per flight: **20 gallons, $61 US Dollars**

Total yearly fuel cost reduction if every flight made this change: **$287 million USD**
(US airlines only)

Sources:

“Commercial airline speed optimization strategies for reduced cruise fuel consumption,” Jensen, L., Hansman, R.J., Venuti, J., Reynolds, T.G., AIAA 2013-4289, 13th AIAA Aviation Technology, Integration, and Operations Conference (ATIO), 12-14 August, 2013, Los Angeles, CA. DOI: 10.2514/6.2013-4289

Cruise Altitude Optimization

Airplanes have an optimal altitude that minimizes fuel consumption. This is not always the altitude chosen by pilots. By flying away from optimal altitudes, aircraft experience higher than necessary fuel burn rates. If every flight operated at optimal altitudes during the cruise phase of flight, airlines could achieve reduced fuel consumption.

Average fuel reduction per flight: **23 gallons, $70 US Dollars**

Total yearly fuel cost reduction if every flight made this change: **$330 million USD**
(US airlines only)

Sources:

"Commercial airline speed optimization strategies for reduced cruise fuel consumption," Jensen, L., Hansman, R.J., Venuti, J., Reynolds, T.G., AIAA 2013-4289, 13th AIAA Aviation Technology, Integration, and Operations Conference (ATIO), 12-14 August, 2013, Los Angeles, CA. DOI: 10.2514/6.2013-4289

Route Optimization (flying more direct routes)

Due to system congestion, airport layouts, terrain (such as mountains), and a wide variety of other factors, airplanes cannot fly direct straight-line paths from their point of departure to their point of arrival. Average "distance inefficiency" is on the order of 9%, meaning that total track distance flown by airplanes is longer than the straight line connecting the airports by an average of 9%.

Image courtesy Boeing

The fuel burn reduction from this effect depends on which phase of flight the extra track distance is flown. Aircraft flying extra air miles at low altitudes waste more fuel than those at high altitudes. A rough estimation of possible fuel saving is provided below, assuming that air traffic control technology and procedures improve to the point where every airplane can fly a perfectly direct route.

Average fuel reduction per flight: **up to 250 gallons, $766 US Dollars**

Total yearly fuel cost reduction if every flight made this change: **$3.6 billion USD**
(US airlines only)

Sources:

http://www.atmseminar.org/seminarContent/seminar6/papers/p_055_MPM.pdf

Engine Washing

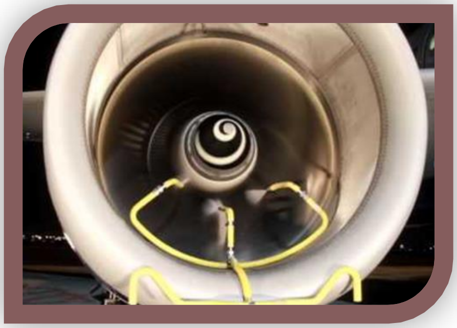

Image courtesy wn.com

Jet engines work most efficiently when all of their moving parts are clean. This is because the internal components of a jet engine are *aerodynamic*. That is, there are carefully-designed components inside the engine intended to compress air, burn fuel, and expel exhaust as efficiently as possible.

As an airplane burns fuel over many hours of operation, a fine layer of soot residue builds up on some of these components. While they still work with the soot layer, the components become slightly less efficient. By regularly washing the soot layer off of engine components, airlines can save fuel on every flight.

Average fuel reduction per flight: **up to 28 gallons, $85 US Dollars**

Total yearly fuel cost reduction if every flight made this change: **$401 million USD**
(US airlines only)

Sources:

http://www.aerojetwash.com/

Single-Engine Taxi

Image courtesy Cory Watts, airliners.net

Aircraft taxiing on the surface of an airport burn a large amount of fuel. This is because jet engines are designed for efficient power generation at high speeds and high altitudes, but are far less efficiency for surface-level ground operation.

A single engine produces ample thrust to move an aircraft on the ground. Therefore, airlines can reduce fuel consumption on airport surfaces by operating with one engine shut down.

If the aircraft is taxiing for takeoff, the other engine(s) is started several minutes prior to takeoff to allow time for warm-up. If the aircraft has landed and is taxiing to the gate, all but one engine are shut down as soon as the aircraft has taxied clear of the landing runway.

Average fuel reduction per flight: **up to 45 gallons, $137 US Dollars**

Total yearly fuel cost reduction if every flight made this change: **$645 million USD** (US airlines only)

Sources:

http://web.mit.edu/~hamsa/www/pubs/KhadilkarBalakrishnanGNC2011.pdf

Jung, Y., "Fuel Consumption and Emissions from Airport Taxi Operations," NASA Green Aviation Summit, 2010. (http://www.aeronautics.nasa.gov/pdf/18_jung_green_aviation_summit.pdf)

Electric Assisted Taxi / Tug Assisted Taxi

Aircraft normally taxi to and from the runway over a network of taxiways under their own power. This requires that at least one engine be running, although normally all engines are running during taxi operations. Jet engines are very inefficient for moving aircraft on the ground.

Tug (currently used for maintenance) that could tow an airplane to the runway

Image courtesy Luke Jensen

An alternative is to move the aircraft from the gate to the runway using an alternative means of propulsion, either internal or external to the aircraft. For example, a tug (similar to those used to push aircraft back from the gate) can be used to tow an aircraft to the runway, where the tug is disconnected, the airplane starts its engines, and takes off normally.

Prototype electric wheel tug system

Image courtesy WheelTug

Another option involves using an electric motor attached to the airplane's wheels to power the airplane to the runway without an external tug. This has the added benefit of allowing the airplane to back up under its own power and reduces ground crew requirements. However, it increases the airplane's weight, so overall fuel burn once the airplane is airborne increases slightly.

Average fuel reduction per flight: **up to 90 gallons, $270 US Dollars**

Total yearly fuel cost reduction if every flight made this change: **$1.3 billion USD** (US airlines only)

Sources:

http://www.airbus.com/presscentre/pressreleases/press-release-detail/detail/airbus-signs-mou-with-honeywell-and-safran-to-develop-electric-taxiing-solution-for-the-a320-family/

Ground Power Use

Commercial aircraft are normally equipped with a small jet engine mounted in the tail that acts as a generator. When the main engines are shut down, pilots can turn on this miniature engine, called the Auxiliary Power Unit (APU) to provide electrical power while the aircraft is at the gate. The APU also powers the systems that are used, in turn, to start the main engine.

Photo courtesy www.b737.org.uk

The APU runs on jet fuel, so extended use at the gate results in increased fuel burn. An alternative is to use external ground power (provided through a cable that is plugged to the aircraft). This ground power is generated much more efficiently and can power all onboard systems until it is time to start the engines, at which point the APU is started briefly.

Average fuel reduction per flight: **11 gallons, $34 US Dollars**

Total yearly fuel cost reduction if every flight made this change: **$157 million USD**
(US airlines only)

Sources:

http://www.southwest.com/html/southwest-difference/southwest-citizenship/environmental-initiatives/

http://www.greenaironline.com/news.php?viewStory=1605

http://aviationweek.com/awin/focus-fuel-savings

http://hub.aa.com/en/nr/media-kit/operations/fuelsmart

https://hub.united.com/en-us/news/company-operations/pages/united-to-save-millions-on-fuel-in-2013.aspx

Airplane Winglets

Drag is the force that resists the motion of an aircraft through the atmosphere. An aircraft must supply enough force, via the engines, to overcome drag. The link between drag and fuel consumption means aircraft manufacturers and airline operators are constantly working to find ways to reduce aerodynamic drag.

Photo courtesy www.b737.org.uk

Aircraft wings produce the least amount of drag when air is moving smoothly over the top and bottom of the wing. But during normal operations it is possible for the air on the top and bottom of the wing to combine near the wingtip, resulting in increased drag. One way to mitigate this effect is to make very long wings, but this would reduce the amount of airplanes that can fit in an airport at the same time.

Instead, most modern aircraft are offered with an option to put small, vertical lifting surfaces on the tips of each wing. These vertical wings, or "winglets," improve aerodynamic drag by reducing the flow of air around the end of the wingtip. However these benefits come at a cost: the winglets themselves can weigh a few hundred pounds, and so the aerodynamic benefits of reduced drag need to outweigh the weight penalty in order to see a net improvement in fuel consumption.

For some operators, this trade makes sense based on the routes they are flying. Southwest Airlines, for example, reported a fuel consumption benefit of 5.5% on their Boeing 737 aircraft.

Average fuel reduction per flight: **155 gallons, $475 US Dollars**

Total yearly fuel cost reduction if every flight made this change: **$2.2 billion USD**
(US airlines only)

Source:

http://www.usatoday.com/story/todayinthesky/2014/04/10/southwest-flies-first-737-with-new-split-scimitar-winglets/7552849/

Aircraft Weight Reduction

The power required to move an aircraft through the atmosphere is related to how heavy it is. A very heavy aircraft requires much more force from the engines, and thus more fuel consumption, than a light aircraft. This relationship between weight and fuel consumption holds regardless of how small the weight changes are: a small reduction in weight still results in an improvement in fuel consumption.

Photo courtesy www.b737.org.uk

With this effect in mind, airlines have started removing specific items from flights to reduce fuel cost. Some of these weight reductions are possible due to improving technology (such as inflight wifi systems), while others are driven by changing expected service standards and customer fare differentiation (for example, removal of certain catering items).

Item and weight	Total yearly fuel cost reduction if every flight made this change(US airlines only)
Inflight Entertainment System for every passenger (7 pounds each)	$117 million USD
Removing one service cart from each flight (50 pounds)	$6 million USD
Removing one book for every passenger (1 pound each)	$18 million USD

Source:

http://fivethirtyeight.com/features/if-everyone-went-to-the-bathroom-before-boarding-the-plane-ticket-prices-might-be-lower/

SAE Standards for Service Carts: http://standards.sae.org/as8056/