Low-hanging fruit? Reducing fuel burn and emissions from taxiing aircraft

Parth Vaishnav, Granger Morgan, Paul Fischbeck

Department of Engineering & Public Policy, Carnegie Mellon University

Background

- In 2005, aviation was responsible for 3.5% of total anthropogenic radiative forcing.
- By 2050, its share is expected to rise to 4.0-4.7% (Lee et al. 2009).
- At the same time, as energy prices have risen, airlines have struggled to maintain profitability.
- The industry is under pressure to reduce its operating expenses, as well as its environmental footprint (e.g., under the auspices of the European Union's Emissions Trading Scheme.

In this context, it is important to understand the costs associated with different measures to reduce the industry's environmental footprint.

Data and Methods

- The analysis is based on 2006 (BTS 2011) data on the taxi times of domestic passenger flights: just over 80% of all US departures (7.9 million flights) are included.
- It is assumed that engines are operated at the idle (7% of maximum) setting while taxiing, and emissions and fuel are estimated using an ICAO (2010) database. Data on auxiliary power unit (APU) fuel burn was obtained from a number of industry sources (Fleuti & Hofmann 2005), (EEA, Inc. 1995)
- In the base case, it is assumed that the aircraft taxies with either one or two main engines running. This base case is compared to two alternatives.
    - The aircraft is towed by a tug powered by diesel, gasoline, or electricity from an on-board battery.
    - The aircraft is propelled on the ground by an APU-powered electric motor embedded in its nose wheel.

This paper contributes to an existing body of research (e.g. Deonandan & Balakrishnan 2010) by estimating both the benefits (lower fuel burn, emissions) and costs (capital, maintenance, labor, fuel) associated with switching from main-engine taxiing to these alternatives.

Future work

- Refine and validate assumptions based on interviews with airline and airport executives, regulators
- Identify operation issues associated with the use of tugs at busy airports
- For the electric motor-in-nose-wheel system, quantify the impact of the increase in aircraft weight.

P R E L I M I N A R Y Results

*Table 1: Switching to petroleum-fuelled tugs would cut emissions in a cost-effective way if we assume that in the base case that airplanes taxi with two main engines, but not if we assume that they taxi with only one**

Assumptions for the case when the aircraft is towed to the runway by a tug				
Fuel for pushback tug	Diesel	Diesel	Diesel	Diesel
Fuel for taxiing tug	Emission-free electricity	US grid electricity	Gasoline	Diesel
Cost of electricity ($ per kWh)	0.08	0.08		
Emission reductions and costs compared to using both main engines (annual, based on 80% of all commercial domestic passenger flights in 2006)				
Reductions in				
Costs (million $)	-30	-30	200	200
CO_2 emissions (million kg)	3000	2000	3000	3000
HC emissions (million kg)	7	7	3	5
CO emissions (million kg)	40	40	-200	30
NOx emissions (million kg)	5	4	0	-8
Cost per tonne of reduction in the emissions of				
CO_2	10	20	-70	-70
HC	Large Positive		Large negative	Large negative
CO	Large Positive		-	Large negative
NOx	Large Positive		Large negative	-

Assumptions for the case when the aircraft is towed to the runway by a tug				
Fuel for pushback tug	Diesel	Diesel	Diesel	Diesel
Fuel for taxiing tug	Emission-free electricity	US grid electricity	Gasoline	Diesel
Cost of electricity ($ per kWh)	0.08	0.08		
Emission reductions and costs compared to using one main engines (annual, based on 80% of all commercial domestic passenger flights in 2006)				
Reductions in				
Costs (million $)	-900	-900	-600	-700
CO_2 emissions (million kg)	600	-	400	400
HC emissions (million kg)	3	3	-1	2
CO emissions (million kg)	20	20	-200	10
NOx emissions (million kg)	5	1	-3	-10
Cost per tonne of reduction in the emissions of				
CO_2	1000	-	2000	2000
HC	Large Positive		-	Large positive
CO	Large Positive		-	Large positive
NOx	Large Positive		-	-

*Table 2: Electric tugs, though uneconomical on average, could be economical at some airports **

Assumptions for the case when the aircraft is towed to the runway by an electric tug										
Airport	DTW	EWR	PHL	BOS	ORD	IAH	LGA	JFK	ATL	CLT
Average total taxiing time (minutes)	26	37	30	26	26	28	34	40	38	25
Fuel for taxiing tug	- - - US Grid Electricity - - -									
Price of electricity ($/kWh)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Emission reductions and costs compared to using both main engines (annual, based on ~90% of all commercial domestic passenger flights in 2006)										
Reductions in										
Costs (million $)	1	20	3	3	3	0	10	10	50	-6
CO_2 emissions (million kg)	60	100	80	60	100	100	100	100	300	50
HC emissions (million kg)	1	0	0	0	0	0	0	0	0	0
CO emissions (million kg)	2	1	1	1	2	1	1	1	3	1
NOx emissions (million kg)	0	0	0	0	0	0	0	0	0	0
Cost per tonne of reduction in the emissions of										
CO_2	-20	-200	-50	-50	-20	-4	-100	-200	-200	100
HC	- - - Large negative - - -									Large positive
CO	- - - Large negative - - -									
NOx	- - - Large negative - - -									

*Table 3: Embedding an APU-powered electric motor in the nose-wheel would cut emissions at negative cost**

Assumptions for when the aircraft is towed by an electric motor embedded in the nose wheel						
Assume that aircraft currently taxi with	Both engines	Both engines	Both engines	Single engine	Single engine	Single engine
Capital cost of retrofitting fitting the system ($)	250,000	500,000	1,000,000	250,000	500,000	1,000,000
Emission reductions and costs compared to taxiing with main engines (annual, based on 80% of all commercial domestic passenger flights in 2006)						
Reductions in						
Costs (million $)	1000	1000	1000	600	500	200
CO_2 emissions (million kg)	4000	4000	4000	2000	2000	2000
HC emissions (million kg)	6	6	6	3	3	3
CO emissions (million kg)	40	40	40	20	20	20
NOx emissions (million kg)	4	4	4	1	1	1
Cost per tonne of reduction in the emissions of						
CO_2	-400	-300	-300	-400	-300	-100
HC	- - - Large negative - - -					
CO	- - - Large negative - - -					
NOx	- - - Large negative - - -					

* All figures have been rounded to one significant digit, as results are preliminary

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