New Zealand Transport Outlook: Future State

Aircraft Movement and Greenhouse Gas Emission Model

November 2017

Short name

Aircraft Kilometre Travelled and Emissions Model

Purpose of the model

The Transport Outlook Aircraft Movement and Greenhouse Gas (GHG) Emission Model projects aircraft-kilometre travelled for domestic air services in New Zealand, and fuel use and GHG emissions by domestic air travel for the years 2018, 2023, 2028, 2033, 2038, and 2043.

Software used

Excel

For questions and comments:

transportoutlook@transport.govt.nz

New Zealand Transport Outlook

Aircraft Movement and Greenhouse Gas Emission Model

1. At a high level, what does this model do?

The Transport Outlook Aircraft Movement and Greenhouse Gas (GHG) Emission Model projects aircraft-kilometre travelled for domestic air services in New Zealand, and fuel use and GHG emissions by domestic air travel for the years 2018, 2023, 2028, 2033, 2038, and 2043. All the projections are at the national level. The projections are based on the projected passenger-kilometres travelled in domestic air travel from the separately documented Origin and Destination Based Domestic Air Passenger Model. Fuel consumption (FC) factors by aircraft type are taken from the EMEP/EEA emission inventory guidebook 2013[1]. Key assumptions used in the projections include the future evolution of the aircraft fleet (see the Appendix) and improvements in aircraft fuel efficiency (see section 3).

The Sabre database (Sabre AirVision Market Intelligence) has been used as the source of domestic air travel data, including the number of flights, available seats, and aircraft-km travelled for individual aircraft types in a year.

2. Where do I find the model results?

This is a spreadsheet model, with all scenarios being modelled in a single workbook. Summary results for aircraft-km travelled, fuel use, and GHG emissions can be found in the "Projection summary" worksheet. Projected aircraft-km travelled for specific years are given in columns F to K from row 6 to row 10. The corresponding compound annual growth rates are given in the same columns from row 29 to row 33.

Projected jet fuel use is given in columns R to W from row 6 to row 10. Projected biofuel use (if any) is given in the same columns from row 17 to row 21. The compound annual growth rates for jet fuel use are given in the same columns from row 29 to row 33.

Projected GHG emissions are given in columns AD to AI from row 6 to row 10. The compound annual growth rates for GHG emissions are given in the same columns from row 29 to row 33. All the projections come from the modelling process in the "Projection modelling" worksheet.

We have compared the modelled jet fuel use for historic years (2002 to 2015) with MBIE's aviation fuel data. The comparison can be found in the worksheet named "Comparison to MBIE's" (columns B to E). The "Historic data modelling" sheet shows how the jet fuel use for historic years is estimated.

3. What are the inputs to this model and where do they come from?

The Origin and Destination-Based Domestic Air Passenger Model projects domestic air passenger-kilometres travelled. The results at the national level can be found in the "TABLES" worksheet of

[1] EMEP/EEA emission inventory guidebook 2013: 1.A.3.a, 1.A.5.b Civil and military aviation

that model (columns S to AA in row 29). The national domestic air passenger-kilometres travelled are an aggregate of passenger-km of individual routes in a year.

First link the projected domestic air passenger-kilometres travelled into the “Input” sheet of this model – columns C to K from row 8 to row 12. Then in the same sheet input assumed shares of individual aircraft types in the total number of flights in future years (columns E to K from row 20 to row 64). Only a few types of aircraft are currently used for domestic air services in New Zealand. We assume that this will hold true in the next 30 years. The Airbus A320 or similar is the only large jet aircraft currently being used. As of 2016, Boeing aircraft are no longer used for scheduled domestic air services. There are two types of mid-sized turbo-prop aircraft: ATR 72 and Dash 8. Small aircraft include Jetstream 32, Cessna Light, Pilatus PC-12 and Saab SF-340 etc. We have modelled the small aircraft as a single class as their shares of use are low and volatile. Finally, input assumed fuel efficiency improvement rates for different types of aircraft – columns P to W from row 20 to row 63.

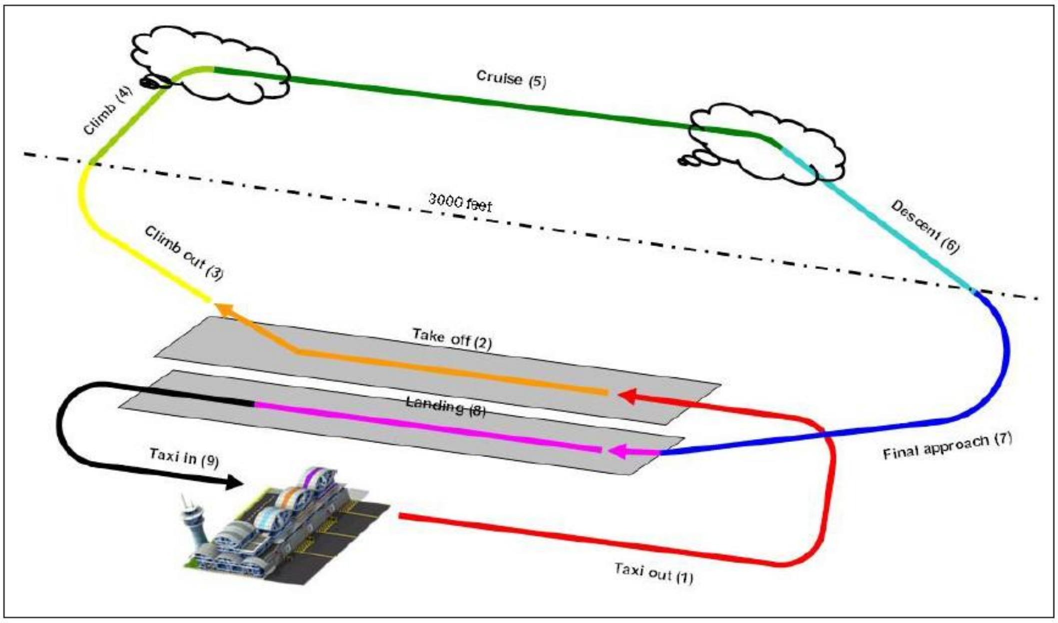
Projecting aircraft fleet evolution in the future is challenging. We have done this based on data on the current operating fleet, airlines’ future fleet projections or purchase plans, and research on the economic life of aircraft. See the Appendix for more details on these assumptions.

A study for the UK's DfT[2] suggests that a new generation of aircraft could be introduced around 2030 and 2040, and that fuel efficiency could be improved by about 15% for aircraft of the new generation. On the other hand, fuel efficiency improvement is generally limited for newly manufactured aircraft of the same generation[3]. We have used this information and the assumed aircraft fleet evolution to work out the assumptions on fuel efficiency improvement rates for different types of aircraft.

4. How does this model derive its results?

The figure below illustrates the standard flying cycles of an aircraft[4].

[2] Horton G (2010), Future Aircraft Fuel Efficiencies - Final Report; prepared for UK Department for Transport.
[3] Kharina A and Rutherford D (2015), Fuel Efficiency Trends for New Commercial Jet Aircraft: 1960 to 2014.
[4] Source: EMEP/EEA emission inventory guidebook 2013: 1.A.3.a, 1.A.5.b Civil and military aviation.



To simplify the modelling process, we divide these nine activities into two broad categories: **the landing and take-off cycle (LTO) and the cruise cycle**. The LTO cycle includes all activities near the airport that take place below a height of 3000 feet (914 m). This includes taxi-in, taxi-out, take-off, climb-out, final approach, and landing. The cruise cycle is defined as all activities that take place above 3000 ft. It includes climb from the end of climb-out in the LTO cycle to the cruise altitude, cruise, and the descent from cruise altitude to the start of LTO operations of landing.

Fuel use during the LTO and cruise cycles has to be estimated separately. This is because, although the distance travelled in the LTO cycle is small, a large amount of fuel is used; that is, fuel use per distance travelled in the LTO cycle will be significantly higher than that in the cruise cycle. Fuel consumption (FC) factors for the LTO and cruise cycles for each aircraft type are taken from the EMEP/EEA emission inventory guidebook 2013. We have followed the Tier 3 approach.

In this model we estimate fuel consumption during the LTO cycle based on the number of flights for each aircraft type at the national level and during the cruise cycle based on the average distance travelled by each aircraft type at the national level in a year. An aircraft can be used in different routes, in which the distance can be very different. However, FC factors for the cruise cycle in the guidebook for every aircraft type are proportional to distance travelled (see the 'Raw_data' sheet). This forms the basis for the use of average distance in estimating FC in the cruise cycle.

Based on the fleet assumptions (see the Appendix) and current distribution of the number of flights among different types of aircraft, we project the likely share of each aircraft type in the total number of flights (S_Flight) in future years. There are several types of small aircraft used in the current fleet. There is a great deal of uncertainty about their future use. Therefore, we combine all of them into one category: small aircraft. The average seats per flight (SPF) for a fleet year can be worked out by using the following formula:

$$\mathbf{SPF = \sum[S\_Flight\ (i) \times Capacity\ (i)]} \qquad \mathbf{(1)}$$

As mentioned above, the Origin and Destination-Based Domestic Air Passenger Model projects domestic air passenger-km travelled. That model projects direct origin-destination (O-D) passenger-km data. The difference between O-D-based and airport departure (leg) based data is that the extra domestic passenger-kms required by the need for connecting flights as well as passenger-kms on domestic legs of international trips are not included in the O-D-based data. However, we have found that the ratio of leg-based domestic air passenger-km to the O-D-based counterpart has been relatively stable (around 1.13) in recent years (2010-2015). Assuming the so-called 'circuity factor' being constant in the future, then:

Airport departure (leg) based domestic air passenger-km travelled = O-D-based domestic air passenger-km travelled x circuity factor (2)

We have also found that the average load factor for a fleet year has also been relatively stable in recent years. We assume the load factor to be constant in the future and we can then project the total domestic aircraft-km travelled using the following equation:

Domestic aircraft-km travelled (leg based) = Airport departure (leg) based domestic air passenger-km travelled / (SPF x Load factor) (3)

In general, larger aircraft are used on longer routes. When smaller aircraft are replaced by larger ones on specific routes, the average distance travelled per flight (DPF) for the larger aircraft type will be reduced. The share of each aircraft type in total aircraft-km (S_AKM) can be estimated as:

S_AKM (i) = [S_Flight (i) x DPF (i)] / ∑[S_Flight (i) x DPF (i)] (4)

We can project the number of flights by each aircraft type using the following equation:

Flights (i) = AKM (i) / DPF (i) = S_AKM (i) x Total AKM / DPF (i) (5)

Finally, we can project fuel use in the LTO stage:

Fuel use of LTO (i) = Flights (i) x Fuel use factor of LTO (i) (6)

And we project fuel use in the cruise stage:

Fuel use of cruise(i) = Flights (i) x DPF (i) x Fuel use factor of cruise (i) (7)

This methodology works well for historic data. The difference between estimated fuel use and MBIE's fuel data is 10% or less in the most recent five years (2012 – 2016; see the "Comparison to MBIE's" sheet).

Biofuel uptake in air transport will be a slow, long-term process (see e.g. "Biofuel a long-term bet: Luxon", *New Zealand Herald*, 5 October 2016)[5]. Currently we have simply assumed no biofuel uptake in all scenarios.

Caveats

(1) The conditions used to develop the FC factors in the EMEP/EEA guidebook may be different from the aircraft operations in New Zealand. For example, the load factors may not be the same.

[5] www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11723018

(2) Large uncertainties are associated with our assumptions on fleet evolution in the future. We have run sensitivity analyses to test the impacts of changes in the fleet mix on aircraft-km and fuel use/GHG emissions.

(3) Fuel efficiency can also be improved by optimising operations of aircraft. However, such fuel efficiency gain is hard to predict and has not been observed clearly in the historic data. Therefore, fuel efficiency improvement due to aircraft operation optimisation is not taken into account in our projections at this stage.

Appendix: Current aircraft fleet and assumptions on future aircraft fleet composition

Domestic air services in New Zealand are provided primarily by two major airlines: Air New Zealand (with about 80% market share) and Jetstar. The share of other small airlines is very low.

Air New Zealand operating fleet (including international) as at 29 February 2016

Aircraft	In Operation	On Order	Average Age (years)
Jet Aircraft			
B777-300ER	7	-	3.9
B777-200ER	8	-	9.8
B787-9	6	6	1
B767-300ER	5	-	20.4
Airbus A320 - Shorthaul	13	-	11.6
Airbus A320 - Domestic	15	2	2.4
Turbo-props			
ATR72-600	9	20	1.7
ATR72-500	11		15.2
Q300	23	-	9.1
Beech 1900D	7		13.9
Totals	104	28	8.5

Air New Zealand's short-term jet fleet projection
(Air New Zealand, 2015 Annual Financial Results presentation)

Projected aircraft in service	2016	2017	2018	2019
Boeing 777-300ER	7	7	7	7
Boeing 777-200ER	8	8	8	8
Boeing 787-9	6	9	11	12
Boeing 767-300ER	4	2	-	-
Airbus A320	29	29	24	16
Airbus A320/A321 NEO*	-	-	6	13
ATR 72-600	12	14	14	14
ATR 72-500	11	11	11	11
Bombardier Q300	23	23	23	23
Beech 1900D	3	-	-	-

Research has found that the average age at which airplanes leave service is around 20 - 25 years[6].

Jet aircraft

Boeing 737-300 and Airbus A320. Air New Zealand began to replace its Boeing 737-300s with A320s in 2009. By the end of 2015, all B737-300s had been replaced. Air New Zealand's A320 fleet for domestic services is very young (2.4 years on average as at February 2016). We assume that Air New Zealand would keep this fleet in operation for the next 20 years. Meanwhile, a small number of new Airbus A320-like aircraft could be brought into the fleet.

[6] Jiang H (2013), Key Findings on Airplane Economic Life- Boeing (www.boeing.com/assets/pdf/commercial/aircraft_economic_life_whitepaper.pdf)

As of April 2016, Jetstar operates nine Airbus A320s in New Zealand[7]. In total, Jetstar has 52 Airbus A320s, with an average age of 6.4 years[8]. No information is available about Jetstar's fleet upgrade plans. We assume that Jetstar would use its current A320s to operate over the next 15 to 20 years.

Boeing 767 and 777. These are very large jets with a capacity of more than 200 or 300 seats. Historically they were occasionally used for domestic air services with a very small share of the total number of flights. They were no longer used for domestic air travel in 2016 and we assume that this will remain true in the future.

Turbo-props

Beech 1900D. Eagle Airways, a subsidiary of Air New Zealand, operates 15 Beech 1900Ds. In November 2014, Air New Zealand announced that it would replace all of its 19-seat Beech 1900D flights with 50-seat Q300 aircraft. From April 2015, Air New Zealand suspended Beech 1900D flights on a few regional routes[9]. All of its Beech flights ceased operation from early February 2016[10].

Dash 8-Q300 (DHC-8-300). From late 2014, some Beech 1900D flights were replaced by Q300 aircraft and in early 2016 all Beech flights were replaced. Air Nelson, another subsidiary of Air New Zealand, operates 23 Q300 aircraft with an average age of 9.1 years as of February 2016. Bombardier has ceased building turboprop aircraft apart from the larger Q400 (70 seats). This has left Air Nelson with the option of purchasing the Q400s or low-hour second-hand Q300s. However, Air New Zealand seems not to want to buy Q400s, fearing an inter-service rivalry with the slower but more economical ATR 72s[11]. In fact, Air New Zealand has ordered 20 ATR 72-600s. Therefore, we assume that Q300 flights will reduce over time, with an increasing share of ATR 72s in service. We assume that all 23 of the Q300 aircraft will be replaced by ATR 72s in the next 10 - 15 years.

Jetstar started to operate five Bombardier Q300s in New Zealand in December 2015. These aircraft are operated by Eastern Australian Airlines[12]. As of early 2016, the average age of Eastern Australian Airlines' Q300s is about 15 years. We assume all of these aircraft will be replaced by ATR 72-600s or similar aircraft in the next five to ten years.

ATR 72. Mount Cook Airlines, a subsidiary of Air New Zealand, operates ATR 72-500 and ATR 72-500 aircraft. Although the nine ATR 72-600s are very new (under two years old in early 2016), the 11 ATR 72-500s are fairly old (over 15 years). We assume that all of the latter will be replaced in the next ten years with new ATR 72-600s.

Other small aircraft types. A few types of small aircraft are used in domestic air travel. However, their share is small and their use is highly volatile and hard to project. We can reasonably assume that their share of domestic air travel will continue to be small.

---

[7] www.jetstar.com/nz/en/about-us/jetstar-group/jetstar-airways
[8] www.airfleets.net/ageflotte/Jetstar.htm
[9] www.airnewzealand.co.nz/press-release-2014-airnz-announces-outcome-of-review-to-deliver-more-sustainable-regional-air-services
[10] http://en.wikipedia.org/wiki/Eagle_Airways
[11] http://en.wikipedia.org/wiki/Air_Nelson
[12] www.jetstar.com/nz/en/about-us/jetstar-group/jetstar-airways

Other relevant announcements

In April 2016, Air New Zealand announced revisions to its domestic schedule effective from 30 October 2016 (CAPA Alerts, 2 May 2016). Air New Zealand will upgrade some Dash 8 operations to ATR 72 and will also increase Airbus A320 operations on some routes.