

Air Carrier Partner 2.0.15 Tool: Technical Documentation 2015 Data Year - United States Version





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1.0 Data Sources

Similar to the other SmartWay tools, air carrier partners provide information concerning fuel usage and aircraft activity including landing and take-off cycles (LTOs) and hours of operation in order to estimate CO₂, NO_x and PM₁₀ emissions, and to account for performance improvements made to their fleets over time.

The approach used to estimate CO₂ emissions associated with aircraft operations focuses on total fuel usage, while NO_x and PM₁₀ emissions are estimated using detailed information about fleet composition and operations. Most airlines provide aircraft-specific activity data to the FAA. To reduce the burden to Partners, the data elements required for this Tool are similar to the data already being reported to the FAA.

1.1 Available Emission Factors

Currently there are two types of aircraft engines used for non-military operations: aircraft equipped with turbine engines that use jet fuel, and smaller aircraft equipped with piston-driven engines that use aviation gasoline. The emission factors used for the fuel-based emission estimates are presented in Table 1.

Table 1 - Fuel-based Emission Factors (g/kg of fuel)

Fuel	g CO ₂ per kg fuel
Jet Fuel	3,131
Aviation Gas	3,146

Note: Alternative fuels such as biojet and synthetic fuels are currently being considered for commercial aviation applications. Only recently have these fuels received certification for aviation use at concentrations up to 50 percent. These fuels are being tested in pilot projects and have yet to be fully commercialized, which is expected to take several years as infrastructure issues related to the distribution and storage of these fuels are addressed. As results concerning the performance and associated emissions of these alternative fuels are released,

these data will be evaluated for possible inclusion in future versions of the SmartWay Air Tool.

The preferred approach for estimating NO_x and PM₁₀ is based on hours of operation and LTO activity data. Therefore fuel-based emission factors are not used for these pollutants. NO_x and PM₁₀ emissions are based on aircraft-specific data obtained from the FAA's Emission Dispersion Modeling System (EDMS). The fuel usage and emission factor data in EDMS are obtained from the International Civil Aviation Organization (ICAO) Aircraft Engine Databank and adjusted to account for the airframe to which the engine is applied. The NO_x and PM₁₀ emission factors have been updated using the most recent EDMS model, version 5.1.4.1. All current aircraft and engines included in version 5.1.4.1 have been added to the Air Tool.

The ICAO testing cycle focused on airport-related emissions. As such, only data on approach, landing, taxi-in, idle, taxi-out, takeoff, and climbout modes were collected. Emission factors for cruising are not provided in the ICAO test data, nor are they calculated in EDMS. For the SmartWay Air Tool, cruising emissions are calculated based on the assumption that the aircraft engines operate at a percent of take-off engine loads (i.e., maximum thrust), as specified by the user (see Engine Load % on the Aircraft Inventory worksheet of the Tool).

1.2 Aircraft Activity Data

Two types of activity data are required for the SmartWay Air Tool: data used to estimate emissions (e.g., fuel usage, hours of operation, and LTOs) and data needed to develop performance metrics (e.g., miles traveled, ton-miles, cargo payload and volume, utilization rates). Much (though not all) of the data needed for this Tool are publically reported, as summarized in Table 2. Some non-reported data, such as ton-miles and cargo volume utilization, will also need to be provided.

Table 2. Activity Data Sources

Activity Measure	Reporting Form	TranStats Database
Fuel Consumption	P-12A ^e	Schedule P-12A
	F-2 ^d	<i>Available on request</i>
LTOs	T-100 and T-100(f) ^a	T-100 Segment (All Carriers)
Distance Between Airports	T-100 and T-100(f) ^a	T-100 Segment (All Carriers)
Passengers Transported	T-100 and T-100(f) ^a	T-100 Segment (All Carriers)
Mail Transported	T-100 and T-100(f) ^a	T-100 Segment (All Carriers)
Freight Transported	T-100 and T-100(f) ^a	T-100 Segment (All Carriers)

Activity Measure	Reporting Form	TranStats Database
Operating Revenue	P-1.2 ^b	Schedule P-12
	P-1.1 ^c	Schedule P-11
	F-1 ^d	<i>Available on request</i>

^a Forms are submitted monthly by foreign, large certificated, commuter and small certificated carriers (14 CFR Parts 217, 241, 298). Foreign T-100(f) data are held confidential for six months. Small carrier data are held confidential for two and a half months.

^b Forms are submitted quarterly by large certificated carriers with annual operating revenues of \$20 million or more. Foreign carriers are not required to report financials. Large carrier financials data (P-1.2 and P-1.1) are held confidential for two and a half months.

^c Forms submitted semiannually by large certificated carriers with annual operating revenues of less than \$20 million.

^d Forms submitted quarterly by commuter and small certificated carriers. Small carrier financials and fuel consumption data (F-1 and F-2) are held confidential for 3 years. Small certificated and commuter carriers are defined by the size of planes in their fleet and the number of trips per week.

^e Forms submitted monthly by large certificated carriers with annual operating revenues of \$20 million or more. Foreign carriers are not required to report fuel usage.

For NO_x and PM₁₀, emissions at and near airports are estimated for individual aircraft by applying annual, aircraft-specific LTOs to the LTO emission factors in the EDMS model. Because aircraft trip lengths can vary significantly, total hours of operation are required to estimate the time spent in cruising mode. The total time associated with annual LTO activities are subtracted from the reported total annual hours to avoid double counting.

1.3 Aircraft Characterization Data

As noted above, CO₂ emissions are simply based on the amount of fuel used by the partner annually. For NO_x and PM₁₀, the two key data elements required to estimate emissions are the aircraft make and model and the associated engine make and model. As any given aircraft model can be equipped with a wide range of engines that have different fuel consumption and emission rates, it is important that partners provide as much detailed information as possible about the engines used in their fleet. In the newest version on EDMS (5.1.4.1), there are a total of 3,055 aircraft and engine combinations. The list of the possible aircraft and engine combinations are available in the AirTool-Aircraft-Engine-Data.xlsx file.

In a future version of the Air Tool, if partners do not know the engine for their aircraft, the Tool will identify default engines for each aircraft. For an engine to be designated as a default for a particular aircraft make and model, a valid aircraft engine combination should first be identified in the EDMS dataset. In some cases there is only engine listed per aircraft make/model in EDMS. For those aircraft, the one available engine is simply designated as the default engine. For other aircraft, Ascends* activity data are used to determine which engines are the most common for each aircraft. If an engine listed in Ascends is not in EDMS, the next most common engine is used instead. If there is no match with the Ascends data, internet search results provide the basis for determining the default engine.

Default engines are designated by a "1" in the Default column in the AirTool-Aircraft-Engine-Data.xlsx file.

In addition, to accurately represent a partner's performance metrics the Air Tool estimates aircraft capacity in units of mass and volume for 2,340 individual aircraft-engine combinations. In October 2014, using Jane's Transportation Reference Guide, Aviation Week's Aerospace & Defense Sourcebook, and other online resources, capacities for the individual aircraft were reviewed and over 125 corrections were made. Current capacities were quality checked by comparing the ratio of capacity and aircraft length, for similar sized aircraft. Capacity corrections were made calculated ratios were outside an acceptable range.

When weight capacity was clearly defined, values were chosen that reflected total passenger and luggage weight (military aircraft totals included munitions). Note that there are often inconsistencies in how capacities are defined, however, leading to uncertainty in these assignments. For this reason partners are encouraged to input their own estimates for weight and volume capacity if available.

2.0 Emission Estimation

Within the SmartWay Air Tool a fuel-based approach is used for the calculation of CO₂ while an operations-based approach is used for calculating NO_x and PM₁₀.

2.1 Emission Calculations Based on Fuel Consumption Data

CO₂ emissions are estimated using the following equation:

$$EM = FU_a \times FC \times EF_a$$

Where:

- EM = Emission estimate for CO₂ (grams per year)
- FU_a = Reported fuel use (gallons/year or tons/year) for fuel type a
- FC = Fuel conversion factor for gallons to kgs (Jet Fuel = 3.07 kilogram/gallon; aviation gasoline 2.73 kilogram/gallon); tons of fuel to kilograms (1 ton = 907.18 kilograms)
- EF_a = Emission factor for fuel type a (grams/kilogram of fuel) - Table 1
- a = Fuel type (e.g., jet fuel or aviation gasoline)

2.2 Emission Calculations Based on Aircraft-specific Data

The operations-based approach allows for NO_x and PM₁₀ emissions to account for individual aircraft in the partner's fleet. The emissions calculation is developed using two types of aircraft operations: 1) airport-related activities (i.e., approach, landing, taxi-in, idle, taxi-out, take-off, and climbout), which are quantified in terms of LTO cycles, and 2) cruising operations between airports, measured in hours.

2.2.1 Airport-related Activities

LTO data can be applied to aircraft-specific fuel-consumption and emission factors, which were developed from data extracted from the FAA's EDMS database. Within the Air Tool, aircraft engine emissions data are applied to time-in-mode data for each segment of the LTO cycle, providing aircraft-specific LTO-based emission factors. The time-in-mode values from EDMS vary by aircraft make and model, and actual time-in-mode values for taxi-in, idle, and taxi-out times can vary significantly between airports. Airport-related delays which affect taxi and idle times are not considered in the Air Tool emissions calculations. Instead, default EPA time-in-mode values are used to generate the LTO emission factors used in the Tool.

The default EPA time-in-mode values are included in the EPA's NEI documentation (http://www.epa.gov/ttnchie1/net/2008_nei/aircraft_report_final.pdf), page 2-14. Note that the NEI builds upon the FAA's EDMS model, and EDMS has two types of default values for takeoff/climbout/approach/landing – the first set matches the time periods used in the ICAO engine testing, while the second set accounts for airport-specific mixing height for climb out and approach. Because the Air Tool is set up to accept data for operations at any airport, the default ICAO times were used. Neither EDMS or ICAO data include default taxi times as these can vary significantly between airports, so the default values noted in the NEI documentation were used (taxi-in time 7 minutes and taxi-out time 19 minutes).

EDMS uses fuel based indexes to estimate emissions, which means the time in mode values are linked to fuel usage rates, which in turn vary based on aircraft model/engine combinations. These fuel usage rates are built into the EDMS model, which then calculates the emissions based on fuel usage. For the Air Tool, EDMS was run for each aircraft make model engine combination using the default times for 10,000 LTOs. The output was then divided by 10,000 to obtain a per LTO emission factor for each make/model/engine combination.

User-provided aircraft-specific LTO activity data (under Total Annual LTOs on the Aircraft Operations screen) is applied to the LTO emission factors using the following equation:

$$EA_{xp} = LTO_x \times EF_{Lxp}$$

Where:

- EA_{XP} = Airport-related aircraft emissions for specific aircraft model and engine combination (x) and pollutant (p) (grams per year)
- LTO_x = Annual LTO activity for specific aircraft (x) (LTOs/year)
- EF_{LXP} = LTO emission factor for specific aircraft (x) and pollutant (p) (grams/LTO)
- X = Specific aircraft make/model/engine combination
- P = Pollutant (NO_x or PM₁₀)

Additional information on the emission factors used for the LTO emission calculations can be found in the AirTool-Aircraft-Engine-Data.xlsx file.

2.2.2 Cruising Operations

Reported aircraft hours of operation include time spent in airport-related activities as well cruising. For this reason it is necessary to adjust the total hours value to estimate the time spent in the cruising mode. As noted, the period of time an aircraft spends in an LTO cycle varies by aircraft make and model, and time-in-

mode values are included in the EDMS model for all modes except idling. The EPA default value used in the latest National Emission Inventory (NEI) for the idling time-in-mode is used in the Air Tool.

The time spent in the cruising mode is estimated using the following equation:

$$TO_x = TH_x - (LTO_x \times LM_x / 60)$$

Where:

- TO_x = Total cruising hours of operation for specific aircraft x (hours/year)
- TH_x = Total hours of operation for specific aircraft (x)
- LTO_x = Annual LTOs for specific aircraft (x)
- LM_x = Total time spent per LTO cycle, minutes (from EDMS, EPA)
- 60 = Conversion - minutes per hour
- x = Aircraft make and model

To estimate cruising emissions, the cruising hours of operation are applied to the cruising emission factors. These emission factors assume that aircraft in cruising mode operate at the fraction of power specified in the Engine Load % field. Cruising emissions are estimated using the following equation:

$$EC_{xp} = TO_x \times (EF_{cXP} \times 3,600) \times LF_x / 70$$

Where:

- EC_{XP} = Cruising aircraft emissions for specific aircraft model (x) and pollutant (p) (grams per year)
- TO_x = Total cruising hours of operation for specific aircraft x (hours/year)
- EF_{cXP} = Cruising emission factor for specific aircraft (x) and pollutant (p) (grams / second)
- 3,600 = Conversion seconds per hour
- LF_x = Load factor specified for each aircraft make/model (x), in percent
- 70 = Default engine load factor percent for cruising operations from EDMS
- x = Specific aircraft make and model
- p = Pollutant

Additional information on the emission factors used for the cruising mode can be found in the AirTool-Aircraft-Engine-Data.xlsx file.

Once LTO and cruising emissions are calculated they are summed to determine total emissions for each aircraft.

2.3 Aircraft Upload Function

The Air Tool provides an upload function which allows the user to import hundreds or thousands of records for individual aircraft, including the engine characteristic and activity data needed to estimate emissions and performance metrics. The Air Tool aggregates the import file to the aircraft/engine level. To perform this aggregation the Tool weights the reported engine loads by total fuel consumption for the given aircraft/engine category. Similarly, individual weight capacity values (in pounds) are weighted by the relative fraction of ton-miles for the category, and volume capacity values (in cubic feet) are weighted by miles. Note that this approach only impacts the reported performance metrics, not the calculated mass emissions.

The SmartWay Air Tool is provided with an Excel file named “starter file.xls” which should be populated with aircraft-specific data for upload. Users can provide one record for each aircraft make/model/engine make/model combination. Each record should include data for the following columns:

- # aircraft
- Fuel Type
- Fuel Units
- fuel usage
- total miles
- total ton-
miles
- LTOs
- operating
hours

- weight
capacity
- volume
capacity
utilized
volume

The first two rows of the starter file contain example inputs for user reference. These rows should be over-written with actual data before importing into the Air Tool. Please be sure to save the updated file using the same name and Excel file format as the original starter file.

3.0 Performance Metrics

The SmartWay Air Tool is designed to apply calculated emissions to a variety of operational metrics. These metrics can be used as reference points to evaluate a partner's environmental performance relative to others. The equations used to estimate the different performance metrics are shown below.

3.1 Grams of Pollutant per Mile

$$PM_p = \sum EM_{PO} / M$$

Where:

- PM_p = Grams of pollutant per mile (grams/mile)
- EM_{PO} = Total annual emissions summed by pollutant (P) for both operation types (O) (grams per year)
- M = Total annual statute miles flown
- P = Pollutant
- O = Operation types (airport and cruising)

3.2 Grams of Pollutant per Ton-Mile

$$PTM_p = \sum E_{PTO} / TM$$

Where:

- PTM_p = Grams of pollutant per ton-mile (grams / ton-mile)
- E_{PO} = Annual emissions summed over operation type (O) by pollutant (P) (grams/year)
- TM = Total annual ton-miles
- P = Pollutant
- O = Operations (airport and cruising)

3.3 Grams of Pollutant per Thousand Cubic Foot-Miles

The Air Tool provides aircraft-specific weight and volume capacity in terms of pounds and cubic feet, respectively. *Volume characterization for a given aircraft make/model includes both passenger and luggage space, as well as the cargo hold.* Capacities were compiled using variety of sources, including manufacturer websites and the Aviation Source Book. The resulting volume capacity estimates were quality checked by comparing the ratio of capacity and aircraft length, for similar type and size aircraft.

Total mass emissions are divided by total fleet volume capacity and miles traveled to obtain emissions per thousand cubic foot-miles, using the following equation:

$$PCF_p = \sum E_{PO} / (CF/1,000 \times M)$$

Where:

PCF_p = Grams of pollutant per aircraft volume (grams/ thousand cubic foot-miles)

E_{PO} = Total annual emissions summed over operations (O) by pollutant (P) (grams/year)

CF = Total fleet capacity volume (cubic feet)

M = Total annual (statute) miles

P = Pollutant

O = Operations (airport and cruising)

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