



Greener Aircraft Taxiing: Single-Engine Taxi-out Evaluations

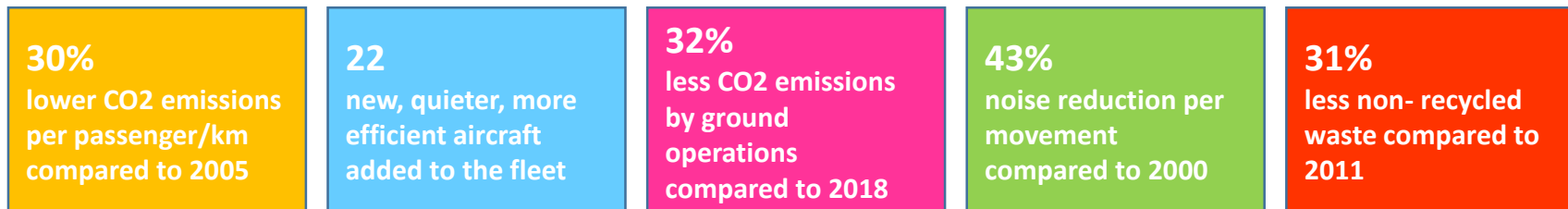
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Aviation Commitment to Environmental Sustainability

- Aviation's contribution to man-made greenhouse gas emissions is 2 - 3%
- The Aviation Industry is aware of its environmental impact, and is committed to reducing it further in its mission to "bring people and cargo all over the world" ...
- Airlines continue to invest into more efficient aircraft, more efficient operations, and the development of sustainable aviation fuels

- Key figures for AF-KLM Group (*Source: AF-KLM Sustainability Report 2019*)

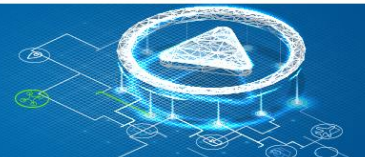


- **Focusing on Flight Operations**

- Fuel-efficient procedures are constantly studied and applied in operations whenever possible: Flight plan precision, Speed adjustments and Optimized procedures, Landing configurations, and, on the ground, **Taxiing with one engine off**

Single-Engine Taxiing

- Aircraft taxiing operations are a significant source of energy consumption and emissions at airports
- Moving on ground ("taxiing") is a short part of a flight, but in this phase jet engines are not at their optimal use
 - Several measures can reduce fuel-burn during ground operations
 - *"wait on stand" thanks to A-CDM/TSAT, minimize usage of APU, optimum taxi speed, ...*
- One improvement is to taxi with one (or several) engine shut down, since "n-1" engines provide enough power to move the aircraft on the ground
- Terminology
 - "Single" engine-off (one-of-two, one- or two-of-four, etc.) vs "All" engines-off (towing)
 - Distinguish Taxi-out (at departure) and Taxi-in (at arrival)



Impact? Possible Gains?

- **Estimates on the exact impact of taxiing are variable**

- *no direct systematic measurement available yet from AFR*

- **Orders of magnitude given in the literature:**

- **"Taxiing accounts for 10 to 30% of total flight time in Europe"**
 - *taxi times vary by airport, but certainly exceed engine warmup/cool-down times*
- **"Taxiing uses 10~13 kg fuel per minute for A320 family"**
- **Single-engine taxiing has the potential to...**
 - **"reduce fuel burn and carbon dioxide emissions by 20% to 40%"**
 - **"reduce emissions of nitrogen oxides by 10% to 30%"**

- **Nevertheless: on the many flights operated every day, multiplying small quantities by many occurrences, will bring benefit**

potential fuel saving per a/c type when taxiing with one engine off

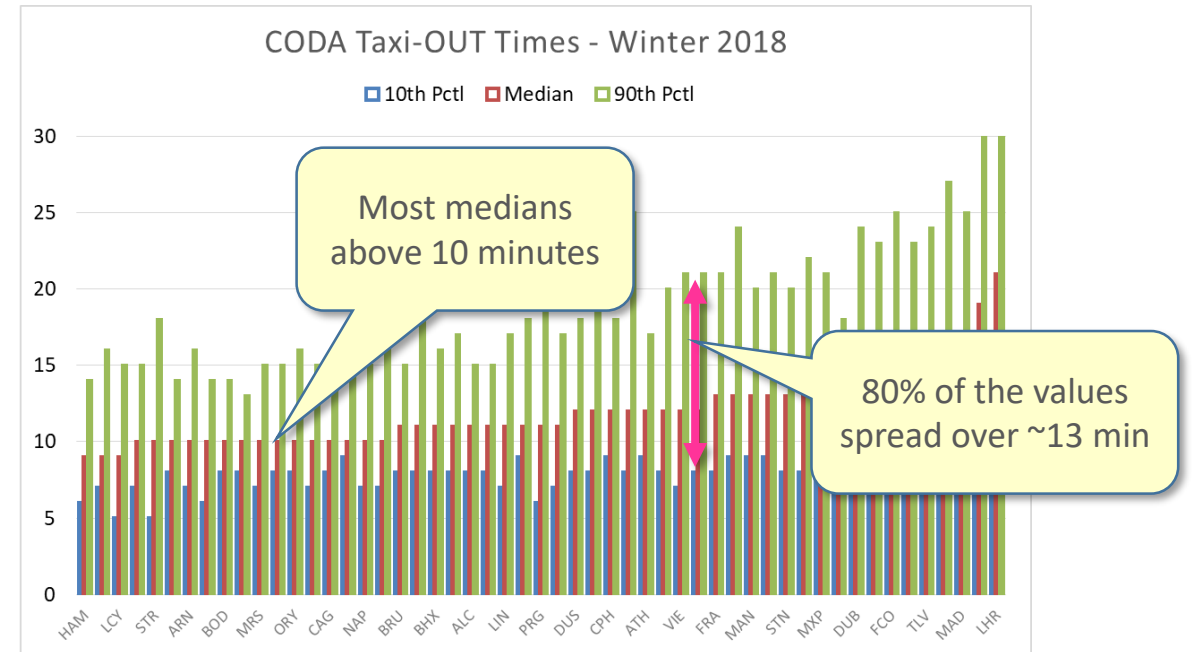
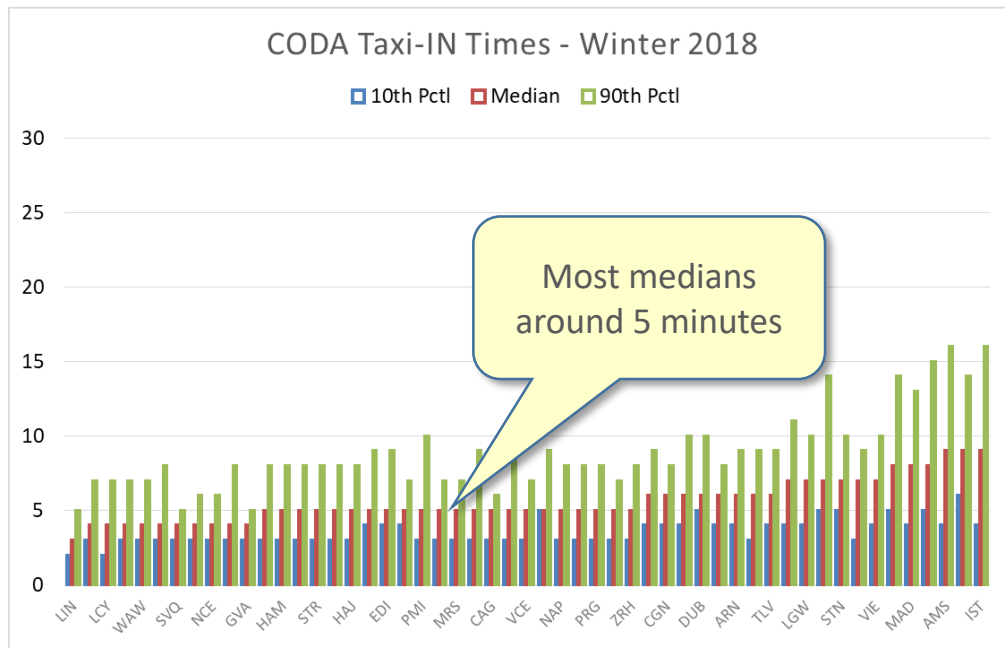
a/c type	saved fuel kg/min	typical cooldown time (seconds)
A320	5	180
B737	5	180
E190	4	120
A330	10	60
AT70	2	120
B777	13	180

typical turbofan warm-up is around 2 minutes UNLESS the engine is cold (2hrs stop)



Observed Taxi Times

- *Taxi-OUT tends to be longer than Taxi-IN*
- *Both are quite variable*



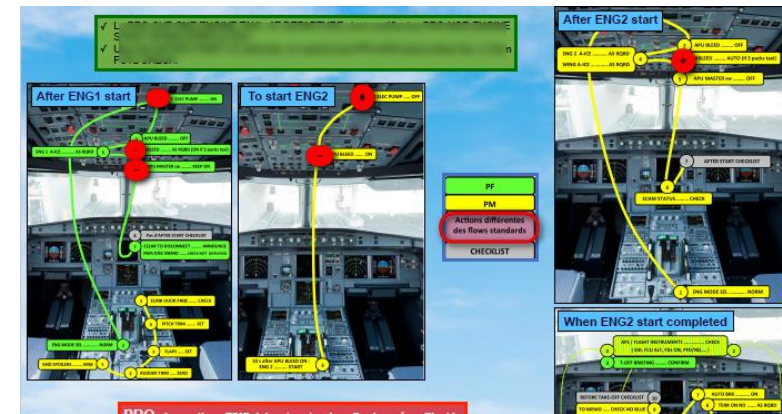
Source :
Eurocontrol CODA Database
Extraction of ~50 European airports

NB:
The two lists contain the same airports, but
are sorted differently (by growing Median)

Less simple than it may appear

- **Single-engine taxiing requires many points of attention**
 - Need to respect engine warmup and cooldown timing (plus fire hazard at **departure**)
 - Need to respect max parameters of the running engine
 - Changes manoeuvrability and balance of the a/c
 - Not possible for certain taxiways (turns, slope, cross active rwy, ...)
 - Simply forbidden at certain airports
 - Not possible depending on rain / wind / visibility ...
 - Not straightforward on certain a/c (power syst. architecture)
 - Workload for single-engine taxi-out at **departure** is higher than for taxi-in at arrival, because of the engine start procedure
- **Widely used on Arrivals**
 - *(estimated at ~50%, which is probably most of the "allowed" circumstances)*
- **...quite infrequent on Departures**
 - *(estimated at less than 10% of all departures – not a recommended procedure in most airlines)*

*A320 ENG1 / ENG2 start-up during taxi-out:
Steps in red are different from standard flow*



Challenges of Single-Engine Taxi-Out

- *"Can we encourage our pilots to perform Single-engine Taxi-OUT more often?"*
- **Uncertainty about the "available minutes" to taxi-out discourages pilots to apply S.E. Taxi-out**
 - Operational Flight Plans give "statistical" taxi times, that do not reflect the real conditions
 - Exact taxiways path, congestion of the platform, Runway pressure, ...
 - An accurate reliable indication of the time until takeoff would give confidence in the decision making, and allow to start the second engine not too late, not too early
- → *"How can we provide accurate departure info to the cockpit ..."*
 - This information exists on ground side (eg. DMAN, or A-CDM...)
 - "Information sharing" should be commodity nowadays (ground-ground and ground-aircraft)
 - *A reliable way to estimate this (TTOT? EXOT?) needs to be discussed with ATM and ACDM-communities*
 - Tower ATCOs may need to perform final sequence optimization, eg. based on wake turbulence
 - A-CDM implementation is not generalized, and practices are not identical on different platforms
 - → Absolute accuracy is not a prerequisite, a minimum available time must be known
 - *Best Ground-Aircraft communication: Voice? Acars? Gatelink? EFB? Display at the gate? ground staff? ...*



Conclusion

- Every measure to reduce environmental impact is good to take
- Single-engine Taxiing can bring a reduction of fuel-burn and emissions at the airport
 - *but Safety comes first!*
- Taxi-OUT appears to have some unexploited potential
 - *but it also has specific challenges*
- *Additional work can be done by Airlines, ATM, Airports, to explore the conditions to encourage wider usage of this technique in standard operations*