Alternative Taxiing Systems

Executive Summary

The global need for the sustainable aviation fuel is increasing and efforts for the carbon emission reduction are intimated from various stakeholders in the industry. Internationally there are two impactful policies introduced - CORSIA and EU-ETS which will drive strategic actions towards carbon emission reduction measures.

Aircraft Taxiing operations accounts for almost 50% of Airport's green house gases emissions which is major reason for Implementation of Alternative Taxiing system, this with along with savings from fuel and FOD maintenance savings presents an option to replace conventional taxiing system utilising both the engines.

Majorly there are two categories of ATS (Alternative Taxiing System/s) - External and Internal. While considering implementation of Internal(on-board) electric taxiing systems Taxiing time and range is critical which determines the operational benefits (feasibility). It is found that Airports with longer taxiing time and distance are the best candidates for implementation of ATS.

Segmentation of Airports of airports is required to synthesise the need and requirement of Airports where ATS can be implemented, this segmentation is done based on three criteria 1) Taxi-out time 2) Taxi-in time 3) On-time performance. New York and Delhi Airport appeared in all the three criteria being a member in Top 20 worst performers, evidently it's found that Delhi Airport has taken action to implement ATS - TaxiBots

Currently There are two ATS in operation that are TaxiBot which is a hybrid electric towing vehicle and WheelTug which is an on-board nose landing gear based Taxiing solution, one ATS is under development which is DLR with Hydrogen fuel cell as power source compared to Auxiliary power unit used in WheelTug's case. Two ATS development Projects - EGTS and Safran had been stopped in 2016 and 2019 our Technological problems as well as lack of confidence in viability of its implementation, Along with this there is some academia participation is also seen with publications on Electrical Taxiing system from Aeronautical Science Foundation of China and university of Nottingham

There are some studies quantifying the cost and fuel savings benefits it is found to be in range of 240k - 385k \$ per aircraft per year for On-Board systems and \$ 5.4m per TaxiBot which is of around \$ 1.5 - 3m cost, It is concluded that overarching evaluation is required which is not available from current research/ studies, to gauge the economical benefits from implementation and making Strategic comparisons among different Alternative Taxiing Systems.

Introduction

The aviation industry is one of the fastest-growing contributors of greenhouse gas emissions (CO2, CO), unburned hydrocarbons (HC) and mono-nitrogen oxides (NOx)

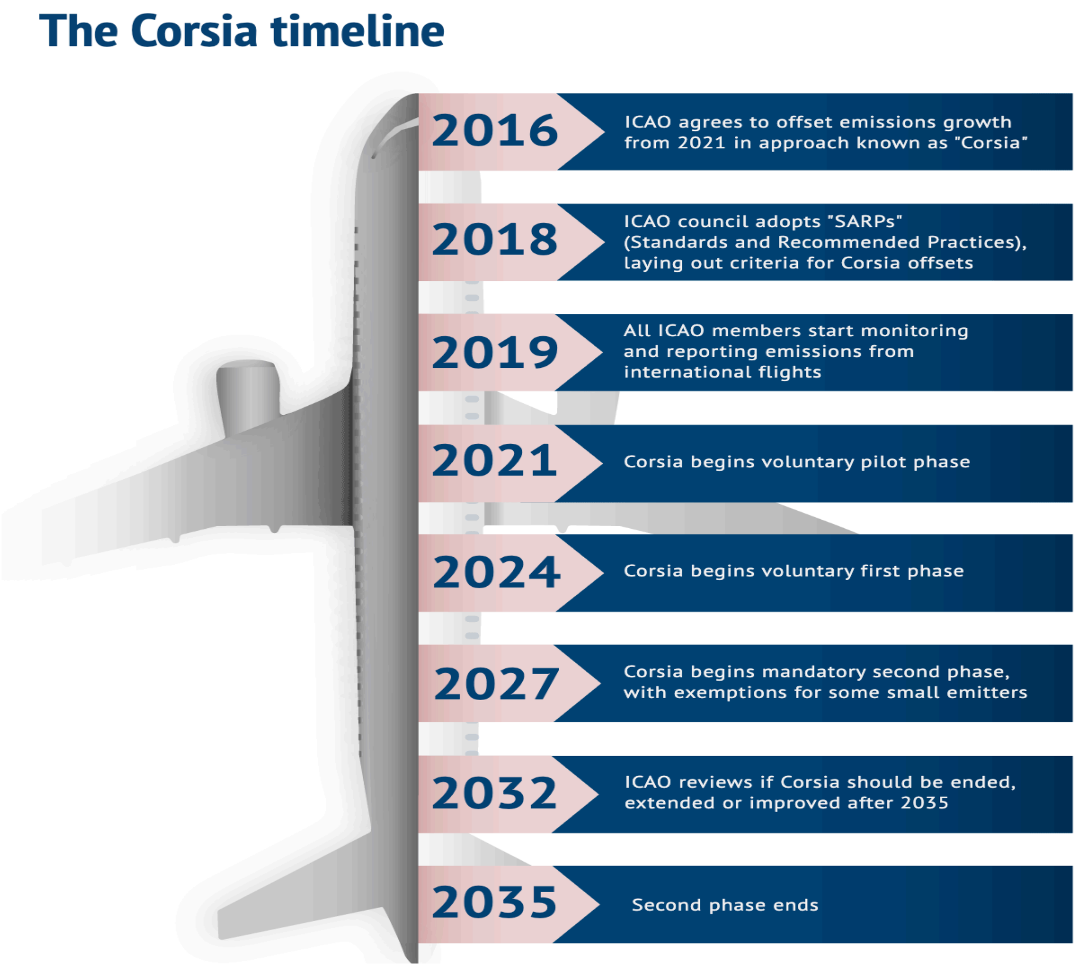
Since engines are optimised for cruising speed, they are highly inefficient when used in idle mode and therefore taxiing is addressed as one of the biggest contributors to the pollution and noise at the airports.

More than 56% of the total NOx generation in 2002 at Heathrow airport was from taxiing phase [0]

Continental legislation regarding emission targets

Unlike EU ETS Policy, Aviation Regulatory Bodies in Asia (Government) hasn't imposed carbon emission reduction targets but is progressing and planning for the same. There is mixed response from the Asian governments on accepting CORSIA [1]

CORSIA is the international Aviation policy which will have significant impact on decisions related to Green House Gas emission reduction in Aviation in coming years.



Policy Implications

- With the mandatory imposition of CORSIA after 2027

Aviation stakeholders will have to utilise stricter methods for emission reductions

The cost of carbon offsetting for operators would range from [2]

- 0.2 to 0.6 per cent of total revenues from international aviation in 2025
- 0.5 to 1.4 per cent of total revenues from international aviation in 2035

Offsetting cost (in 2012 Billion $)	**2025**	**2030**	**2035**
Less optimistic scenario (with IEA High carbon price)	6.2	12.4	23.9
Optimistic scenario (with Additional low carbon price)	1.5	2.9	5.3

Source: CAEP analysis presented at EAG/15)

- Fuel consumption during Taxiing is about 4% of overall flight fuel consumption
- CO2 emissions due to Taxiing Aircraft is about 36m ton annually which accounts for approximately 50% to Airports' CO2 emission

The study conducted in [3] shows that block-fuel (i.e., taxi fuel + flight fuel) savings for sole aircraft are highly dependent on the total ground time and flight distance. As expected, with the same flight distance, the longer is the total ground time the higher is the total fuel saved, as reported in Fig. 13

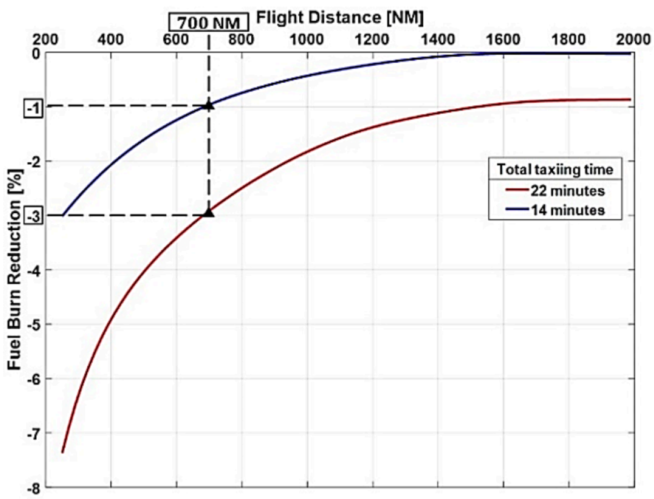


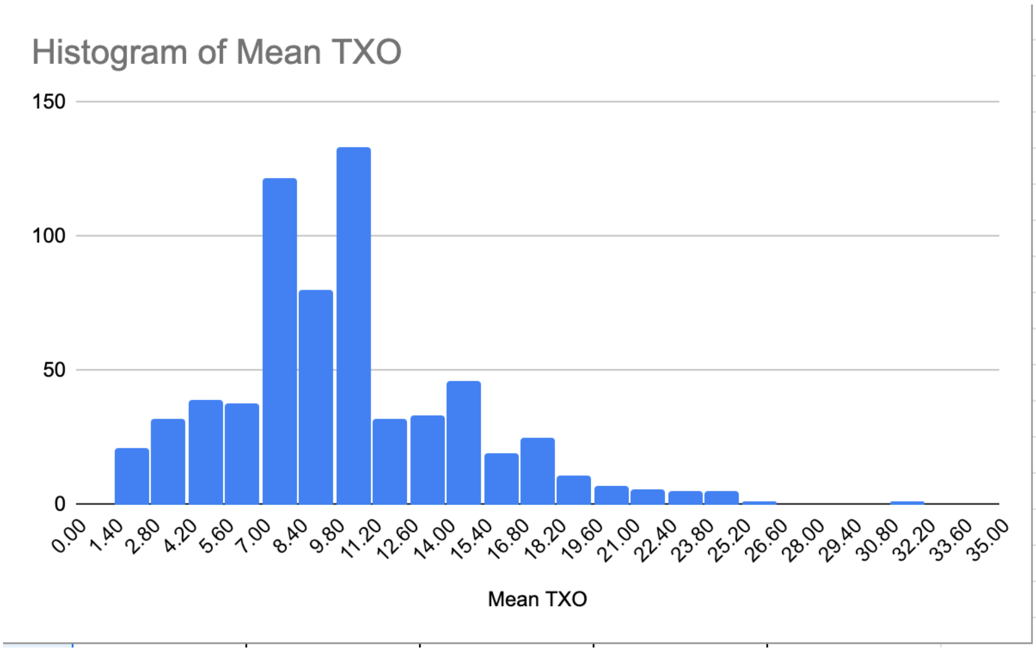
Fig. 13. Block-fuel reductions in respect to sector length and taxiing

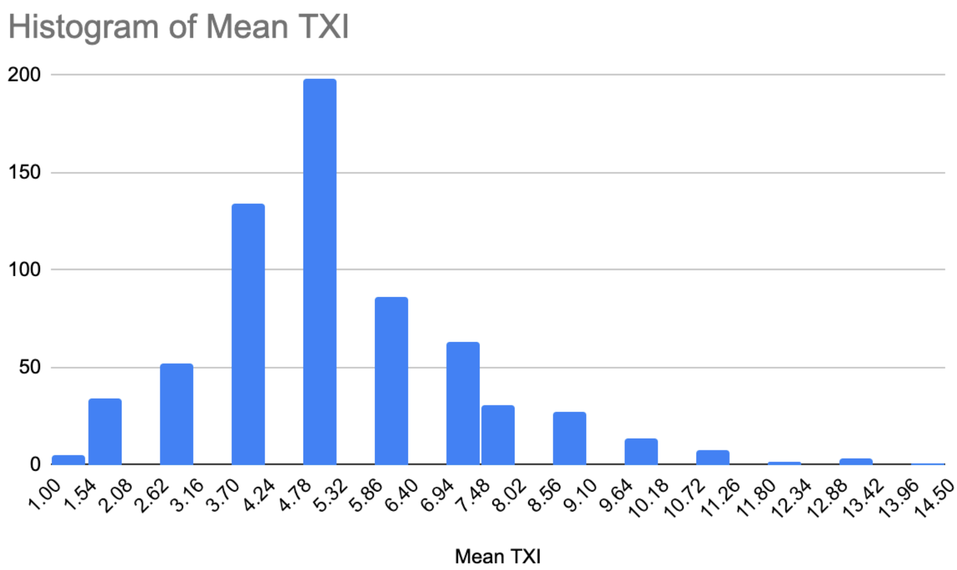
1 NM (Nautical miles) = 1.852 km

Market Segmentation - Airports :

Taxiing time is the most crucial parameter to consider for evaluating the feasibility of Implementing Alternative taxiing system and identify which solution suits the requirement of Airports

Data Source - [13]





Airport Name A	Mean TXO
New York	32
Chengdu	26
Newark	25
Las Vegas/Nevada	25
Philadelphia	25
Beijing	25
Atlanta Intl/Hartsfi	24
Washington	23
San Diego Intl/Calif	23
Mexico City	23
Manila	23
Bogota Intl/ Eldorado	23
Chicago O Hare Intl	22
San Francisco	22
Delhi	22
Guangzhou	22
London/Heathrow	21
Houston Intl/Texas	21
Montreal/Dorval	20
Vancouver Intl	20

Airport name B	OTP 2018
Kuala Lumpur	70.41%
Frankfurt	70.71%
Hong Kong	71.51%
Munich	71.98%
Beijing	73.87%
Boston	74.05%
London Heathrow	74.06%
Rome Fiumicino	74.09%
Melbourne	74.69%
San Francisco	75.64%
Delhi	76.01%
New York JFK	76.03%
Istanbul Ataturk	76.09%
Sydney	76.10%
Chicago O'Hare	76.67%
Orlando	76.98%
Fort Lauderdale	77.17%
Bangkok	77.21%
Amsterdam	77.73%
Dallas/Fort Worth	78.23%

Airport Name	Mean TXI
Los Angeles	14
New York	13
Jeddah	13
Simferopol	13
Krasnodar	12
Bombay	12
Luanda, Angola	11
Atlanta Intl/Hartsfi	11
Miami Intl/Florida	11
Ikaria Island	11
Fortaleza	11
Bogota Intl/ Eldorado	11
Bishkek	11
Delhi	11
Toronto Intl/L.B. PE	10
Johannesburg/ J.Smuts	10
Baltimore Washington	10
Detroit/Metropol Way	10
Newark	10
Madrid/Barajas	10

Figure: Top 20 Airports in 3 categories

1) worst mean taxi-out time 2) worst On Time Performance 3) worst mean taxi-in time

- OAG's definition of on-time performance (OTP) is flights that arrive or depart within 15 minutes of their scheduled arrival/departure times.
- Cancellations are also included.
- Airports must have a minimum of 2.5m departing seats to be included in the report.

Analysis from the data:

- New York and Delhi Airports are among the most suitable choice for implementation of ATS.
- It appears in all Top-20 list of longest taxi-in, taxi-out times and worst on-time performance.
- Bad on-time performance correlates with long taxi-out time for 6 airports
- There are 20 Airports among major busiest airports with average taxiing time out time exceeding 20 mins

Various Green Taxiing Alternatives [4]

Criteria	Taxibot	Wheeltug	DLR	EGTS	Safran
System Configuration	External	On Board (NLG+geared)	On Board (NLG+geared)	On Board (MLG + geared)	On Board (MLG + direct drive)
Status	Operational (2014)	2019	N/A	Stopped 2016	Stopped 2019
On-board Weight [Kg]	-	130-140	N/A	400	320-380
Power Source	Diesel generators	APU	Hydrogen fuel cell	APU + Main engines*	APU + Main engines*
Max Power [KW]	500	N/A	50	120	120
MaxSpeed [knots]	23	9-10	13.5	20	20

Criteria	Taxibot [8],[7]	Wheeltug [9]	DLR [10]	EGTS [11]	Safran [12]
Cost	$1.5-3 m	Pricing by Hour	N/A	-	-
Savings	$5.4 m py per Taxibot	$385k pa py	N/A	$240k-283k pa py	$250k-500k pa p
Towing Capacity [t]	68-85 (Narrow body)	78 (B737)	78 (A320)	78 (A320)	N/A
GHG Emission reduction	-98% CO_2	-60% of total emissions	N/A	-47% NO_x -62% CO_2 -74% HC -74% CO	-51% NO_x -62% HC -61% CO_2 -73% CO
Fuel Saving	98% of taxi fuel	50% of taxi fuel	~100% of taxi fuel	3% of block fuel	4% of block fuel

Model Example for Savings [14]

An A320 aircraft with two CFM56-5B5 engines, APU GTCP 131-9A, 2 h flight, TOT . 25 min (0.42 h, 1500 s).
We estimate the weight of the electric taxi system to be 300 kg with
1 kg of fuel = 0.75 EUR.

Fuel Cost Conventional = 2 engines*0.092 kg/sec*1500sec = 276 kg of fuel burnt

For the FCA, we expect a maximum workload fuel consumption
of the APU, which may reach up to 130 kg/h (0.036 kg/sec).

Fuel Cost ATS = 0.036 kg/sec *1500sec = 54 kg of fuel

FCC-FCA = 222 Kg of Fuel (167 EUR)

Additional savings will be from FOD maintenance savings and carbon emission taxes

This 167 EUR is for 1 cycle of ATS usage annually let say 1000 cycles take place so approximately 167K EUR are saved while in the case of TaxiBot benefits may vary.

Developments and Technological challenges

1. Taxibot

TaxiBot is an external ETS developed by Israeli Aerospace Industries (IAI). It is a semi-autonomous hybrid electric tractor designed to tow the aircraft during all the on-ground procedures (i.e., pushback, taxi-out, and taxi-in).

three narrow-body models have been operating for Lufthansa LEOS (i.e., ground handling company of Lufthansa) at Frankfurt International airport. Development still ongoing for Wide Body Aircraft TaxiBot

In May 2017, the EASA also certified the TaxiBot for the Airbus A320 family. In October of the same year, the TaxiBox certification in the old continent was followed by the Federal Aviation Administration (FAA) certification for the Boeing 737 family.

In October 2018, the TaxiBot was brought into service even at Delhi airport, with the goal of extending its motor pool up to 40 tractors to be employed at the busiest Indian airports in the next four years [5]
Considering TaxiBot, the major challenge is of economic nature. The narrow body is expected to have a unit cost of approximately $1.5 million, whereas the wide body roughly prices $3 million [6]

2. WheelTug

Wheel tug possess patent Mesh con drive for Mechanical geared drive for Motor attachment to NLG and on the positive side has received more than 1100 orders from 20 airlines

Regarding the certification process, in January 2017, the FAA has approved WheelTug's plans for Boeing 737 NLG, while Air Transat has voluntarily offered to help with the related efforts

Stirling Dynamics, a UK leader in landing gear development, has been chosen by WheelTug to design a new nose wheel for a better fitting of the the motor drive

The rise of power level requested from the APU represents an actual challenge for the future of the on-board ETSs. Such demand could be solved by redesigning the APU, in order to power new ET and other common aircraft electrical loads and at the same time providing enough bleed air for engine start-up.

This would, in turn, make the adoption of on-board ETSs even more unfavourable and costly for both the aircraft manufacturers and airlines

3. DLR

The DLR ETS was tested in 2011 at Hamburg Finkerwerder airport on an Airbus A320 .

Despite the major perceived advantages, its bottleneck is represented by the fuel cells, which are still not technologically fully developed for mobile applications. In fact, there are still weight and safety issues associated with on-board hydrogen storage.

4. EGTS and Safran

The main challenges faced EGTS is the geared Mechanical drive placed at MLG and Thermal Management. Even though the demonstration provided a positive outcome, Safran and Honeywell decided to terminate the EGTS project in 2016.

Safran continued to work on ETS under Clean Sky 2 framework involving Airbus in collaboration but in Dec, 2019 Safran suspended electric jet taxiing project reason being the system didn't offer enough technical maturity and performance in its current form

Research and Development Activities

Apart from industry in Academia few projects are undertaken related to On-board Electric Taxiing system

The Aeronautical Science Foundation of China - Project 2018ZC09002

University of Nottingham and Safran collaborated with the Airbus, Adeneo and DLR system under the CleanSky Joint Technology Initiative, for continuing the work of and developing a direct-drive on-board ETS for MLG

Conclusion on Alternative Taxiing Systems

Cost Benefits

- Savings related to carbon, GHG emissions

- FOD Cost savings

- Fuel savings

Disadvantages

- Maintenance Costs

- One time expenses

- Delays (in case of WheelTug or DLR)

From the research and study done on this Topic, It is concluded that further research including overarching evaluation is required which is not available from current research/studies, to gauge the economical benefits from implementation and making Strategic comparisons among different Alternative Taxiing Systems