International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 1
January 2018

Remedial Approaches to Reduce Impact of Aviation Emission

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***Abstract**:*

Aviation industry is associated with a variety of aircraft emissions and noise concerns that have an impact on global and local environment. Locally, in the vicinity of the airport, noise is one of the most commonly voiced concerns, and local emissions of concern are CO_2, volatile organic hydrocarbons, and nitrogen oxides. Aviation emissions account for approximately 3.5% of the human contribution to global warming from fossil fuel use. This will probably grow to 5-6% of the total effect by 2050. Aviation contributes an estimated 2% of the emissions of CO_2 from fossil fuels, and this is expected to grow to 3% by 2050. The present study briefly reviews the various aspects of emission caused by aviation industries and there short and long term effects on local and global environment. Few approaches requiring technological amendments and/ or advancements to curve the release of harmful gases and particulates in the atmosphere by aviation industries has also been briefly discussed.

Keywords

Engine, Aircraft design, Airports, Flight operational procedure, Fuel efficiency, Policies

1. Introduction

India is the fourth worst country in the world in environmental problems according to Environmental Performance Index (2018), out of 180 countries. India ranked 177, only better in environmental performance than the Democratic Republic of Congo, Bangladesh and Burundi. This is especially worrying because India's rank was 141 in 2016. India’s low scores are influenced by poor performance in Environmental Health policy objective. Institute for Health Metrics and Evaluation, 2017 estimated deaths attributed to PM2.5 have risen over the past decade and are estimated at 1,640,113, annual. Despite government action, pollution from solid fuels, coal and crop residue burning, and emissions from motor vehicles continue to severely degrade the air quality for millions of Indians.

The contribution of aviation in emission is smaller than road or railway transport modes but it emits emission at higher altitude in both the lower stratosphere and higher troposphere which is of great concern for environment. The principal emissions from aviation combustion processes comprise CO_2 and water vapor with a share of approximately 70% and a little less than 30% respectively. The remainder consists of NO_x, CO, SO_x, VOC, particulates and other trace components including HAPs as shown in figure 1. Globally, the important atmospheric constituents of environmental concerns are CO_2 and water vapor, nitrogen oxides (NO_x), and sulfur oxides. CO_2 has a 100-year atmosphere lifetime, and is well mixed throughout the atmosphere and extra carbon dioxide increases the greenhouse effect. More heat is trapped by the atmosphere; caused increase in global temperature. The vast majority of emissions (90%) occur during the cruise cycle, with the exception of CO and VOC, for which the share is 30 % on the ground and 70% on higher altitudes. The CO_2 from aviation operations is indistinguishable from that from other sources.

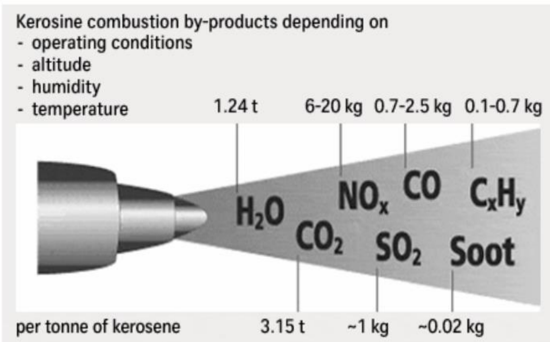

Figure 1: Emissions from Jet fuel combustion

The nitrogen oxides, sulfur oxides, water vapor and particles have a much shorter residence time, and remain concentrated near the flight routes, mainly in

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the northern mid-latitudes where most of the world's air travel occurs. However, the impact of these emissions is difficult to quantify. Ozone is not emitted directly into the air but is formed by the reaction of NO_x and VOC in the presence of heat and sunlight. The effects of aircraft NOx, water vapor, and particulates in combination with CO_2 could be two to four times the effect of the CO_2 alone.

In addition to its contribution to climate change, aviation has a number of other impacts, most notably on ambient air quality and subsequently on public health. The major air pollutant from aircraft operations is NO_x and to a considerably minor degree CO, SO_x, VOC and PM. Poor air quality is known to have a damaging effect on health. Depending on the level and type of pollution, symptoms can range from minor irritation to severe effects (particularly amongst those suffering from respiratory illnesses). Air pollution can also damage vegetation and ecosystems. Pollutants are emitted from aircraft engines, particularly affecting those working and\living near an airport. Ground vehicles operating at airports, passenger transport, employee transport and delivery vehicles also contribute to aviation's pollutant emissions. Emissions from aircraft are likely to become more significant as a source of air pollution around airports. Furthermore, even if the full potential of technical and operational measures to reduce emissions were achieved, overall levels of emissions from an increased number of all sources would still be expected to rise. The numbers of people potentially affected by these emissions would depend on their proximity to the pollution sources and the local conditions affecting dispersal of the pollutants. Most air quality assessments and emission inventories focus on aircraft emissions released during the landing and takeoff cycle (LTO) of an aircraft below 3000 feet, although 90% of emissions occur at the cruise cycle. Emissions also arise from various activities concerning ground transportation and power generation at the airport.

IPCC projected five different future emission scenarios and finds a range of outcomes between 1.03 and 2.41 Gt increase in CO_2 emissions by 2050. This means that CO_2 emissions will grow annually by 2.8% in the worst case and by 0.8% in the best case scenario between 2000 and 2050 and are projected to make up between 10% and 16% of total transportation carbon emission. The same simulations for NO_x emissions vary from a 2% increment to a 0.1% decline per year by 2050. A number of CO_2 emission estimations with different assumptions and outcomes are shown in figure 2. Drawing from this picture, it is clear that CO_2 emissions will continue to rise in the future.

Air transport is one of the major contributors to the growth in global gross domestic product. It also generates significant employment in all countries. There are features that distinguish aviation from other transportation modes and industries that must be factored into environmentally-motivated strategies. At present, India is the world's ninth largest aviation market with more than 80 operational airports with 17 airports having international operations, more than 700 aircraft, 14 scheduled airlines and nearly 120 non-scheduled operators. Currently, India's aviation industry caters to nearly 122 million domestic and 47 million international passengers. Over the next decade, the market could reach 337 million domestic and 84 million international passengers. Therefore, the Indian aviation industry has a large potential for growth in the years to come. Aviation places a high premium on safety, which demands the incorporation of only proven and technically sound technologies to reduce environmental impacts. Aircraft are high cost and have a long life span, requiring long lead times for new technologies to be widely incorporated in the fleet. Airframe and engine manufacturers as well as airlines will need to invest the capital to build and operate aircraft with new technologies for aviation to realize the environmental and operational benefits. Airport infrastructure requires substantial planning and construction effort, as well as public and financial support

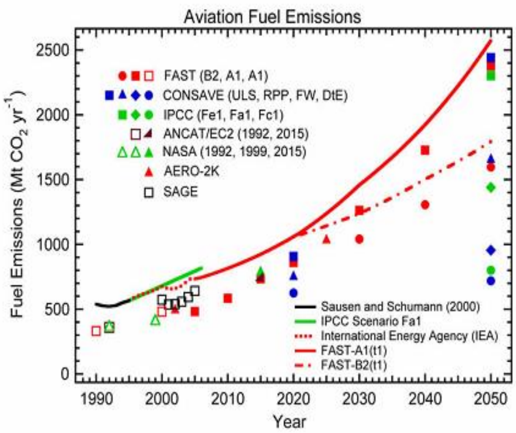

Figure 2: Future projections for aviation emissions

The intent of this study is to review various approaches to increase aircraft fuel efficiency and to reduce aircraft emission. Also, initiatives by Indian regulatory bodies to mitigate emission and its effects on environment takes has been briefly discussed

2. Approaches to Reduce Aviation Emission

Over the years, new technologies have been introduced to reduce the amount of emissions but with the technologies the demand of transportation is also increasing and these advances have not kept pace with the increased demand for air transportation. Emission can be reduced by increased fuel efficiency, more fuel burn will result more emission, in approximate terms, every ton of aviation fuel burned produces between 3.15 and 3.18 tons of CO_2, therefore the best approach to reduce emission is to adopt new and modified technologies, instruments, equipment etc. so that aircraft could reach to its destination but with lesser amount of fuel.

Indian Aviation industries are more fuel efficient than earlier with step by step changes in engine design, aircraft design, fuel technology, fleet upgradation, operation procedure and Air traffic management (ATM). ICAO (2010) in Environmental Report stated that 50% fuel efficiency will be improved by 2050 relative to the aircraft currently produced as shown in figure 3.

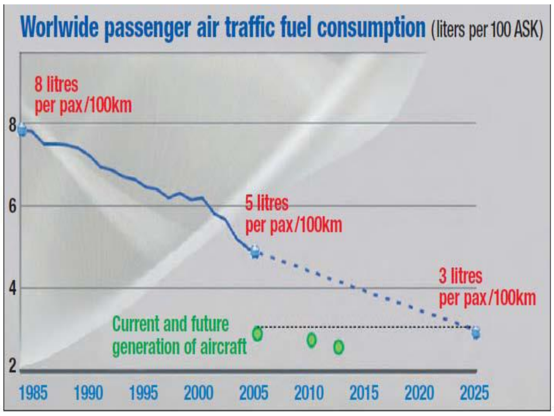

Figure 3: Air traffic fuel efficiency

2.1 Engine Technology

To increase fuel efficiency or to reduce CO_2 emission, higher value of thermal as well as propulsive efficiency is required. There have been a number of significant advances in engine design that have led to huge improvements in efficiency since 1960 from turboprop engine to turbofan engines, geared turbofans and openrotor engines. Multiple engine upgrade programs have already reduced the fuel burn per unit of delivered thrust by up to 2 % fuel burn in the last decade. Scheduled maintenance activities also help to keep engines operating at peak efficiency levels. According to ICAO, there should be some compromise with excess weight and cost factor to increase fuel efficiency by improved combustion at higher operating pressure ratio, by installation of new and advanced instrumentation and equipment. ICAO predicted the future of engine fuel consumption as shown in figure 4.

NOx emissions from aircrafts can be reduced by using advanced multi staged combustor chambers which control NOx by switching (staging) between pilot and main burner zones arranged in concentric circles. Combustion at higher pressure results increased thrust but also leads to more NOx emissions which is undesirable. The open-rotor architecture provides a solution for this along with offering benefits for lower NOx emissions. However, the open-rotor configuration raises some challenges for the designer with respect to Noise.

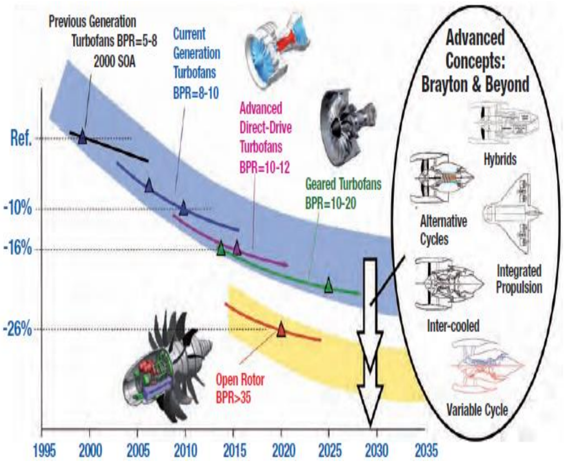

Figure 4: Future of engine fuel consumption trends

2.2 Aircraft Design

During flight, aircraft overcome drag force which opposes its motion through the air using the force of thrust provided by the engines after consumption of fuel. Drag force depends upon weight and shape of an aircraft so aircraft designers constantly experimenting to improve existing design to reduce aircraft weight, shape to maintain smooth flight with less drag and to achieve higher fuel efficiencies. Drag can be minimized with modified curvature of an airfoil, reducing turbulent skin friction,

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minimizing wetted areas and optimizing exhaust devices and with installation of winglets.

Use of advanced alloys and composite materials mainly carbon- and glass-fiber reinforced plastic and has much better strength-to-weight ratio than metals sometimes by as much as 20%. Innovative manufacturing techniques using advanced welding technologies such as laser beam, electron beam and friction stir welding remove the need for traditional rivets, thereby reducing aerodynamic drag as well as decreasing aircraft weight. Some other interesting and promising improvements include new aircraft paints weighing 10-20 % lesser and more resistant to chipping and cracking. With a fully integrated design by including wing, tail, belly fairing, pylon, engine, high lift devices etc. aircraft performance can be improved

2.3 Alternative Fuels

The majority of fuel used by aircraft since the beginning of powered flight has been derived from petroleum with very limited amounts produced from coal and natural gas. Jet fuel refined from oil (kerosene) is the most widely used by commercial aviation and is also known by its technical designations for civilian (Jet A and Jet A-1) uses. Jet fuel must meet very strict certification standards for a range of key operating parameters including composition, volatility, fluidity, combustion, corrosion, thermal stability, and contaminants. Biofuels used by civilian aircraft (also known collectively as biojet) are produced from biological feedstocks (Figure 5) and must also meet the strict qualification standards implemented by ASTM International and other associated organizations globally.

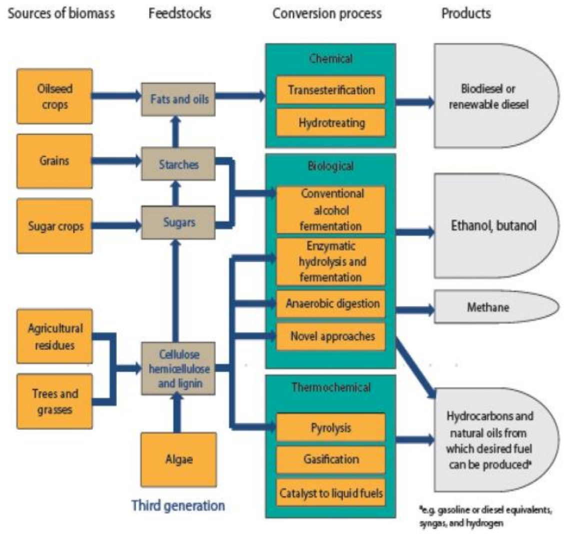

Figure 5: Feedstock/ conversion pathways (OECD, 2011)

Fossil fuels introduce new carbon into the atmosphere; biofuels are only recycling into the atmosphere carbon that was absorbed from it in growing the biofuel crop. In this way, the combustion of biofuel has come to be regarded as carbon neutral. In effect, under this approach, unless the emissions involved in producing a biofuel exceed the combined emissions from both producing and burning a fossil fuel, the biofuel is deemed to reduce greenhouse gas emissions.

For instance, the ICAO reports that life cycle analysis of different alternative fuels show a significant variability; emissions can be between ten times lower or eight times higher compared to those from conventional jet fuel. The deployment of sustainable aviation fuel faces serious environmental, social, economic and technical challenges. Environmental aspects pertaining to these challenges include, among others, a comparison of life cycle GHG emissions, land use change, ecosystem interaction, soil and water use. Another issue often raised in relation to bio fuels is food security. Second-generation biofuels from cellulose have the potential to be low-carbon fuels. Some researchers believe cellulosic material has the potential to be low-carbon because it takes little energy (and emissions) to grow and will potentially have high yields and derived from the production of biomass (e.g. Camelina, Algae, Jatropha and Halophytes), natural gas, coal or hydrogen.

2.4 Operational Procedure

The best way to improve fuel efficiency is to add new modernized aircraft in fleet incorporating with latest and updated technologies and with better flight management systems. Other improvements in operational procedure includes increased load factors by eliminating non-essential weight (The lighter an aircraft is, the less fuel it will burn), limiting use of auxiliary power and reducing taxiing and Continuous Descent Approach. Changes to aircraft operational procedures both in the air and on the ground can reduce the amount of fuel they burn and hence the volume of CO_2 they emit.

Continuous Climb Operations and Continuous Descent Operations aim to make the climb to or descent from cruising altitude more efficient. Just as in a car, smoother acceleration and deceleration burns less fuel, so a smoother, steadier climb with fewer changes of speed will require less aircraft fuel. A similar principle applies to descent, where a smoother descent with engine shut down, reduces the need for braking and re-acceleration and produces less noise. Clearly, this requires detailed flight planning and assistance from air traffic control.

In India, the operators are being advised on improvement in fuel efficiency in their respective fleet. The operators have already started to reduce fuel consumption by adopting better operational procedures such as minimum usage of APU, reduced flap takeoff and landings, idle reverse on landing, proper flight planning system, adhering to proper maintenance of aircraft, weight reductions in the form of reducing the weight of cabin equipment, catering services, avoiding carrying extra fuel on board, etc. IATA estimates that within India, a streamlined ATM system can cut airlines' fuel bills and thus emissions by more than 50 % as shown in figure 6.

2.5 Traffic Management System

It has been estimated that improvements in automatic traffic management system could lead to increases in energy efficiency, estimated to be in the order of 6-12 %. Aircraft burn fuel and emit emissions at differing rates during the different stages of a flight. A high rate of fuel burn during takeoff due to climb to cruise altitude and air at a lower altitude is denser, creating more drag on the aircraft: at this stage the aircraft is at its heaviest because it holds all the fuel needed for the journey. Flight at cruise altitude is the most fuel-efficient stage of the flight because the air is less dense and the aircraft is flying at its most efficient operating speed. At the time of landing most of the fuel has been consumed, requires less power emitting proportionally lower emissions than at the start of the flight.

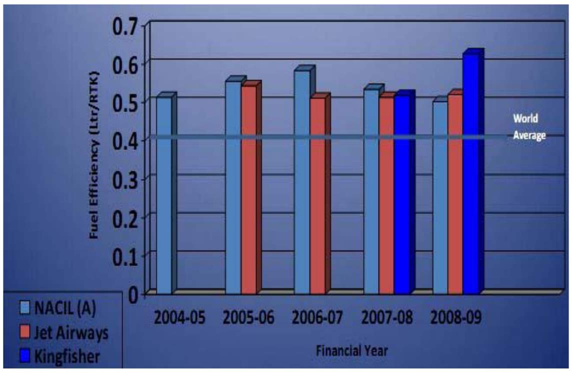

Figure 6: Fuel consumption trends in Indian operators in the international sector

Due to high emissions at the start of a journey, short-haul flights are deemed the most inefficient because they spend a greater proportion of their total journey in the high emissions phase. These aircraft are also likely to do more short flights during a day, spending more time in the take-off and climb phase than longer haul aircraft. Long-haul journeys are broadly speaking the next most inefficient type of flight. Although the aircraft spends a long time at its most efficient cruise altitude, the aircraft has to carry more fuel to cover the long distance and this extra weight makes it burn more fuel. Medium distance flights of between 2,000 and 5,000 km are therefore the most fuel-efficient flights and tend to emit the lowest emissions per km travelled.

2.6 Airports

Airports should install electrical supplies directly to aircraft to reduce fuel use and carbon emissions and Limit use of Auxiliary power unit to save fuel and to minimize pollution. Fuel cells should utilize in place of separate power generation/ storage systems. These cells could reduce carbon emissions by over 6,000 tons per aircraft over its operational life.

New Indian Airports should be designed by Green building codes and also encouraged to use solar panels, waste management plants, waste water treatment and rain water harvesting systems. Also, the vehicles operated inside the airports must be working on compressed natural gas to reduce the carbon emissions

Aircraft noise monitoring systems should be installed at various locations. Performance Based Navigation procedures should implement at all airports and airspace to optimize airspace utilization and enhance airport capacity by taking advantage of airborne capabilities and Global Navigation Satellite Systems (GNSS).

2.7 Airlines

Airlines should cut down aircraft weight for better performance and fuel efficiency. Some of the ways to reduce weight are Lighter beverage cart, seats made with lighter metal/alloy, eliminate ovens to provide hot meals on selected flights, remove magazine racks and replacing hard cabin dividers with curtains. Store water bottle according to the number passengers on board rather than completely filling the water tanks for each flight. Routinely inspection of aircraft exterior surfaces during regular maintenance checks to identify and correct defects including chipped paint, scratches and damaged seals can also reduce the annual fuel consumption of an aircraft by 0.5%.

3. Initiatives to Reduce Emission in India

According to the DGCA, the best performing airline in terms of improving fuel and carbon efficiency was Jet Airways, with smaller improvements by SpiceJet, GoAir and the Air India Group whereas small performance declines by IndiGo and Jet Lite. Some Indian scheduled passenger airlines are below the global average while others are above, suggesting there is room for further improvements in efficiency.

There has been some encouraging progress, such as the development by the Hydro-Processing Lab at the Indian Institute of Petroleum of jet fuel from jatropha for engine testing that meets international specifications. Both Jet Airways and Air India have plans to use biofuel on a domestic demonstration flight.

DGCA had proposed a number of actions including further development of the annual carbon footprint report, the dissemination of information and reporting on emissions and the holding of regular workshops for Indian airlines and airport operators. This should be used to promote increased awareness concerning aviation's role in climate change, improving data collection procedures, identifying areas for efficiency interventions and encouraging collaboration and close cooperation amongst stakeholders to achieve emissions reductions.

The DGCA also noted the decision by ICAO to develop a global market-based measure for international aviation emissions for approval at the next Assembly and implementation from 2020. India signed the UNFCCC on 10th June, 1992 and ratified it on 1st November, 1993. The Kyoto Protocol to the UNFCCC was adopted in 1997, which requires developed countries and economies in transition to reduce their Greenhouse Gas (GHG) emissions below 1990 levels. India acceded to the Kyoto Protocol on 26th August, 2002. As per the UNFCCC and its protocol, developing countries such as India, do not have binding on GHG mitigation commitments in recognition of their small contribution as well as low financial and technical capacities.

India is engaging actively in multilateral negotiations in a positive, constructive and forward looking manner with an objective to establish an effective, cooperative and equitable global approach based on the principle of Common but Differentiated Responsibilities (CBDR) and respective capabilities. The success of India's efforts would be significantly enhanced provided the developed countries affirm their responsibility for GHG emissions and fulfil their commitments to transfer new and additional resources and climate friendly technologies to support both adaptation and mitigation in developing countries rather by imposing the same level of standards and requirements on all States to developed countries.

3.1 Airline initiatives

Recent improvements to newer, more fuel-efficient aircraft joining Indian fleets such as the Boeing 787 with Air India and the Bombardier Q400s operated by SpiceJet along with the fitting of fuel-saving devices such as sharklets and winglets on narrow-body Airbus and Boeing aircraft. Other initiatives include engine washing by Air India, single-engine taxi procedures by Blue Dart, onboard weight reductions by Jet Airways and fuel management improvements made by SpiceJet.

Biofuels have been identified as a major source for reducing CO_2 emissions which have the additional advantages of bringing the possibility of local production of feedstocks such as jatropha along with a reduction in fuel price volatility and the reliance on fossil fuels.

3.2 Airport initiatives

Usage of battery operated vehicles for transferring passengers from one terminal to another in the airport. Adoption of Carbon Accounting & Management System (CAMS) for reducing airports GHG emissions which is based on the guidelines provided in the ISO 14064-1 for quantification and reporting of greenhouse gas emissions and removals. Airports are also using Environment Management System (ISO 14001), Energy Management System (ISO 50001:2011) and Green House Gas Reporting (ISO 14064) mechanism which helps them to develop and implement policy, objectives and action plans taking into account legal and other requirements for GHG reduction;

Participation in Airport Carbon Accreditation Programs at various levels for emission reduction; as of now, Bangalore, Hyderabad, New Delhi and Mumbai airports are members of Airport Carbon Accreditation and have been accredited at different levels such as Optimization and Reduction levels.

Participation in Leadership in Energy and Environment Design (LEED) with an objective to reduce pollution & waste management, provision for eco-friendly vehicles, use of recycled water, energy-efficient electric lighting, etc;

Use of advanced aerobridges fitted Fixed Electrical Ground Power (FEGP) and Preconditioned Air (PCA) in order to minimize aircraft and vehicular pollution at the airport and prevents the use of APU at parking bay

Use of dedicated Compressed Natural Gas (CNG) vehicles and electrically operated baggage tugs and buggies for transport of baggage, cargo and passenger in the apron, cargo and passenger terminal building;

Installation of solar power plant at airside premises and solar water heaters at the terminals in order to promote renewable energy use

Continuous Descent Approach (CDA) and Continuous Decision Making (CDM) procedures to reduce taxi time leading to fuel saving; and

DIAL monitors air quality at five locations inside the airport and two outside on regular basis for Suspended Particulate Matter (SPM), Sulfur dioxide (SO2), Oxides of Nitrogen (NOx), Hydrocarbon Carbon (HC) and Carbon Monoxide (CO).

At various locations in and around the airports Ambient Noise monitoring conducted regularly. DIAL is an integral part of the “working group on airport noise” formed by DGCA, exploring various possibilities and developing feasible measures to reduce excessive noise. All Diesel generators sets are provided with acoustic barriers.

Green House Gas inventory program to establish emission data for mobile and ground vehicles. It also facilitates employees to reduce their carbon foot print by Carpool network initiative.

To reduce the APU and GPU utilization DIAL have installed Fixed Ground Power Unit (FGPU) facility in its New Terminal.

3.3 Air Navigation Services initiatives:

Air navigation services initiatives such as the Future India Air Navigation programme and the Indian Ocean Strategic Partnership to Reduce Emissions (INSPIRE).

India has launched the Future India Air Navigation System (FIANS) initiative, which is based on projects in the fields of communication, navigation and surveillance. Indicative projects include implementation of Performance Based Navigation (PBN), use of Automatic Dependent Surveillance-Broadcast (ADS-B), harmonization with international systems, human resources development and training, etc. PBN roadmap has been developed and several projects have already been launched. For example, PBN implementation at some airports has already reduced flight distance resulting in fuel saving. In future, more emphasis will be given on PBN and ATM related technical issues to further streamline congestions at airports and airspace, avoid delays at runways for take-off and landings, etc.

India has launched GPS-aided geo augmented navigation (GAGAN) satellite based navigation system which has been jointly developed by Indian Space Research Organization and Airport Authority of India and certified by the DGCA. The system provides improved efficiency, direct routes, approach with vertical guidance at runways, reduced workload of flight crew and air traffic controllers, increased fuel savings and reduction in carbon emission for the benefit of environment.

3. Conclusion

Aviation industry is one of the fastest growing global industries. The intense stimulation of economic development and employment growth in the sector and associated sectors are positive effects of air transport expansion. The liberalization of the global air transport market was a key issue for the development of the aviation sector. The dynamic development of flight connections and the decrease in ticket prices are the result of the liberalization of regulations governing air transportation. Rapid change in aviation industry requires changes in the design and construction of airfield and landside facilities will be necessary to accommodate the larger aircraft that will enter service and the new navigation and air traffic control systems that will be deployed in the near future. Innovative planning approaches are essential to timely development of new airport facilities, and environmental documentation is a key component of the planning process.

The modern airport is pushing its capacity limits because of demand driven by economics, larger and more efficient aircraft, and improvements in navigation, safety, and communications. This will inevitably bring even larger, faster, higher-flying aircraft that will carry more passengers and more cargo and require airport development runways, taxiways, terminals, and roads all with known and maybe some unknown environmental impacts. New advances will require continued research into the state-of-the-art environmental assessment issues.

ICAO 2016 predicted the greenhouse gas emissions of the aviation sector which shows the extent to which improvements to the aviation sector itself could help to cut emissions.

The effect on net CO_2 emissions association with the 100% replacement of jet fuel with alternatives by 2050 is expected. It requires complete shifting from petroleum refining to biofuel production and a substantial expansion of the agricultural sector, both of which would require substantial policy support.

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e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 1
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