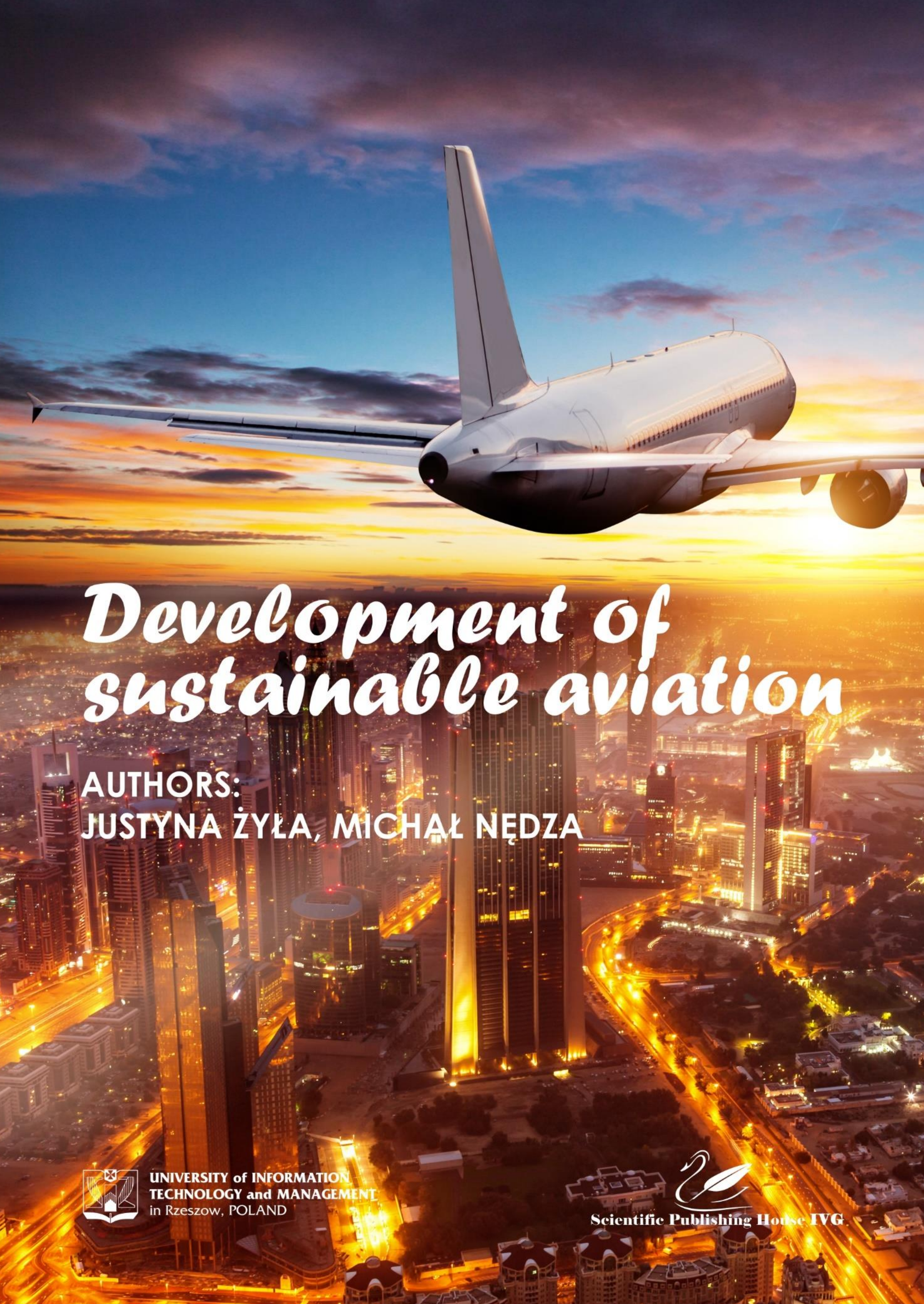

# Development of sustainable aviation

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# Abbreviation

| | |
|---|---|
| ATAG | Air Transport Action Group |
| ACI | Airports Council International |
| ASK | Available Seat Kilometer |
| APK | Available Passenger Kilometer |
| ATC | Air Traffic Control |
| ATM | Air Traffic Management |
| CAA | Civil Aviation Authority |
| $CO_2$ | Carbon Dioxide |
| EASA | European Aviation Safety Agency |
| EUROCONTROL | European Organization for the Safety of Air Navigation |
| FAA | Federal Aviation Authority |
| FSNC | Full Service Network Carrier |
| GDP | Gross Domestic Product |
| GSP | Ground Service Provider |
| IATA | International Air Transport Association |
| ICAO | International Civil Aviation Organization |
| ISAGO | IATA Safety Audit for Ground Operations |
| LCC | Low Cost Carriers |
| MRO | Maintenance, Repair and Overhaul |
| RPK | Revenue Passenger Kilometer |
| USD | United States Dollars |
| UN | United Nation |

*Book try to explain new conceptual model of responsible and conscious aviation that sees its development in line with the interests of the social and natural environment and takes into account existing ecological barriers and expectations of the society.*

*Authors strongly believe that understanding the opportunities and challenges facing the aviation sector are essential to ensuring that aviation can grow sustainably in the future - maximize its economic potential and deliver environmental and social benefits.*

*Authors*

# CHAPTER 1

# AVIATION OVERVIEW: SUSTAINABLE DEVELOPMENT

## 1.1. General definition and interpretation of sustainable concept

The phrase "concept of sustainable development" or words "sustainable" or "sustainability" are often used by people and institutions at random, with different interpretations and meanings. As a result, in literature we can find many differing definitions of "sustainable development". However, at a government level the first and the most widely accepted definition of "sustainable development" came from a report entitled *"Our Common Future"* published in 1987 by the United Nation World Commission on Environment and Development. According to the document:

*"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*.

As we can see above, the definition is very general and targeted to a wider audience. The report emphasizes only that the main goal of sustainable development is to enable people to satisfy their basic needs and enjoy a better quality of life without compromising the quality of life for future generations. However, for the first time in history, the document considers sustainability from a holistic perspective - that is, the ecological, social and economic dimensions, recognizing that everything must be considered together to find lasting prosperity.

The milestones in understanding the present concept of sustainable development were made in 1992 and 2012 during the first and second *United Nations Conference on Sustainable Development* (called respectively *Rio Conference and Rio+ Conference*). At the first conference dedicated to the environment and sustainable development, 185 UN Member States recognized the necessity for international cooperation on development issues, pointing out that finding the right solutions to the challenges that face them needed a concerted international effort. As a result of the meeting the concept of sustainable development was specified by two documents: *Declaration on the Environment and Development* and *Agenda 21*. The first document contains 27 general principles to help countries with sustainable development, while *Agenda 21* was a comprehensive plan of action for sustainable development, containing recommendations for countries and organizations. The document was divided into four sections:

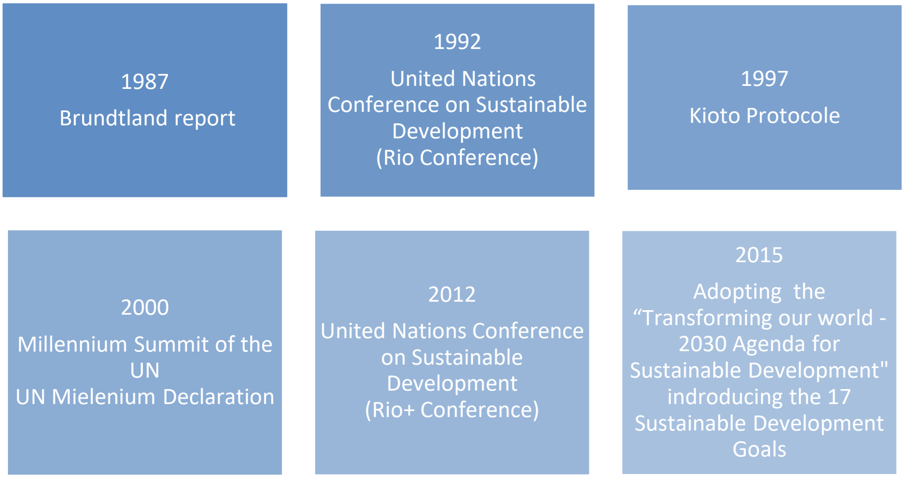
1. Social and economic dimensions;
2. Conservation and management of resources for development;
3. Strengthening the role of major groups;
4. Means of implementation.

The conference was also important because of the *Kyoto Protocol,* the first agreement between nations, aimed at reductions in greenhouse-gas emissions, that emerged from the *United Nations Framework Convention on Climate Change* (UNFCCC) signed 4 June 1992 during the Earth Submit.

During the second *Rio+ Meeting* in 2012 UN Member States decided to launch a process to develop a set of *Sustainable Development Goals* (SDGs). This was one of the greatest and most important challenges that was successfully achieved in 2015, when organizations adopted the "*Transforming our world – 2030*" agenda for sustainable development[1] including a set of the goals that the World should achieve by 2030. The agenda introduced the 17 *sustainable development goals*[2] that aimed to improve living conditions and economic prosperity.

[1] Also known as the Brundtland Report from the name of the author.
[2] Supersede the eight Millennium Development Goals, which were set up in 2007, as a result of the Millennium Submit in 2000.

Figure 1. Sustainable development milestones.




Source: Own work.

## 1.2. Aviation and sustainability concept

As the first part of this chapter proves, at present the universal definition of sustainable development does not exist, major aviation stakeholders made some suggestions about the interpretation of this innovative concept:

*"Sustainable development seeks to balance social, economic and environmental objectives in order to secure the well-being of present and future generations. These objectives are interdependent and thus equally important. Finding the optimum balance means that difficult choices sometimes have to be made and concessions may be required"*[3].

IATA

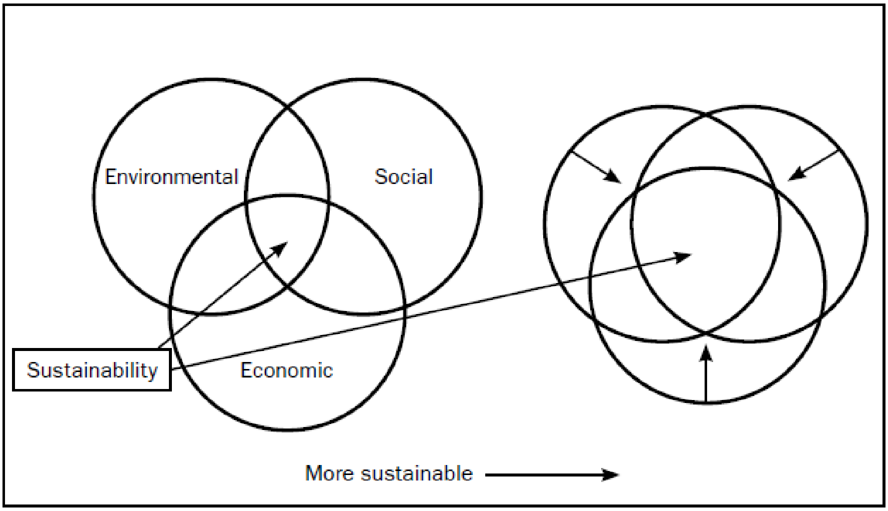
*"Sustainable development takes the three areas of economy, society and environment and finds ways of balancing the three interests to produce the results that will benefit most people"*[4].

ATAG

[3] Frantz Buch Knudsen, *Defining sustainability in the aviation sector,* European Organization for the Safety of Air Navigation EUROCONTROL, 2004, p. 36, based on http://www.iata.org/industry_issues/environment/index.htm.
[4] https://www.atag.org/our-activities/sustainable-development.html, browsed at 01.05.2018.

All the above mentioned definitions, once again, point out that the concept of sustainability should take into account a balance of social, economic and environmental imperatives. This is why we have to remember that this term is not constrained to just "reducing the negative environmental impact as much as possible", which is nowadays the most widely discussed issue in aviation, but also focuses on the economic and social aspects. Indeed, all three dimensions are vital.

Figure 2. The sustainability paradigm.




Source: *Aviation & sustainability. Special state. Determining the complex environmental, economic and social impacts that are defining aviation's future,* ICAO, 2011.

ATAG/INFRANS[5] specified criteria and indicators to make the three dimensions of the sustainable air transport easier to understand. Although, we have to keep in mind that this interpretation presents only a point of reference, not an exclusive list.

Economic criteria - the most important aspects:

- Job creation and growth contribution – e.g. multiplayer effect in regard to job creation and income;
- Access, travel time, speed – e.g. better accessibility between destinations (cities, countries, regions);
- Productivity e.g. development of unit cost/price;
- Market distortion;
- Recovery of infrastructure costs.

Social criteria - the most important aspects:

- Safety (regional, global) – number of accidents;
- Accessibility of remote areas (regional);
- Participation – involvement of different aviation stakeholders (e.g. NGO) within international aviation decision – making process/fora.

Environmental criteria - the most important aspects:

- Energy efficiency and climate change (including $CO_2$ and NOx emission, as well as other related substances;
- Noise (especially in the surroundings of airports);

[5] *Sustainable aviation,* INFRANS for Air Transport Action Group, 2000, p. 11-12.

- Air pollution (NOx, VOC and $PM_{10}$ emissions);
- Land use (sealed surface area of the airport).

Scale of dealing with sustainability[6]:

1. Global (intercontinental) – implies the entire world, chosen continents or their vast areas;
2. Regional (continental, national) - embrace a country, or its parts;
3. Local – individual airport and surrounding area/community.

What is more, as we can see below, the Aviation industry can play an instrumental role in supporting 15 of the 17 Sustainable Development Goals[7].

- ✓ Goal 1. End poverty in all its forms everywhere.
  Sample[8]: The Aviation sector directly and indirectly creates jobs and working opportunities.

- ✓ Goal 2. End hunger achieve food security and improved nutrition and promote sustainable agriculture.
  Sample: Aviation delivers vital humanitarian aid to besieged or devastated areas.

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[6] M. Janic, *The sustainability of air transportation: a quantitative analysis and assessment,* Aldershot: Burlington, VT: Ashgate, 2007, p. 11.
[7] ATAG, *Air transport and the sustainable development goals,* 2017.
[8] Only chosen example how aviation can have a direct or indirect impact on the particular GDS.

- ✓ Goal 3. Ensure healthy lives and promote well-being for everyone of all ages.
  Sample: Aviation very often assists with providing vital medical care (e.g. transporting time-sensitive medical supplies)

- ✓ Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
  Sample: Aviation has a direct impact on the possibility of movement of people, and as a result provides access to educational opportunities. What is more, aviation promotes education in science, engineering, technology and related disciplines.

- ✓ Goal 5. Achieve gender equality and empower all women and girls.
  Sample: Aviation promotes gender equality and is working hard to achieve gender balance in all areas.

- ✓ Goal 6. Ensure availability and sustainable management of water and sanitation for all.
  Sample: A large number of airports have robust water management plans.
- ✓ Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

Sample: The aviation industry is strongly focused on projects in the area of alternative fuels or renewable energy to be used in the future by airports.

- ✓ Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
  Sample: Aviation provides working opportunities (direct, indirect, induced, catalytic) and makes an important contribution to world GDP.

- ✓ Goal 9. Build resilient infrastructures, promote inclusive and sustainable industrialization and foster innovation.
  Sample: Aviation is perceived as one of the most innovative industries - continually developing new, efficient and innovative technology as well as urban infrastructure (e.g. airport, navigational infrastructure.

- ✓ Goal 10. Reduce inequality within and among countries.
  Sample: Aviation enables people to travel all over the world and gives each country access to goods and services, which is especially important for those in remote communities.
- ✓ Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.

Sample: Aviation-related infrastructure is a vast part of urban and rural areas and has direct impact on connectivity of people through integrated transport links.

- ✓ Goal 12. Ensure sustainable consumption and production patterns.
  Sample: The Aviation Industry has been working on improving the recycling process and developing sustainable alternative fuel feedstocks.

- ✓ Goal 13. Take urgent action to combat climate change and its impacts.
  Sample: The Aviation Industry has been working hard to limiting the environmental impact of emissions from international aviation.

- ✓ Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

- ✓ Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
  Sample: Aviation, with partners (governments, NGO) are working to combat the illegal wildlife trade.

- ✓ Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

- ✓ Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development.

  Sample: Aviation stakeholders, especially the UN, ICAO, IATA and local governments are working together in all sectors of aviation.

## 1.3. Sustainable aviation – main stakeholders

Over the past few decades, dealing with the concept of sustainability has been consolidated as a major part of the agenda for almost all aviation stakeholders[9] classified into 4 main categories[10]:

1. Users – passengers and freight shippers;
2. Air transport operators;
3. Aerospace manufacturers;
4. Investors, including:
    a) international aviation organizations,
    b) non-governmental organizations and lobby groups,
    c) organizations of international cooperation,
    d) local/central governments.

[9] An individual or group or organization in aviation, who may affect, be affected by, or perceive itself to be affected by particular issue/topic.
[10] M. Janic, *The sustainability of air transportation: a quantitative analysis and assessment,* Aldershot: Burlington, VT: Ashgate, 2007, p. 11.

### 1.3.1. Users – passengers and freight shippers

Users of the air transport services (sometimes called "consumers") are all the people who actually travel using air services and the freight/mail shippers. They are usually focused on social and economic benefits rather than the negative effects of air transportation.

### 1.3.2. Air transport operators

Air transport operators meet consumers' expectations by operating a fixed infrastructure, facilities and/or equipment as well as the means of transport (aircraft).

The Air Traffic Control/Management (ATC/ATM) service providers are mainly focused on safety issues, service efficiency and effectiveness and better use of the available aerospace capacity. As a consequence of ATM and ATC activities we are able to notice the improvement in the efficiency and effectiveness of air services.

Airlines very often include social, economic and environmental issues in their business models. One of the top priorities for many airlines is to improve economic efficiency. Air carriers can achieve this goal by investing in significant upgrades to their fleets, adopting the latest, most fuel-efficient aircraft. These actions are helping to reduce fuel consumption or associated emissions of air pollutants. Furthermore, through direct/indirect employment, air carriers bring economic and social contributions to the sustainable development concept.

Airports all over the world have different approaches to sustainable development. However, most of them are trying to reduce their negative environmental impact (for example by launching policy measures for mitigating environmental impact, decrease noise pollution, etc.), prioritizing economic growth or generating social progress (by the creation of jobs).

### 1.3.3. Aerospace manufacturers

The category of aerospace manufactures includes the aircraft manufacturers (e.g. Boeing, Airbus, Bombardier), engine manufacturers (e.g. GE Aviation, Rolls-Royce, and Pratt & Whitney) as well as the manufacturers of the other related equipment. All are strongly focused on production and performance according to the sustainability concept: reduction of fuel consumption, managing air and noise pollution or a recycling process.

### 1.3.4. Investors

The most important "investors" dealing with aviation sustainability are:

ICAO - the United Nation specialized agency, established in 1944 to manage the administration and governance of the Chicago Convention. According to the article 44 of the Convention the aims and objectives of the ICAO are to develop principles and techniques of international air navigation to foster the planning and development of international air transport so as to:

a) Ensure the safe and orderly growth of international civil aviation throughout the world;
b) Encourage the arts of aircraft design and operation for peaceful purposes;
c) Encourage the development of airways, airports and air navigation facilities for international civil aviation;
d) Meet the needs of the peoples of the world for safe, regular, efficient and economical air transport;
e) Prevent economic waste caused by unreasonable competition;

f) Ensure that the rights of contracting States are fully respected and that every contracting State has a fair opportunity to operate international airlines[11].

The organization strongly focuses on work with its member states and industry groups to reach a consensus on international civil aviation Standards and Recommended Practices (SARPs) and global policy guidance (e.g. the *Procedures of Air Navigation Services* (PANS)). All policies launched by ICAO support a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector.

The organization has five Strategic Objectives:

- Safety;
- Air Navigation Capacity and Efficiency;
- Security and Facilitation;
- Economic Development of Air Transport;
- Environmental Protection.

IATA is a trade association founded in Havana (Cuba) on 19 April 1945. Today the organization represents some 280 airlines, comprising 83% of the total air traffic. IATA's mission, according to art. 4 from the Article of Association (organization funding act) is "value creation and innovation driving a safe, secure and

[11] Article 44, *Convention on International Civil Aviation,* Ninth edition, 2006, (Doc 7300/9) on https://www.icao.int/publications/pages/doc7300.aspx.

profitable air transport industry that sustainably connects and enriches our world"[12]:

a) to promote safe, regular and economical air transportation for the benefit of the people all over the world, to foster air commerce, and to study the problems connected there with;
b) to provide means for collaboration among the air transport enterprises engaged directly/indirectly in international air transport service;
c) to cooperate with the ICAO and other international organizations.

ACI is non-profit organization, representing the interests of airports (641 members operating 1953 airports in 176 countries). Functioning of the ACI is based on six objectives/rules[13], including:

a) Maximize the contributions of airports to maintaining and developing a safe, secure, environmentally compatible and efficient air transport system;
b) Advance the development of the aviation system by enhancing public awareness of the economic and social importance of airport development;

[12] http://www.iata.org/about/Pages/mission.aspx, browsed at 10.02.2018.
[13] http://www.aci.aero/About-ACI/Overview/Mission-Objectives-Structure, browsed at 10.02.2018.

c) Achieve cooperation among all segments of the aviation industry and their stakeholders as well as with governments and international organizations;

ACI works closely with the ICAO, IATA and other stakeholders to ensure that airports' voices are taken into account as policies or recommendations are developed.

ATAG – an independent, non-profit coalition of aviation organizations/institutes and companies throughout the aviation industry launched in 1990. In 2018, it has 50 members including a wide range of aviation stakeholders: air transport operators (airports, airlines), chambers of commerce, aerospace manufacturers (e.g. Airbus, Boeing), tourism and trade partners, etc. The main aim of the ATAG is "to promote aviation's sustainable growth for the benefit of our global society" through collaboration within the industry, providing a forum on the most important issues in the aviation sector, including: the sustainable development concept, benefits of aviation, climate change, industry communication, etc.

- ✓ The phrase “concept of sustainable development” or words "sustainable” or “sustainability” are often used by people and institutions at random, with different interpretations and meanings.
- ✓ Very often, the interpretation of the sustainable concept in the aviation industry has been and remains constrained to just “reduction of negative environmental impact"', with lesser focus on the economic and social aspects. In fact, all three dimensions are vital.
- ✓ The main group of aviation stakeholders in the area of sustainable development are: users – passengers and freight shippers, air transport operators, aerospace manufacturers and investors (International aviation organizations, non-govern-mental organizations and lobby groups, organizations of international cooperation, local/central governments).

## 1.4. Aviation Overview: The past and the future

Studying aviation history is important because we can understand the past, which in turn allows us to understand our present. That is why, in this section of the chapter the authors explore the global air traffic passenger demand, including characterization of air travel demand from ancient times up to the XXI century and finally, examine current long-term air traffic forecasts.

### 1.4.1. Historical view

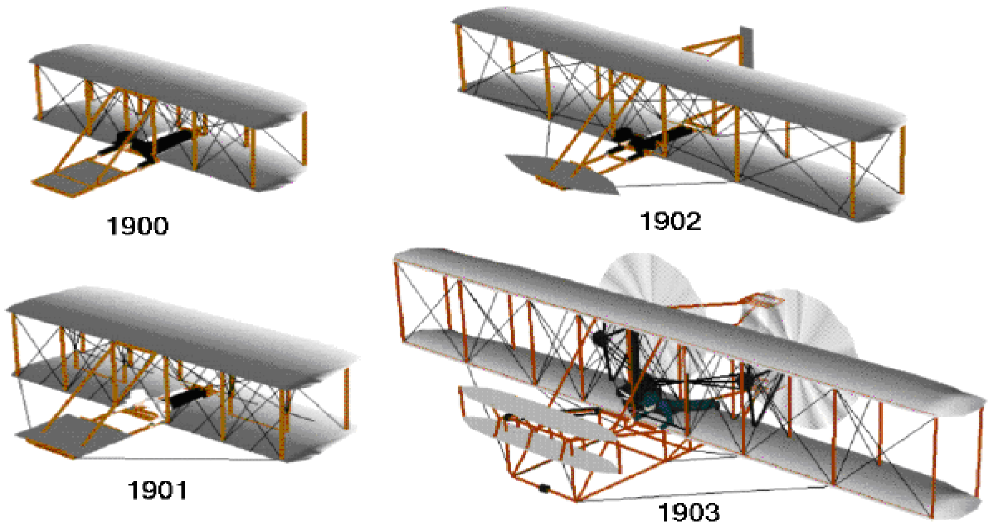
*"Man must rise above the Earth - to the top of the atmosphere and beyond - for only thus will he fully understand the world in which he lives"*.

Socrates

This quote of the famous ancient philosopher shows how aviation is an extremely important part of our life. Since the beginning of time man has looked to the birds and has wondered why can't we fly? Nearly all ancient cultures contain myths about flying, one of the most famous being that of Icarus and Daedalus. The father and son flew with wings of wax and feathers. However, Icarus grew proud and flew too close to the sun. As a result, the wings of wax melted and Icarus fell in the ocean. It is worth mentioning, that for the people of ancient civilizations flying was the province of the gods. In Macedonia citizens believed that Alexander the Great harnessed four mythical wings animals (Griffins) to a basket and flew around his kingdom. In Persian literature, we could read that Kaj Kaoos, who was a king, attached eagles to his throne and flew around in it. The first form of aircraft was the kite, designed in the 5th century BC in China. Later, in the 13th century, Roger Bacon, an English monk, performed experiments which later gave him the idea that air could support aircraft just like water supports boats. Leonardo da Vinci in "*Codex on the Flight of Birds*" (1505-1506) outlined a number of observations and concepts that would find a place in the successful development of the airplane in the early twentieth century. Over the next few years he made a set of drawings of aircraft and helicopters. What is more, da Vinci envisioned three different types of heavier-than-air craft: the helicopter, glider, and ornithopter - a machine with mechanical wings which flap to mimic a bird. Although Leonardo da Vinci at that time did not have the technology capable of accomplishing his designs, they became an inspiration for the next thousand years. A few century later, in 1783 the Montgolfier Brothers constructed a balloon, the first lighter-than-air vehicle and Sir George Cayley created the concept of the modern aeroplane as a fixed-wing flying machine with separate systems for lift, propulsion, and control. He also made a lot of kites and flight tests demonstrated that the elevation of a man into the air need a suitable carrier. An interesting fact is that the planes which can be observed today are derived from the construction of his glider model dated 1804. Furthermore, at the end of the nineteenth century, German, Otto Lilienthal, considered the "first true aviator" managed to take several flights in gliders of his own design. Other famous inventors were Jean Marie Le Bris (glider developer) and Samuel Langley.

However, the first true airplane flight is attributed to brothers Orville and Wilbur Wright. They created their own theories about the possibility of flight. In the beginning they tested those theories with kites and balloons and then decided to build their own aircraft.

Picture 1. Wright brother's aircraft.




Source: National Aeronautics and space administration (NASA)[14].

The first biplane was built in 1900 featuring 15 square meters of wingspan and had a forward elevator for pitch control. On their second glider built by in 1901 the wingspan was increased to 26 square meters. However, even this improvement would not bring success. The third attempt (1902) perceived after months of preparation turned out to be a minor success, yet the glider still did not perform as the brothers expected. The brothers re-turned in 1903 to Kill Devil Hills, where they had a camp, on 17th December. During the fourth flight of the day, Wilbur Wright flew 852 feet (259 meters) over the sand in 59 seconds. This was

[14] http://wright.nasa.gov/airplane/planes.html, browsed at 12.04.2018.

a milestone in aviation history, because for the first time, a heavier-than-air machine had demonstrated powered and sustained flight under the complete control of the pilot.

When World War I broke out in 1914, nobody expected how powerful a weapon an aircraft would become and how it would revolutionize the conduct of war. Just few years after the first success of the Wright brothers, the plane was used for the first time in combat during the Italy-Turkish War. The first operational use of an aircraft to be observed was when Captain Carlo Piazza made history's first reconnaissance flight near Benghazi in a Blériot XI[15]. The experience of the first two decades of the twentieth century caused all major armies in the world to want modern and efficient aircraft. Engineers started to construct airplanes, which were designed mostly for military purposes. When World War I ended, no one had any doubts that aviation was just as important on the battlefield as infantry, artillery or navy. Every few months people could see the introduction of a new or improved fighter plane to combat the latest version developed by the opposing side - each new variation of aircraft represented a leap forward in technology.

While Europe was absorbed by war, in the United States, commercial aviation was slowly developing. The milestone in the

[15] D.L. Rhoades, *Evolution of international aviation*, ASHAGATE, 2008, p. 15.

civil aviation sector was in the late 30s – by introducing the Douglas DC-2 in 1934 and the DC-3 in 1936. In 1939, the Boeing Aircraft Company and American Government began work on a 4 engine bomber, that would be able to fly long distances and could carry nuclear weapons. As a result of their work the Americans created the B-29[16]. On August 6, 1945, a B-29 Bomber Enola Gay, piloted and commanded by Colonel Paul Tibbets dropped the world's first atomic bomb on Hiroshima and a few days later a second bomb on Nagasaki.

The international nature of aviation and the increasing demand for air travel were the main reasons for the creation of common rules and rights. The oldest convention, that adopted the principle of state sovereignty over its own airspace was the Paris Convention signed in 1919. However, one of the most important conventions in aviation history was signed on 7 December 1944. *The* Convention on International Civil Aviation, also known as *The Chicago Convention* introduced a set of commercial aviation rights called “the freedoms of the air".

[16] B. Yenne, *The story of the Boeing Company*, MOTORBOOKS INTL, 2005, p. 70.

Table 1. Freedom of the air introduce by Chicago Convention.

| | Explanation |
|---|---|
| First Freedom of the Air | The right or privilege, in respect of scheduled international air services, granted by one State to another State or States to fly across its territory without landing. |
| Second Freedom of the Air | The right or privilege, in respect of scheduled international air services, granted by one State to another State or States to land in its territory for non-traffic purposes. |
| Third Freedom of the Air | The right or privilege, in respect of scheduled international air services, granted by one State to another State to put down, in the territory of the first State, traffic coming from the home State of the carrier. |
| Fourth Freedom of the Air | The right or privilege, in respect of scheduled international air services, granted by one State to another State to take on, in the territory of the first State, traffic destined for the home State of the carrier. |
| Fifth Freedom of the Air | The right or privilege, in respect of scheduled international air services, granted by one state to another state to put down and to take on, in the territory of the first state, traffic coming from or destined to a third state. |
| Sixth Freedom of the Air | The right or privilege, in respect of scheduled international air services, of transporting, via the home State of the carrier, traffic moving between two other States.<br><br>The so-called Sixth Freedom of the Air, unlike the first five freedoms, is not incorporated as such into any widely recognized air service agreements such as the "Five Freedoms Agreement". |
| Seventh Freedom of the Air | The right or privilege, in respect of scheduled international air services, granted by one State to another State, of transporting traffic between the territory of the granting State and any third State with no requirement to include on such operation any |

| | |
|---|---|
| | point in the territory of the recipient State, i.e. the service need not connect to or be an extension of any service to/from the home State of the carrier. |
| Eighth Freedom of the Air or consecutive cabotage | The right or privilege, in respect of scheduled international air services, of transporting cabotage traffic between two points in the territory of the granting State on a service which originates or terminates in the home country of the foreign carrier or (in connection with the so-called Seventh Freedom of the Air) outside the territory of the granting State. |
| Ninth Freedom of the Air or "stand alone" cabotage | The right or privilege of transporting cabotage traffic of the granting State on a service performed entirely within the territory of the granting State. |

Source: ICAO, *Manual on the Regulation of International Air Transport* (Doc 9626, Part 4).

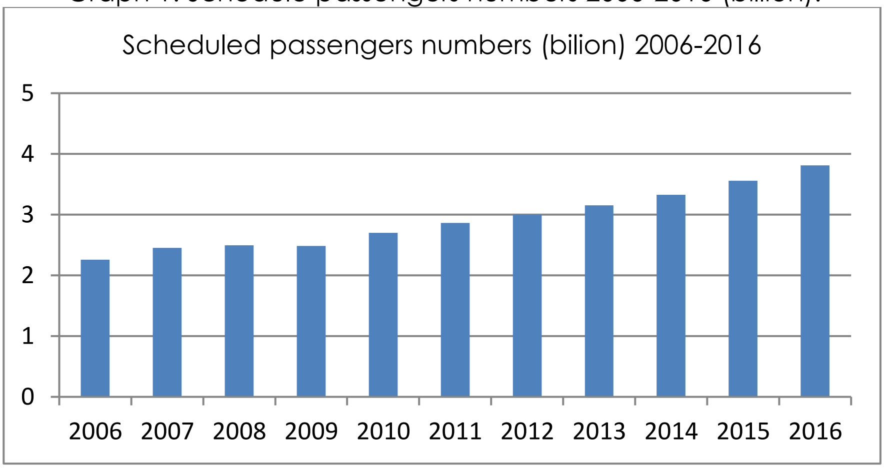
The end of the war also became the end of a period in which demand for air transportation was boosted mostly by military purposes. After 1945, commercial aviation grew very rapidly, as more and more people decided to use air transport for commercial purpose.

To sustain supremacy during the cold war the USA, Germany, Japan, and Britain struggled to keep their aircraft up-to-date, almost constantly modifying them and introducing new variants. In 1955 The United States developed the U-2 spy plane to fly even higher, then soviet missiles were able to reach and to cover great distances nonstop. What is more, few years later, in 1947 Chuck Enker became the first pilot to fly at supersonic speed – speed greater than the speed of sound. When we talk about aviation and airplanes, we cannot forget about one of the biggest breakthroughs in flight. 4th October 1957 will remain in the memory of many people, because it was the beginning of space flight and ejection into space; the first ever artificial satellite of the Earth, Sputnik-1 produced by the USSR. The other important date is 12th April 1961 and the first space flight with the pilot Yuri Gagarin. In July 1969 American pilots-cosmonauts Neil Armstrong and Edwin Aldrin, landed on the Moon.

### 1.4.2. Aviation nowadays and in the future

Air transport is increasingly popular means of transport. The following table shows how the changes in passengers volume between 2006-2016.

Graph 1. Schedule passengers numbers 2006-2016 (billion).




Source: IATA, *Fact sheet industry statistics,* December 2017.

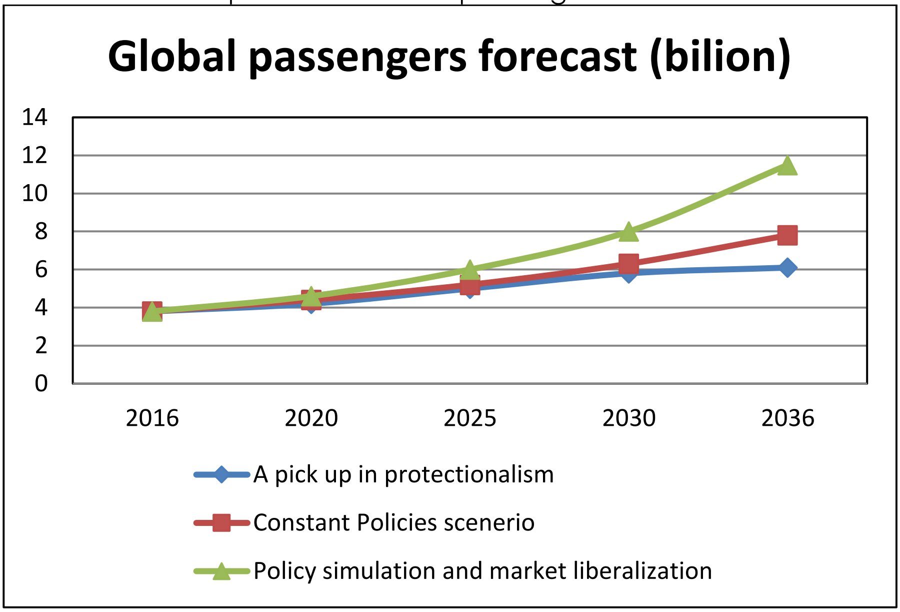
Over the years the air transport industry has experienced rapid expansion and doubled in size every fifteen years. The number of passengers has risen despite repeated shocks from recessions, war, disease or terrorism. In 2016 world airlines carried 3.8 billion passengers.

Demand is volatile but consistently returns to a rapidly growing trend. Moreover, numerous air traffic forecasts[17] show that this upturn trend will be continued over the next twenty years.

According to The International Air Transport Association (IATA) – one of the biggest trade associations representing 280 airlines from all over the world (83% of total air traffic) about 7.8 billion passengers will be using air transport in 2036 (in the most likely scenario).

[17] Long-term forecast of air traffic has several important practical applications. First of all, their support commercial air transport developments, in particular planning issues related to airports and airlines – by shaping their strategy and provides guidance for long-term business planning. Secondly the are quite important for governments and international organization. Forecasts help to determine risk on the one hand and opportunity on the other, connected to the aviation market and determine the impact of this sector for the economy. When we are talking about long-term air traffic forecast we cannot forget about private companies. For many of them assessment of future global air transport markets trends are necessary to conduct a business (e.g. airplane manufactures).

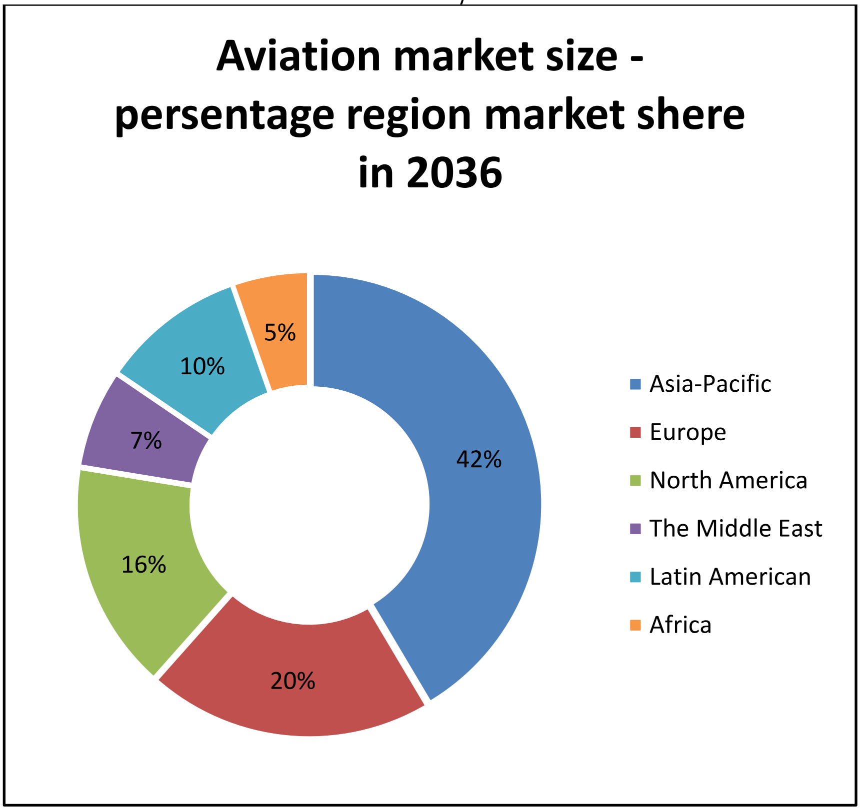
Graph 2. IATA Global passengers forecast.




Source: http://www.iata.org/pressroom/pr/Pages/2017-10-24-01.aspx.

The international organization based its prediction on the assumption that annual Compound Average Growth Rate (CAGR) will be equal 3.7%. IATA forecast for passenger growth points out that the biggest driver of air demand will be the Asia-Pacific region with an overall market size of 3.5 billion passengers and annual average growth rate of 4.6%. Second in terms of carried passengers will be Europe with a total market of 1.5 billion passengers and a growth rate of 2.5% annually. The last region with the number of air travelers that surpassed one billion will be North America. This region will grow by 2.3% annually to carry a total of 1.2 billion passengers in 2036.

Graph 3. Aviation market size in terms of carried passengers (2036, billion).




Source: IATA, *20-Year air passenger forecast,* IATA.

IATA also anticipates that China will displace the US as the world's largest domestic market (defined as traffic to, from and within country) by 2022. What is more, the United Kingdom in the next 20 years will also lose its position as the third biggest domestic market and be surpassed by India and Indonesia.

Table 2. Major domestic market 2016 vs 2036.

| 2016 | 2036 |
|---|---|
| United Stated of America | China |
| China | United Stated of America |
| UK | India |
| Japan | Indonesia |

Source: *20-Year air passenger forecast,* IATA.

The domination of the Asia-Pacific region is confirmed also by The International Civil Aviation Organization (ICAO) and the main airplane manufacturers: Boeing and Airbus. A United Nations special agency estimates that domestic demand in the southwest Asia region will grow at around 10% annually, twice as fast that the average global passenger traffic (4.6% annually by 2032). According to Boeing, with a forecast[18] of a 6.1% annual growth rate, China's domestic market will head the world statistics and, Asia, with projected annual growth at a level of 5.7% will become the largest air travel market. In regions with a traditionally developed and mature aviation market, such as North America and Europe, Boeing predict that growth rate will not exceed the global average.

Airbus claimed that world passenger traffic expressed in terms of RPK between 2017-2036[19] will be equal to 4.4. Between 2017-2027 we can expect a growth at an average annual rate

[18] Boeing, *Current Market Outlook 2017-2036.*
[19] Airbus, *Global Market Forecast 2017-2036.*

of 4.9%, while in the last decade the report shows a slowdown and forecasted traffic growth of 4.1%.

- ✓ From a long-term historical perspective air transport has experienced rapid expansion, doubling in size every fifteen years.
- ✓ The number of passengers has risen despite repeated shocks from recessions, war, disease or terrorism. Demand is volatile but consistently returns to a rapidly growing trend.
- ✓ Numerous air traffic forecasts (from the most important aviation players e.g. IATA, ICAO, Boeing, Airbus) point out that this upturn trend will be continued over the next twenty years.

# CHAPTER 2

# AVIATION AND ENVIRONMENT

Aviation is a critical part of transportation sector, enabling the movement of people and goods throughout the world and hence enhancing worldwide economic growth. However, there are always two faces of coin, along with necessity of growth in aviation for sector there have been some concerns regarding the environmental impacts. Environmental impact includes:

- ✓ noise,
- ✓ air quality,
- ✓ water quality,
- ✓ impacts on climate.

Due to most projections highlighting a prominent rapid growth of air transport, the environmental consequences of aviation may increase. In addition to this from last decade especially after “Stern’s review on the economies of climate change” public awareness of environmental issues, and political pressure to manage environmental impacts, have increased radically. Due to this reason now-a-days the environment is one of top priority in the aviation industry.

Aviation affects the environment at the local, regional and global levels. Water quality around airports is adversely affected by runoff from aircraft and airfield deicing operations, as well as other sources such as fuel leaks, spills, and solid and liquid waste treatment and disposal. All this gets added to the ground water table thereby polluting it. Noise from aircraft causes health deteriorating hassles viz. sleep disturbance, hearing issues and adversely affects property values around airports. As a result, local communities often vigorously oppose airport expansion plans.

At the local and regional level, emissions from aircraft, airport traffic and stationary airport sources adversely affect air quality and therefore health. At the global level, aircraft emissions contribute to climate change by increasing the levels of greenhouse gases in the atmosphere. More about water quality, noise, emission and climate change will be discussed in subsequent sections.

There are numerous challenges in limiting aviation in keeping view on the environmental impact due to it as the aviation intensification is directly associated with the economic growth. Introducing unsuitable restrictions on aviation may have negative consequences for world economies. Due to this reason we have to think of a balance which will involve balancing growth rate of aviation and its environmental impact. To efficiently make equilibrium the aviation sector and environmental protection, the aviation industry must tackle an ample collection of scientific, design and policy problems that require joint attention to noise, air quality and climate issues.

## 2.1. Regulatory bodies

Introduction of policies and regulations by regulatory bodies is one of the main ways to limit the impact of aviation on the environment. The regulations employed by the regulatory bodies are of following type:

**Indirect regulation:**

Indirect regulation involves indirect actions against harming factors. Indirect regulation can be in the form of incentives provided to organizations or households against the credence of social and ethical costs. For example, airports provide incentives to the people complaining of noise levels from aircraft.

**Direct regulation:**

Direct regulation involves direct actions against harming factors. Direct regulation is also sometimes termed as "Regulation by force". Example of direct regulation is the night curfew at airports which deny them to allow air traffic at airports during nights.

ICAO is a United Nations body that issues international regulatory standards for aircraft noise and emissions by proposing suitable standards that regulatory bodies in member nations around the world can adopt. With regard to the environmental impact of aviation, ICAO attempts to limit or diminish the number of people affected by significant aircraft noise, the impact of aviation emissions on surface air quality, and the impact of aviation greenhouse gas emissions on the global climate[20]. Within ICAO, the *Committee on Aviation Environment Protection* (CAEP) is responsible for setting standards relating to noise and emissions. However, this process has not led to a common set of rules around the world because of the actions of local and regional groups. Airports and airlines are subject to different standards imposed by local and regional bodies. Most nations have one or more governmental agencies that are responsible for managing the impact of aviation on the environment.

In Europe, the European Union monitors and limits emissions by means of Directives issued by the Environmental Council. The EU Directives aim to harmonize monitoring strategies, measuring methods, calibration and quality assessment methods across the EU[21]. Previously, emissions standards were set at national levels. Aircraft noise levels in the vicinity of airports are regulated by the *Joint Aviation Authority* (JAA). In addition to these governmental bodies, the communities around airports are having an increasing influence on airport and aircraft operations. In the USA, the *Environmental Protection Agency* (EPA) is responsible for the

[20] www.icao.int, browsed at 14.02.2018.
[21] www.ec.europa.eu, browsed at 15.05.2018.

establishment and enforcement of US environmental protection standards.

## 2.2. Noise

Aviation causes noise pollution in form of noise produced by any aircraft and operations related to it. Noise is produced during various phases of a flight:

- On the ground while parked such as auxiliary power unit;
- During Landing, taking-off and taxiing;
- On run-up from propeller;
- Jet exhaust from engines;
- Underneath and lateral to departure and arrival paths;
- Over-flying while a route.

The noise generated by above stated phases can be broadly categorized into three main types:

- aerodynamic noise,
- engine and other mechanical noise,
- noise from aircraft systems.

**Aerodynamic noise**

Aerodynamic noise is caused due the airflow around the aircraft fuselage and control surfaces. This type of noise increases with aircraft speed and also at low altitudes due to the density of the air. Jet-powered aircraft create intense noise from aerodynamics. Low-flying, high-speed military aircraft produce especially loud aerodynamic noise.

The shape of the nose, windshield or cover of an aircraft affects the sound produced. Much of the noise of a propeller aircraft is of aerodynamic origin due to the flow of air around the blades. Typically, noise is generated when flow passes an object on the aircraft, for example the wings or landing gear.

**Engine and other mechanical noise**

Jet Engines are responsible for much of the aircraft noise during takeoff and climb. The high velocity air jet leaving the back of the engine creates a considerably huge amount of noise in jet engines than mechanical parts. The majority of engine noise is due to jet noise. High bypass-ratio turbofans also have considerable fan noise. Mechanical noise in propeller aircraft comes from the propellers and various transmission chains. The mechanical sources produce narrow band high intensity peaks relating to the rotational speed and movement of the moving parts.

**Noise from aircraft systems**

Cockpit and cabin pressurization and conditioning systems are often a major contributor within cabins of both civilian and military aircraft. However, one of the most significant sources of cabin noise from commercial jet aircraft other than the engines is the *Auxiliary Power Unit* (APU). An APU is an on-board generator used in aircraft to start the main engines, usually with compressed air, and to provide electrical power while the aircraft is on the ground. Other internal aircraft systems can also contribute in the noise.

The chart below depicts the various noise-level produced by various aircraft[22].

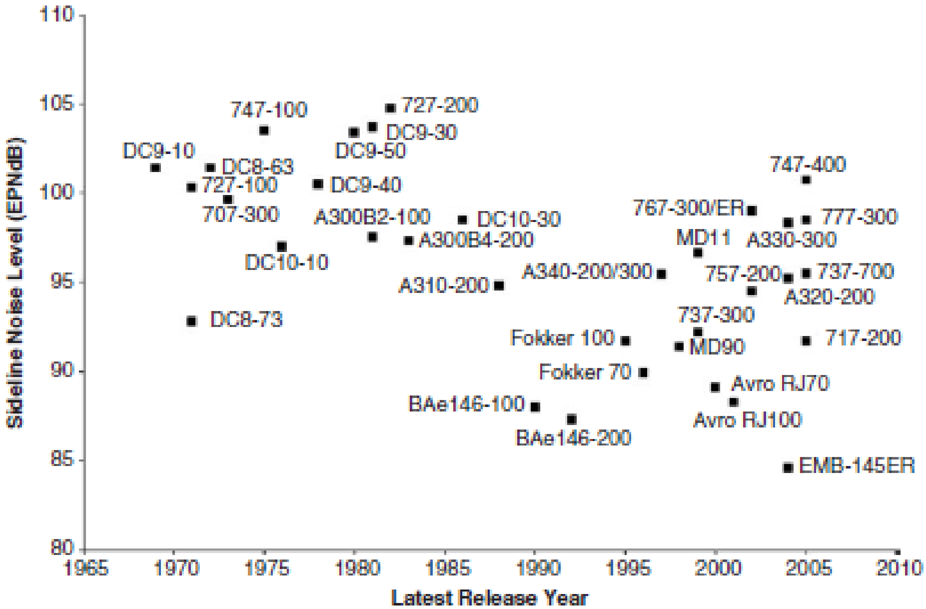



Table below shows the residential response to the noise levels[23].

[22] www.faa.gov, browsed at 20.03.2018.
[23] www.fican.org, browsed at 25.03.2018.

Table 3. Residential response to the noise levels.

| **DNL (db)** | **Hearing loss** | **Annoyance** | | |
|---|---|---|---|---|
| | | **% of population highly annoyed** | **Average community reaction** | **General community attitude towards area** |
| 75 and above | May begin to occur | 37 | Very severe | Noise is likely to be the most important of all adverse aspects of community environment. |
| 70 | Will likely not occur | 22 | Severe | Noise is one of the most important of all adverse aspects of community environment. |
| 65 | Will not occur | 12 | Significant | Noise is one of the most important of all adverse aspects of community environment. |
| 60 | Will not occur | 7 | Moderate to slight | Noise might be considered as an adverse aspects of community environment. |
| 55 and below | Will not occur | 3 | Moderate to slight | Noise might be considered as an adverse aspects of community environment. |

Source: www.fican.org.

**The effects of aircraft noise:**

## Annoyance

Noise can lead to people feel stressed and angry. It may interfere with conversations and leisure activities at home, disrupt activities requiring concentration, and discourage people from using outdoor spaces. Further factors may affect whether noise is viewed as 'annoying':

- Occurrence of exposure – noise may be more annoying if it occurs often, even if each noise event is quieter;
- Fear of accidents – concerns about air crashes may increase some people's sensitivity to aircraft noise;
- Fear of the future – especially about future growth in air travel and potential increases in the frequency of flights;
- Lack of control – inability to alter or escape from the noise source may make it more annoying[24].

## Sleep disturbance

Sleep interference pattern is frequently reported by those living near airports operating night flights. A recent study of residents in high noise areas close to Heathrow, Gatwick, East Midlands and Coventry airports found between 1 in 5 and 1 in 10

[24] P. Upham et al (eds), *Towards sustainable aviation,* Earthscan, 2003.

people often reporting difficulty getting to sleep or being woken early.

**Effects on Health:**

Frequent exposure to loud noise effects cardiovascular system and mental balance but still the evidence is very limited and there has to be further research before any guideline will be offered.

Approaches to reduce Noise:

1. **Balanced Approach to Aircraft Noise Management**

In 2001, the ICAO Assembly legitimated the concept of a "balanced approach" to aircraft noise management. The Assembly in 2007 reaffirmed the "balanced approach" principle and called upon States to recognize ICAO's role in dealing with the problems of aircraft noise. This consists of identifying the noise problem at an airport and then analyzing the various measures available to reduce noise through the exploration of four principal elements, namely:

- Reduction at source (quieter aircraft);
- Land-use planning and management;
- Noise abatement operational procedures;
- Operating restrictions;
- Noise Charges.

The goal of these measures is to address the noise problem in the most cost-effective manner. ICAO has developed policies on each of these elements, as well as on noise charges[25].

## 2. Reduction of Noise at Source

Much of ICAO's effort to address aircraft noise over the past 40 years has been aimed at reducing noise at source. Aircraft and helicopters built today are required to meet the noise certification standards adopted by the Council of ICAO.

## 3. Land-use Planning and Management

Land-use planning and management is an effective means to ensure that the activities nearby airports are compatible with aviation. Its main goal is to minimize the population affected by aircraft noise by introducing land-use zoning around airports. Compatible land-use planning and management is also a vital instrument in ensuring that the gains achieved by the reduced noise of the latest generation of aircraft are not offset by further residential development around airports. The ICAO manual on Land-use planning and management provides guidance on the use of various tools for the minimization, control or prevention of the impact of aircraft noise in the vicinity of airports and describes the practices ad-opted by some countries.

[25] www.icao.int, browsed at 01.04.2018.

## 4. Noise Abatement Operational Procedures

Noise abatement procedures enable reduction of noise during aircraft operations to be achieved at comparatively low cost. There are several methods, including preferential runways and routes, as well as noise abatement procedures for take-off, approach and landing. The appropriateness of any of these measures depends on the physical lay-out of the airport and its surroundings, but in all cases the procedure must give priority to safety considerations.

## 5. Operating Restrictions

Noise concerns have led some countries, mostly developed countries, to consider banning the operation of certain noisy aircraft at noise-sensitive airports. However, operating restrictions of this kind can have significant economic implications for the airlines concerned, both those based in the countries taking action and those based in other countries that operate to and from the affected airports. On each occasion, the ICAO Assembly succeeded in reaching an agreement – contained in an Assembly resolution – that represented a careful balance between the interests of developing and developed countries and took into account the concerns of the airline industry, airports and environmental interests.

## 6. Noise Charges

ICAO's policy with regard to noise charges was first developed in 1981. The Council recognizes that, although reductions are being achieved in aircraft noise at source; many airports need to apply noise alleviation or prevention measures. The Council considers that the costs incurred may, at the discretion of countries, be attributed to airports and recovered from the users. In the event that noise-related charges are levied, the Council recommends that they should be levied only at airports experiencing noise problems and should be designed to recover no more than the costs applied to their alleviation or prevention.

## 2.3. Air Quality

Aircraft and airport emissions can also have serious effects on the environment. Although noise is currently the primary environmental constraint on airport operations and expansion, many airports either put air quality concerns on an equal footing with noise or anticipate they will be on an equal footing soon[26]. While the connection between noise and human health is somewhat unclear, emissions are known to have a direct impact on human sickness to lead to an increased risk of premature death. In addition, the link between emissions and climate change (which in turn affects human and ecosystem health) is becoming ever clearer with continuing research. Emissions impacts occur over several different timescales. Air quality is immediately affected and varies on a daily basis with emissions volumes, while health impacts may take longer to emerge and tend to persist for longer periods. The impact of emissions on climate change persists for decades or centuries.

Commercial air travel is expected to double in the next 20 years, which will in turn increase the amount of contaminants emitted to the atmosphere. The following contaminants are emitted during the different phases of operation[27]:

[26] www.icao.int, browsed at 01.04.2018.
[27] Ibidem.

- Nitrogen oxides (NOx) includes nitrogen oxide (NO) and nitrogen dioxide ($NO_2$);
- Carbon Monoxide (CO);
- Unburned hydrocarbons;
- Sulphur Oxides;
- Particulate Matter (PM), leaves the exhaust as carbon black soot;
- Volatile Organic Compounds (VOCS) such as benzene and acrolein;
- Ozone ($O_3$), is formed from the nitrogen oxides and volatile organic compounds emitted;
- Semi- Volatile Organic Compounds (SVOCS);
- Metals;
- Noise – this contaminant is discussed in the Noise section;
- Odor.

The Table below highlights the effect on health and environment due to above stated containments.

Table 4. Residential response to the noise levels.

| Pollutant | Representive Health Effect |
|---|---|
| Ozone | Lung function impairment, effects on exercise performance, increased airway responsiveness, increased susceptibility to respiratory infection, increased hospital admissions and emergency room visits, and pulmonary inflammation, lung structure damage. |
| Carbon Monoxide | Cardiovascular effects, especially in those persons with heart conditions (e.g. decreased time to onset of exercise-induced angina). |
| Nitrogen Oxides | Lung irritation and lower resistance to respiratory infections. |
| Particulate Matter | Premature mortality, aggravation of respiratory and cardiovascular disease, changes in lung function and increased respiratory symptoms, changes to lung tissues and structure, and altered respiratory defense mechanism. |
| Violate Organic Composed | Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment. |
| **Pollutant** | **Representive Environment Effect** |
| Ozone | Crop damage, damage to trees and decreased resistance to disease for both crops and other plants. |
| Carbon Monoxide | Similar health effects on animals as on humans. |
| Nitrogen Oxides | Acid rain, visibility degradation, particle formation, contribution towards ozone formation. |
| Particulate Matter | Visibility degradation and monument and building soiling, safety effects for aircraft from reduced visibility. |
| Violate Organic Composed | Contribution towards ozone formation, odors and some direct effect on buildings and plants. |

Source: quietskiescoalition.org/files/Impacts_of_jet_polution_on_health.pdf.

Most of the focus of international efforts has been on the reduction of NOx so far (ICAO has an engine certification standard for NOx). Further assessment of the impacts of some of these contaminants (for example, particulate matter and metals) needs to be conducted in order to assess the risk to human health and to further the goal of reducing emissions. Besides NOx, ICAO has established limits for emissions of CO and unburned hydrocarbons.

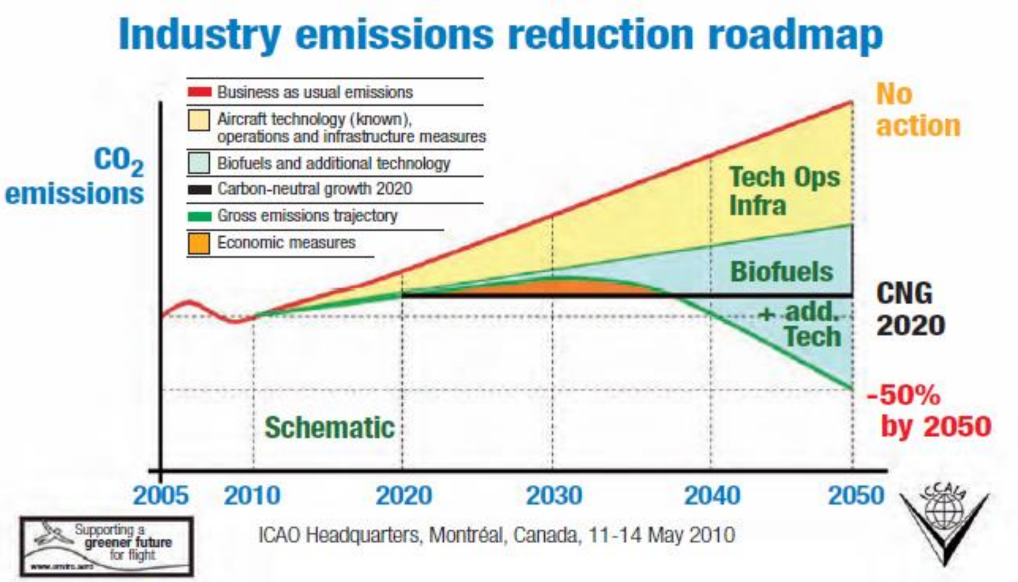
Auxiliary power units are also sources of contaminants. However, they are not certified for emissions and it is difficult to estimate emissions from these sources as manufacturers consider the emission rate information proprietary. Aircraft engine emissions and auxiliary power units are the only sources under the remit of ICAO.

**Emission Control**

*Committee on Aviation Environmental Protection* (CAEP) largely undertakes ICAO's environmental activities. It was established by the Council in 1983, superseding the *Committee on Aircraft Noise* (CAN) and the *Committee on Aircraft Engine Emissions* (CAEE). ICAO has approved four terms of reference for designing standards for emission control, standards must be:

- Technological feasible;
- Economical reasonable;
- Environmental beneficial;
- Balanced to account for interrelationships between emissions and noise.

This approach aims to develop realistic regulations and standards that take account of current, medium and long-term engine technology availability and types of fuel being used, while weighing the relative benefits of reductions in emissions, thereby providing a compromise between community benefits and implementation costs.




Because most operations in the vicinity of airports involve taking off and landing (as opposed to flying at cruise latitude), ICAO defines a landing and takeoff cycle to characterize the operational conditions of an aircraft engine within the environs of an airport. The emissions standards are applied to all newly manufactured turbojet and turbofan engines that exceeding certain rated thrust output at international standard. The chart below depicts the Aviation industry roadmap which highlights the reduction in $CO_2$ emission[28].

Some of the measures which are commonly used at airports to address emission below 1000 ft are as follows[29]:

- Low fuel/emission aircraft departure procedures;
- Continuous Descent Approach and Low Power - Low Drag techniques;
- Avoiding aircraft queuing on the ground;
- Avoiding unnecessary use of aircraft Auxiliary Power Units;
- Taxiing management (e.g. towing and single engine taxi);
- Increasing the use of public transport, cycling and pedestrian access to an airport (probably the major potential source of benefit);
- Supporting and encouraging staff to "car share" or to use more sustainable transport access;
- The use of electric vehicles or less polluting fuels (liquid and natural gas);
- Use less polluting fuels in airport buildings;
- Ensure adequate vehicle maintenance;
- Avoiding combustion equipment running when not required;

[28] www.icao.int/environmental-protection/Documents/Publications/ENV_Report_2010.pdf, browsed at 30.04.2018.
[29] www.eurocontrol.int, browsed at 05.05.2018.

- Energy management in buildings and for airfield systems (very often the most cost effective opportunity);
- Fugitive emission controls.

## 2.4. Water quality

Airports affect the quality of water in adjoining areas mainly through surface discharge of polluted water. The main sources of pollutants are as under:

**Aircraft deicing:**

During winters Aircraft Deicing is a major environmental concern. Deicing chemicals run off from aircraft and airport surfaces and disperses into surface water, thereby polluting it to a greater extent.

**Aviation fuel spills**:

Generally, aviation fuel spills occurs as a result of human fault. Fuel spills can be due to following:

- Refueling spills during warm periods when the sun's heat on aircraft wings can lead to overflows from fuel vents on full fuel tanks;
- Leaks and spills from the fuel farm and fuel supply infrastructure;
- Surface runoff from ground transport areas, including car rental bases, bus stops and bus stations, car parks and roads.

**Improper storage, handling or disposal of oils and other chemicals**:

Spills from oil and other chemicals containers not stored, handled or disposed of carefully leads to ground water contamination.

**Usage of Pesticides and herbicides**:

Pesticides and herbicides used by airport run off into the groundwater and adversely affect plant and animal life.

**Aircraft and ground support Vehicle Washing:**

Runoff from wet washes of aircraft and ground vehicle can contain heavy metals like lead and cadmium, oils, grease, detergents and solvents. This runoff is always a significant ground water pollutant.

**Managing Water Quality:**

As the aircraft deicing is the main environmental concern, its impact can be reduced by using lower-toxicity chemicals, using lower amounts of chemicals, or by controlling runoff[30]. Alternative Aircraft deicing fluid (ADF) with lower toxicity, lower bio-

[30] www.epa.gov, browsed at 10.05.2018,2002.

logical oxygen depletion and higher biodegradability should be used.

ADF use on aircraft, as well as runoff, can be reduced by applying ADFs using computerized spraying systems that work in a similar manner to automatic car washes. These systems can reduce the total volume of fluid used and the time needed for deicing. Deicing runoff can also be collected; it can be reused or disposed of in ways that have varying degrees of environmental impact. Regarding other water pollutants appropriate and adequate steps should be taken to reduce runoff.

## 2.5. Impact on Climate

The topic of greatest uncertainty and contention at this time concerns the impact of aviation on climate change. In Europe, where aviation's share of greenhouse gas emissions is 3% and growing, climate change is considered the single most important environmental impact from aviation.

Climate change is a change in the "average weather" that a given region experiences, including such factors as storm frequency, temperature, wind patterns and precipitation. The rate and magnitude of global climate changes over the long term have many implications for natural ecosystems. As society becomes increasingly reliant on energy consumption in work at home and for mobility, the heat-trapping nature of the atmosphere has increased. As our scientific understanding of this situation increases, so does public concern and the requirement for a policy response. Aviation contributes a small but growing proportion to this problem (less than 4% of man-made atmospheric emissions). A key factor however, is that some of aviation's emissions are emitted in the upper atmosphere and may have a more direct effect. The science of climate change is still relatively new and the future is uncertain. However, there is a broad consensus that policy needs to be enacted now if climate change related problems and costs are to be avoided.

Subsonic aircraft-in-flight contribute to climate change in various ways. Aircraft disturb the atmosphere by changing background levels of trace gases and particles and through condensation trails (contrails).

Aircraft emissions include greenhouse gases such as CO2, NOx and water vapors that trap earthly radiation and chemically active gases that alter natural greenhouse gases. Particles may directly interact with the Earth's radiation balance or influence the formation and radiative properties of clouds.

Aircraft "Contrails" are lines of ice crystals that are formed by the aircraft disturbing the air in certain conditions (e.g. moisture content, temperature etc.) with some contribution from combustion exhaust. It is now widely believed that these contrails can trigger the formation of cirrus clouds which thus affect climate. In 1992, aircraft contrails were estimated to cover about 0.1% of the Earth's surface on an annually averaged basis with larger regional values. Contrails tend to warm the Earth's surface, similar to thin high clouds. The contrail cover is projected to grow to 0.5% by 2050 at a rate which is faster than the rate of growth in aviation fuel consumption[31].

The necessary steps which can be undertaken to reduce the consumption of fuel in aircrafts are listed below:

[31] www.eurocontrol.int, browsed at 05.05.2018.

- Making routes more direct;
- Aiming for a fuel optimized flight profile;
- Increasing load factor and the capacity (and use) of more fuel optimized routes;
- Operating more fuel efficient aircraft;
- Avoid holding and queuing aircraft with engines running (in the air and on the ground);
- Avoiding noise restrictions and procedures that do not achieve sufficient benefit compared to the other environmental impacts;
- Using effective fuel optimized speeds when circumstances change;
- Using the other potential management options in the air quality section.

Closer to the ground, airport related operations contribute to climate change, through emitters such as aircraft, passenger transport trips, airfield ground transport, airport buildings and airfield systems. Below 1,000 ft aviation related emissions also affect air quality which is covered elsewhere. Measures to improve climate change impact at heights of less than 1,000 ft above the ground, may also have an air quality benefit. This is subject to trade-offs as covered in the air quality section.

There are a number of policy options being considered at governmental level and, instruments such as ICAO engine emission standards are helping to reduce aircraft fuel use and greenhouse gas emissions. However, other than general efficiency aims and, because the science on the relative climate effects of altitude, contrails and NOx is not yet fully understood the evaluation of potential policy solutions with the certainty of a positive result is incomplete.

**The Kyoto Protocol**

Many countries have signed The Kyoto protocol which is a modification to the *United Nations Framework Convention on Climate Change* (UNFCCC). These countries commit to reduce carbon dioxide and five other greenhouse gases or engage in emissions trading if they maintain or increase emissions of these gases. A total of 141 countries have ratified the agreement. Notable exceptions include the United States and Australia. The Kyoto protocol was negotiated in Kyoto, Japan in December 1997, opened for signature on March 16, 1998, and closed on March 15, 1999. The agreement came into force on February 16, 2005 following ratification by Russia on November 18, 2004. It is likely that commitments to Kyoto, and emerging science and growing concern about the effects of emissions and contrails in the upper atmosphere, will raise aviation's profile on the international climate change policy agenda[32].

[32] www.eurocontrol.int, browsed at 05.05.2018.

**Emissions Trading Scheme**

As part of that process of reducing emissions the ICAO has endorsed the adoption of an open emissions trading system to meet CO2 emissions reduction objectives. Guidelines for the adoption and implementation of a global scheme are currently being developed, although the prospects of a comprehensive inter-governmental agreement on the adoption of such a scheme are uncertain.

Within the European Union, however, the European Commission has resolved to incorporate aviation in the *European Union Emissions Trading Scheme* (ETS). A new directive has been adopted by the European Parliament in July 2008 and approved by the Council in October 2008. It was supposed to enter into force on 1 January 2012, but due to lack of bilateral agreements between legalizers and airlines originated from outside EU, the introduction was postponed up to 2020 and requires more consultations.

## 2.6. Mitigation and Strategy to reduce Aviation Emissions – Five-Pillar Environmental Approach

Mitigation the ways people use to emit less greenhouse has emissions, by creating different limits for example as cup systems, kerosene taxation. There are also several schemes which directed for less emissions.

The ability of plants to capture carbon and release into the atmosphere varies between species. A short biomass of rotation, such as agro biomass, quickly decays after growth. A long biomass of rotation, such as pine or spruce in boreal forests, can exceed the rotation period of 100 years and, therefore, act relatively long, like storage of organic carbon. The period of rotation of carbon is a very important factor that should be taken into account when assessing the effectiveness of various methods of using biomass to mitigate the effects of climate change. A large reserve of terrestrial carbon is a soil, which is also affected by the use of biomass. The coefficient of fluidity of this pool is usually slow, but anthropogenic changes in land use can turn the soil into a strong source of emissions.

FAA sets its specific goals for environmental initiatives based on the latest scientific understanding of aviation's environmental impacts. The Agency focuses on five pillar system.

PILLAR 1: Improved Scientific Knowledge and Integrated Modeling

Activities based on a solid scientific foundation as aviation environmental analyses, impact determinations, and mitigation decisions for NextGen. For the improve scientific understanding of the impacts of aviation it requires continued investments in research. In addition, developing and using advanced decision support tools that account for interdependencies of impacts and cost-benefit analyses of potential solutions facilitates more informed decision-making. Prospective solutions and combinations of solutions have different impacts, benefits, and costs. Some solutions optimize for one area of environmental protection at the expense of another; where trade-offs are made they are explicitly defined and as transparent as possible.

*Centers of Excellence* (COE). The FAA has long had a successful partnership with the nation's academic research community, working with more than 75 U.S. colleges and universities to foster important research conducted by faculty and students. For almost two decades, these efforts have contributed significantly to advancing aviation science and technology while providing the agency and the industry a high return on investments. Through FAA COEs, the government, academic institutions, and industry leverage the combined resources available for aviation research and maximize technological competence for public purpose.

*Alternative Fuel Effects on Contrails and Cruise Emissions* (ACCESS). NASA initiated the ACCESS program as a follow-on to the APEX emissions measurement projects as part of their *Fundamental Aeronautics Aviation Emissions Research* program. With FAA's active participation, the first ACCESS project sampled aircraft cruise emissions with inflight testing of a 50/50 blend of an alternative jet fuel and conventional jet fuel. Tests were conducted over a range of power-settings at different altitudes. Also, extensive measurements of ice particle size and concentrations were made to evaluate contrail formation. Additional alternative jet fuel testing and inflight emissions measurements will be part of future ACCESS projects conducted in the next few years. These projects may also provide an opportunity to verify the models used to evaluate aviation emissions impacts.

Aviation Emissions Characterization (AEC) *Roadmap*. *The AEC Roadmap* is a unified regulatory research and development (R&D) roadmap for understanding and quantifying aircraft emissions. FAA, NASA, DOD, and EPA all are members of the AEC Roadmap Coordination Council. There is collaboration on the roadmap with manufacturers, airports, airlines, and other stakeholders. The Roadmap coordinates research activities and communicates research findings among stakeholders and other parties with an interest in PM, hazardous air pollutants (HAP), and other emissions from aviation sources. The Roadmap's objective is to gain the necessary understanding of emissions' formation, composition, and growth and transport mechanisms to assess aviation's emissions and understand their impact on human health and the environment. The AEC Roadmap does not fund research projects, but it does help agencies identify research priorities and leverage their budgets to accomplish more than they would otherwise.

*Airport Cooperative Research Program* (ACRP). FAA funds an industry-driven, applied research program that develops near-term, practical solutions to problems faced by airport operators. The *Transportation Research Board* (TRB) of the National Academy of Sciences manages ACRP. The program carries out applied research on problems that are shared by airport operating agencies, which may not be adequately addressed by other federal research programs. A substantial number of ACRP projects have addressed environmental concerns ranging from emissions measurement campaigns to model development and enhancement to practical guidance to airports for improving their environmental performance. Of FAA's $15 million annual funding for the ACRP, $5 million is allocated for environmental projects. Since the ACRP is identified in FAA reauthorization legislation, 86 it is anticipated that this program will continue in the future.

Aviation Climate Change Research. In 2010, FAA initiated the 3-year *Aviation Climate Change Research Initiative* (ACCRI) program under its climate change research program to evaluate the impacts of aviation emissions on climate change from a 2006 baseline and into the future (2050). It evaluated the effects of aerosols, induced contrail effects, contrail-induced cirrus effects, and aerosol indirect effects. In addition to the tools FAA developed, this research used a number of large-scale general circulation models and simple climate models, satellite and laboratory measurements, and detailed aerosol and ice-particle microphysical models. This research recognized the potential impact of indirect aerosol and contrail effects. Quantifying these impacts is the subject of ongoing current climate research. 87 The current scientific opinion as expressed in this effort emphasizes the need to lower uncertainties while characterizing the aviation chemical and physical impacts on climate. Additional studies are currently underway in analyzing data from 2012 to estimate their reliability and accuracy.

PILLAR 2: Air Traffic Management Modernization

Developing and integrating advanced operational procedures and infrastructure improvements enhances operational capabilities that function more efficiently, improving energy efficiency and thus mitigating environmental impacts. Air traffic management modernization and improvements being made as part of NextGen increase the efficiency of aircraft operations, both in the air and on the airport surface. Improving efficiency saves time and fuel. Reducing fuel consumption reduces CO2 emissions that affect climate and other emissions that adversely affect air quality. Performance Based Navigation (including area navigation (RNAV) and required navigation performance (RNP)) routes can cut fuel burn, emissions, and flight times. Optimized Profile Descents (OPD) can reduce noise, emissions, and fuel consumption. New technology and procedures that optimize gate-to-gate operations are being demonstrated with international partners in Europe and Asia-Pacific to reduce fuel burn, emissions, and noise. One of the most significant programs for improving operations is NextGen.

Transforming the Air Transportation System – NextGen. FAA has begun the transformation of the air transportation system through NextGen a metamorphosis of the air traffic control system. The FAA's environmental vision for NextGen is to provide environmental protection that allows sustained aviation growth. NextGen will provide many opportunities for accomplishing emission mitigation goals by giving impetus to and accommodating changes that are needed for system efficiency and operational improvements. FAA is developing NextGen capabilities that will guide and track aircraft more precisely and efficiently in the air and on the ground to save fuel, decrease emissions and manage the impact of noise on communities. In addition, the

Agency is advancing efforts to reduce aircraft fuel burn, emissions, and noise through innovative aircraft technologies. In this way, FAA's environmental goals mesh well with the broader agency goals.

PILLAR 3: New Aircraft and Airport Technologies

Historically, new technologies have offered the greatest success in reducing aviation's environmental impacts. New engine and airframe technologies continue to play key roles in achieving aviation environment and energy goals. The FAA and other agencies support advances in engine technology and airframe configurations to lay the foundation for the next generation of aircraft. Its technological strategy envisions a fleet of quieter, cleaner aircraft that operate more efficiently with less energy. The FAA and NASA, along with the Department of Defense, closely coordinate efforts on aeronautics technology research through the National Aeronautics Research and Development Plan. Each agency focuses on different elements but they share the same national goals. The FAA's focus is on maturing technologies for near term application while NASA focuses on a broader range of time frames of technology development. FAA's Continuous Lower Energy, Emissions and Noise (CLEEN) program is a NextGen effort to accelerate development and commercial deployment of environmentally promising aircraft technologies and sustainable alternative fuels. The aircraft technologies focus on reduction in aircraft noise, emissions, and fuel burn. Under this program, FAA has awarded five-year agreements to Boeing, General Electric, Honeywell, Pratt & Whitney, and Rolls-Royce. The total federal investment is expected to be $125 million over five years.

*Continuous Lower Energy, Emissions, and Noise* (CLEEN). The CLEEN program is a five-year effort to accelerate technology development. Advancements from the program reduce aircraft emissions, fuel burn, and noise through a cost shared initiative between FAA and industry where companies provide at least 50% or greater funding.

CLEEN has demonstrated engine technology that reduced landing and takeoff NOx emissions by more than 60 percent below the ICAO standard adopted in 2004. It is also developing aircraft technology that contributes toward a 33% aircraft fuel burn goal relative to current technology with commensurate energy consumption and greenhouse gas emission reductions. Improved engine technologies, avionics, aircraft aerodynamics, and weight-related technologies also are being developed that will reduce aircraft fuel burn further. These achievements are expected to appear in the commercial airline fleet in the next several years.

CLEEN has also made significant contributions in the development and deployment of alternative jet fuels that are a drop-in replacement to fuels derived from petroleum. Alternative jet fuels are being tested to confirm the environmental benefits, technological feasibility, and economic cost. The efforts of CLEEN on aircraft technology maturation and alternative fuels development and deployment will help the FAA ensure that NextGen provides environmental protection that allows sustained aviation growth.

Following the success of the CLEEN program to date, FAA has established new goals for a second phase program, CLEEN II, from 2015 to 2020. CLEEN II will again have components focusing on emissions, fuel burn, and noise. New technologies, new aircraft designs, new system designs, and new alternative fuels from this program are expected to appear in use in the commercial fleet beginning at the end of this decade and will achieve reduced emissions, fuel burn, and noise in the decades to come.

*Voluntary Airport Low Emission* (VALE) program and Zero Emission Airport Vehicle and Infrastructure Pilot Program (ZEV). The FAA's Office of Airports has two specific programs underway to reduce emissions from ground support equipment and other airport vehicles. The VALE program 88 expands eligibility for airport low emission projects under the Airport Improvement Program (AIP) and the Passenger Facility Charges (PFC) program.

Through the use of funding and emission credit incentives, the voluntary program supports converting airport vehicles and ground support equipment to low emission technologies, modifying airport infrastructure for alternative fuels, providing terminal gate electricity and air for parked aircraft, a pilot program to explore retrofit technology for airport ground support equipment, and other related emissions improvements. Between 2005 and 2012, more than $146 million 89 from AIP, PFC, and local matching funds has been invested thorough the VALE program to reduce airport emissions. The ZEV program90 allows FAA to award AIP funds to airports to purchase zero emissions vehicles and make infrastructure changes necessary to charge or otherwise fuel these vehicles. Authorized in 2012, the ZEV program encourages the use and development of electric and hydrogen fuel cell vehicles. There are an Aviation Emissions, Impacts & Mitigation: A Primer wide variety of vehicles used at airports, from automobiles and vans to large passenger buses, and this program encourages manufacturers to develop zero emission alternatives to meet these needs.

PILLAR 4: Sustainable Alternative Aviation Fuels

Developing and deploying sustainable alternative aviation fuels enables environmental improvements, energy security, and economic stability for aviation. The aviation industry is committed to converting its fuel supply to alternative fuels. 91 Government and industry are working cooperatively with coordinating mechanisms such as the *Commercial Aviation Alternative Fuels Initiative* (CAAFI) and are supporting alternative fuels research. Near term efforts include adding new classes of fuels to the approved alternative jet fuel standard by *American Society for Testing and Materials* (ASTM) *International* and conducting aircraft flight tests using alternative fuels to confirm their suitability and environmental benefits. To date, these efforts have led to the certification of three alternative jet fuel types by ASTM International. ASTM International D7566 specification 92 covers the manufacture of aviation turbine fuel that consists of conventional and synthetic blending components.

To date, three alternative jet fuels have been approved for blending with jet fuel by standard setting organization ASTM International. They include fuels from biomass, coal or natural gas known as *FischerTropsch* (FT) jet fuel; fuel from fats, plant oils and greases known as *Hydro-processed Esters and Fatty Acids* (HEFA) jet fuel; and, fuel from fermented sugars known as *Synthesized Iso-Paraffins* (SIP) jet fuel. At this time additional fuel types are under evaluation for future approval.

One of the hallmark efforts in this area is Farm to Fly, commenced in July 2010, as a result of the U.S. Department of Agriculture (USDA), Airlines for America Inc. (A4A) and the Boeing Company (Boeing) signing a resolution formalizing their commitment to work together on the initiative. The FARM to FLY 2.0 program 93 will "accelerate the availability of a commercially viable and sustainable aviation biofuel industry in the United States, increase domestic energy security, establish regional supply chains, and support rural development". In April 2013, the USDA and FAA joined with industry partners from Airlines for America (A4A), Aerospace Industries Association (AIA), Airports Council-North America (ACI-NA), National Business Aviation Association (NBAA) and the General Aviation Manufacturers Association (GAMA) in an expanded "Farm to Fly 2.0" collaboration "to enable commercially viable, sustainable bio-Jet Fuel supply chains in the U.S. that are able to support the goal of one billion gallons of bio-Jet Fuel production capacity and use for the Aviation Enterprise by 2018. In July 2014 the U.S. DOE also signed on as a partner to the agreement. Commercial Aviation Alternative Fuels Initiative (CAAFI), CAAFI 94 is a coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participants, and U.S. government agencies formed to develop and deploy alternative jet fuels for commercial aviation. CAAFI's goal is to develop alternative jet fuel options that offer equivalent levels of safety and compare favorably on cost with petroleum based jet fuel, while also offering environmental improvement and security of energy supply. To date, CAAFI has seen three fuel development pathways approved by ASTM and more than 1500 international demons-tration and commercial aircraft flights using alternative fuels. Since aviation is international in scope, highly integrated in its fuel supply chain, and has a significant ability to align and coordinate within the industry, it is a very promising first mover among customers for alternative fuels.

*Unleaded Avgas Transition* (UAT Plan). Almost all aviation gasoline (avgas) used to power piston engine general aviation aircraft is designated “100 low lead”. 100 low lead contains small amounts of tetraethyl lead, which boosts fuel octane. High-octane fuels are required in many aircraft so that their piston engines will not “knock”, which can cause severe engine damage. However, EPA and the Centers for Disease Control and Prevention (CDC) have found in the past decade that there is no safe level of lead in blood. For that reason, the aviation community and government are coming under pressure to eliminate lead emissions from aircraft. At the request of the aviation, petroleum, and other concerned interests, FAA has initiated and is implementing the UAT Plan, which calls for a two-phase approach to identifying and approving an operationally safe unleaded avgas. One component of the plan is formation of the Piston Aircraft Fuels Initiative, which is composed of members from FAA, general aviation industry, and petroleum interests who will fund and coordinate identification and approval of the most promising unleaded candidate fuels. At the same time EPA is working to gain a better understanding of aircraft lead emissions and potential exposure through monitoring, modeling, demographic, and other studies. FAA's goal is to have a replacement fuel for leaded avgas available by 2018, 95 which is usable by most general aviation aircraft.

PILLAR 5: Policies, Environmental Standards, and Market-Based Measures.

Developing and implementing appropriate policies, standards, programs, and mechanisms are critical steps in quickly integrating advantageous technology and operational innovations into the commercial fleet, the airport environment, and entire national aviation system. An example is the development of the NextGen Environmental Management System (EMS), which integrates environmental protection objectives into NextGen. Cooperative partnerships between government and industry focus effort and leverage funding in ways that are beneficial for aviation and good for the environment. Internationally, the U.S. is leading efforts at ICAO to limit and reduce international aviation emissions, most notably through development of an aircraft CO2 standard and an engine PM certification requirement. ICAO has additionally agreed to explore more ambitious goals for the aviation sector including carbon neutral growth in the mid-term and reductions in the long term. The FAA is exploring the effectiveness of various policies, including economic incentives to limit and reduce CO2 emissions. Additionally, to achieve environmental and energy goals beyond the near term, policies are needed that accelerate the integration of new technologies into the civil fleet compared to the normal rate of introduction and replacement.

*Aviation Sustainability Center* (ASCENT). FAA recently established a new Center of Excellence for Alternative Jet Fuels and Environment. ASCENT will explore ways to meet the environmental and energy goals for NextGen, which will provide environmental protection that allows sustained aviation growth.

ASCENT is structured as a cost sharing partnership with academia to provide R&D support to inform FAA's environmental commitments and aspirational goals. To achieve the aspirational 2018 alternative jet fuels target of one billion gallons used 96 per year and help to ensure the wide spread use of sustainable alternative jet fuels in the longer term, ASCENT will assist the FAA and the community with research to develop viable supply as well as secure ASTM International approval of alternative jet fuels.

*Partnership for Air Transportation Noise and Emissions Reduction* (PARTNER). PARTNER, an FAA COE, was cosponsored by NASA, Transport Canada, the U.S. Department of Defense, and the U.S. Environmental Protection Agency. PARTNER was comprised of 12 universities, 97 and approximately 50 advisory board 98 members including aerospace manufacturers, airlines, airports, national, state and local government, professional and trade associations, non-governmental organizations and community groups. They were united to foster collaboration and consensus to jointly advance environmental performance, efficiency, safety and security.

As an incentive to collaboration, equal matches were required for federal funds granted to PARTNER. The universities provided some of these matching funds, but most were obtained from the organizations represented on the advisory board. This collaborative process fueled unique research efforts on emissions, operations, alternative fuels, noise, and policy evaluations involving a wide spectrum of participants. More than 48 research projects have been completed or are underway representing a total budget of more than $56 million over the past 10 years. With the completion of the PARTNER program, a new Center of Excellence, ASCENT, was established. Some of the PARTNER projects were transitioned, through a competitive process to ASCENT, discussed above.

## 2.7. Reducing Aviation Emissions in the Future

FAA has made significant progress addressing environmental concerns through the strategy and programs it has created under the *Five Pillar Environmental Approach*. New engine designs and technologies, like those developed in the CLEEN program, are improving fuel efficiency further, while simultaneously reducing noise, NOx and PM emissions. New aircraft designs are taking advantage of advanced computer models to improve operating performance and fuel efficiency, reducing all pollutants at the same time. New air traffic control technologies and operating practices are reducing emissions by reducing fuel consumption. Airports are using low emission equipment. And alternative jet fuels are being developed that will cut the impact of aviation on climate change and air quality significantly. More progress in reducing environmental impacts will be needed, however, to meet the challenges of the future posed by growth in aviation and the need to reduce emissions beyond current levels, particularly with respect to climate emissions.

It is clear that aviation emissions' impacts on health and the global climate will drive the FAA's research program in the future. These impacts are continually interpreted through regulatory and policy mandates, such as the *Clean Air Act*, the *National Environmental Policy Act*, FAA's NextGen program, and ICAO requirements, which in turn set new levels of performance that must be achieved. Those mandates are evaluated using the *Five-Pillar Environmental Approach* to define research plans and objectives as noted in Figure 8: Defining research initiatives.

3 main goals and their ways to achieve in the reduction pollution are presented in the table below[33]:

Table 5. Three Goals for Aviation Industry.

| GOAL 1 | GOAL 2 | GOAL 3 |
|---|---|---|
| PRE - 2020 AMBITION | IN LINE WITH THE NEXT UNFCCC COMMITMENT PERIOD | ON THE 2C PATHWAY |
| 1.5% AVERAGE ANNUAL FUEL EFFICIENCY IMPROVEMENT FROM 2009 TO 2020 | STABILISE NET AVIATION C02 EMISSIONS AT 2020 LEVELS THROUGH CARBON - NEUTRAL GROWTH | REDUCE AVIATION'S NET CO2 EMISSIONS TO 50% OF WHAT THEY WERE IN 2005 BY 2020 |
| PROGRESS | PROGRESS | PROGRESS |
| Currently tracking well above goal (2,9%), although figure is expected to normalise. | Industry is pushing for action at an intergovernmental level. | Significant research efforts underway. |
| HOW IS INDUSTRY ACHIEVING THIS? | HOW IS INDUSTRY ACHIEVING THIS? | HOW IS INDUSTRY ACHIEVING THIS? |
| Through actions in the first three pillars: new technology, more efficient operations and better use of infrastructure | Through the full four-pillar strategy, including a global market-based measure at the International Civil Aviation Organization(ICAO) | Two main areas of actions: development of sustainable alternative aviation fuels; research into future design concepts by aircraft and engine manufacuters |

Source: quietskiescoalition.org/files/Impacts_of_jet_polu-tion_on_health.pdf.

33 www.npi.gov.au/reducing-pollution.

## Methods of mitigation

Mitigation of the effects of aviation on land can be achieved through measures that are most obvious and perhaps the most economical of them is the reduction in fuel consumption, as this accounts for 28% of airline spending. Nevertheless, there is a wide range of other options available to minimize the impact of aviation on the glass environment, which are listed below

## Aircraft efficiency

Since reducing the direct combustion of fuel on an airplane is the most obvious and, perhaps, the most economical way to reduce emissions associated with the aviation there are some types of aircraft which produce less emissions than current generation.

Boeing 787 Dreamliner promises to provide 20% less fuel burn than present type of aircraft. As noted earlier, the reduction in direct combustion of fuel by air is the most obvious and perhaps the most economical way to reduce aviation emissions. Over the past 40 years, commercial jetliners have become 70% more economical and are projected to use fuel by 25% more by 2025.

**Route optimization**

Currently, air traffic corridors that aircraft are forced to follow place unnecessary detours on an aircraft's route forcing higher fuel burn and an increase in emissions. An improved *Air Traffic Management System* with more direct routes and optimized cruising altitudes would allow airlines to reduce their emissions by up to 18%.

In the European Union, a Single European Sky has been proposed for the last 15 years so that there are no overlapping airspace restrictions between countries in the EU and so reduce emissions. As yet, the *Single European Sky* is still only a plan, but progress has been made. If the *Single European Sky* had been created 15 years ago, 12 million tons of $CO_2$ could have been saved.

## 2.8. Biofuels

What is biofuel? A biofuel is a hydrocarbon that is made by or from a living organism that we humans can use to power something. In practical consideration, any hydrocarbon fuel that is produced from organic matter that live in a short period of time (days, weeks, or even months) is considered a biofuel while fossil fuels take millions of years to form and with other types of fuel which are not based on hydrocarbons (nuclear fission, for instance).

What makes biofuels tricky to understand is that they need not be made by a living organism, though they can be. Biofuels can also be produced by using chemical reactions, carried out in a laboratory or industrial setting, that use organic matter (called biomass) to make fuel. The only real requirements for a biofuel are that the starting material must be $CO_2$ that was fixed (turned into another molecule) by a living organism and the final fuel product must be produced in short period of time rather than long period of time.

Biofuels which is agro-fuel were made from biomass or from bio waste. These fuels can be used for any goals, but mostly they have to be brought is in the transportation sector. Most of the vehicles require fuels which provide high power and are dense so that storage is easier. These engines require fuels that are clean and are in the liquid form.

The big plus is that they can be easily pumped, and also easy to process. This is the main reason why almost all cars use a liquid fuel form for combustion purposes. There are also other types of fuel, like wood. These non-transportation applications can use these solid fuels from biomass because they easily tolerate a low specific external combustion power. Wood was put into operation with a very long period and is one of the main factors of global warming.

Biofuels or agro-fuels are the best alternative for reduction the emission of greenhouse gasses. They can also be seen as a way of ensuring energy security, which acts as an alternative to fossil fuels that are limited in availability. Nowadays, the use of biofuels becomes more popular throughout the world.

The major producers and users of biogases are Asia, Europe and America. Theoretically, biofuel can be easily produced through any carbon source; making the photosynthetic plants the most commonly used material for production. Almost all types of materials derived from the plants are used for manufacturing biogas. One of the greatest problems that is being faced by the researchers in the field is how to covert the biomass energy into the liquid fuel.

There are two ways to solve the problems above. In the first, sugar crops or starch are grown, and ethanol is produced during fermentation. In the second art, plants are grown that naturally produce oil, like jatropha and algae. These oils are heated to reduce their viscosity, after which they are directly used as a fuel for diesel engines. This oil can be further processed to produce biodiesel, which can be used for various purposes. Most of the biofuel comes from biomass or bio-waste. Biomass can be called a material that is obtained from a living organism. Most of the biomass is derived from plants and animals, and also includes their products. The most important feature of biomass is that they are renewable energy sources, unlike other natural resources such as coal, oil and even nuclear fuel. Some agricultural products that are specifically grown for biofuel production are millet, soybean and corn in the United States. Brazil produces sugar cane, sugar beet and wheat in Europe, while cassava and sorghum are produced in China, macaroni and palm oil are produced in Southeast Asia, and jatopha produced in India.

**Types of biofuel**

There are some types of liquid biofuels: ethanol, biodiesel, methanol, biobutanol.

Ethanol starches from wheat, corn, sugar cane, molasses, potatoes, other fruits. In comparison with fossile fuel gassoline ethanol has approximately half the energy per mass of gasoline, which means that twice as much ethanol is needed to produce the same energy. Ethanol burns cleaner than gasoline but produces less carbon monoxide. However, ethanol produces more ozone than gasoline, and contributes significantly to smog. The motors must be modified to work on ethanol.

Biodiesel usually it is oils and fats including animal fats, vegetable oils, nut oils, hemp, and algae. Biodiesel in comparison with regular diesel has only slightly less energy than regular diesel. It is more corrosive to engine parts than standard diesel, which means engines have to be designed to take biodiesel. It burns cleaner than diesel, producing less particulate and fewer sulfur compounds.

Methanol inedible plant matter. In compare with methan Methanol has about one third to one half as much energy as methane. Methanol is a liquid and easy to transport whereas methane is a gas that must be compressed for transportation.

Biobutanol also as ethanol Starches from wheat, corn, sugar cane, molasses, potatoes, other fruits. In compere with butane Biobutanol has slightly less energy than gasoline but can run in any car that uses gasoline without the need for modification to engine components.

**Biofuels Contribute to Global Warming**

Assuming we can overcome the problem of biofuels interrupting the food supply (such as growing algae in the ocean), can we overcome the problem of biofuels contributing to global warming? The answer, surprisingly, may be yes.

It is true that biofuels produce carbon dioxide, which is a potent greenhouse gas and the one most often blamed for global warming. However, it is also true that growing plants consumes carbon dioxide. Thus, the equation becomes a simple balancing act. If the plants we grow utilize the same amount of carbon dioxide that we produce, then we will have a net increase of zero and no global warming. How realistic is this view?

It may seem like a simple matter to only produce as much carbon dioxide as plants use. After all, couldn't we only burn biofuels and thus keep the equation balanced? Well, the math actually doesn't quite add up. Research has shown that energy must be invested into producing crops and converting them into biofuels before any energy is obtained. A 2005 study from Cornell University found that producing ethanol from corn used almost 30% more energy than it produced. In other words, you can't produce a perpetual motion machine using biofuels because you lose the energy you invest in creating them in the first place. In fact, you can't even break even.

The other problem that we run into with biofuels is that carbon dioxide is not the only greenhouse gas we have to worry about. Other chemicals, like nitrous oxide, are also greenhouse gases and growing plants using fertilizer produces a lot of nitrous oxide. Basically, fertilizer contains nitrogen, which plants need to grow. However, most plants cannot convert molecular nitrogen into the elemental nitrogen they need. For this process, plants rely on bacteria. As it turns out, bacteria not only produce nitrogen that plants can use, they also produce nitrogen products like nitrous oxide, and probably more than was previously thought. The net result is that we may be balancing the $CO_2$ equation by using biofuels, but we are unbalancing the $N_2O$ part of the equation and still causing global warming.

There are list of airlines that making some investment to save environment by reducing the use of fossil fuel. And there are some examples:

Virgin Atlantic Airways good example, their one engine is operating on a blend of 20% coconut oil and 80 % traditional jet fuel, also Continental airlines which one engine operates on a blend of 44% jatropha oil, and 6% algae oil and a 50% traditional jet fuel.

**Case Study: Continental Airlines and the Environmental Agenda**

Continental Airlines has shown its dedication to minimize its environmental impact through a comprehensive environmental agenda aimed at reducing greenhouse gas emissions. The Agenda highlights the various techniques and approaches incorporated by continental Airlines to reduce ill impacts on environment.

**Agenda:**

Fleet Modernization:

- Continental Airlines has invested more than $13 billion to acquire 300 fuel-efficient aircraft and related equipment over the past 12 years. Current fleet is equipped with fuel-saving modifications to further reduce emissions, such as winglets or efficient fan blades.
- Continental Airline has also committed to invest in additional new, fuel-efficient aircraft and ground equipment worth more than $10 billion through 2016.

Improving operational procedures:

- The airline employs an enhanced flight-planning system to minimize fuel burn and will be implementing a new flight-planning system with next-generation technology.
- Where-ever possible, aircraft are parked at the gate with air conditioning and electric power sourced via alterna-

tive, energy-saving methods rather than the aircraft's own auxiliary power units.

- Continental uses ground equipment instead of aircraft engines to move aircraft from gate to gate whenever possible and only one engine during ground taxi whenever possible.
- The airline also uses Low Emissions Vehicles and electric ground service equipment where possible.

Recycling:

- Since 2008 Continental has been recycling onboard aircraft, at airport terminals and at other supporting facilities.
- Continental also works with contract caterers at the non-hub airports it serves to encourage recycling.

Alternative fuels:

- Continental works with industry partners to develop alternative jet fuels that are safe, economically viable and more environmentally friendly than today's fuels and that can be available in reliable quantities.
- In January 2009, Continental became the first U.S. carrier to perform a two-engine aircraft flight demonstration using sustainable bio-fuels made from algae and Jatropha.

Employee efforts:

- At the airline's New York hub at Newark Liberty, employees have worked together to establish a local "Green

Team," who review the impact of the airline on the environment at Newark Liberty and suggest innovative ideas to tackle their emissions.

**Outcomes:**

- ✓ By modernizing its fleet, Continental airlines has reduced greenhouse gas emissions and fuel consumption by 38% per revenue passenger mile since 1997.
- ✓ The winglets installed on some of Continental's fleet result in a reduction of up to 5% in emissions and noise.
- ✓ The Low Emissions Vehicles and electric ground service equipment have reduced nitrogen oxide emissions by 75% from ground equipment at Houston's Bush Intercontinental Airport – Continental's largest hub.
- ✓ Between 2006 and 2009, the airline collected more than 16.6 million pounds of recyclable materials from its hub airports.
- ✓ More than 91% of Continental's domestic catering partners and more than 87% of its international caterers recycle.
- ✓ Overall life cycle greenhouse gas emissions related to a bio-fuel of the nature used on the Continental demonstration flight are estimated to be reduced by 60 to 80% as compared to traditional jet fuel.

Source: ATAG, 2011.

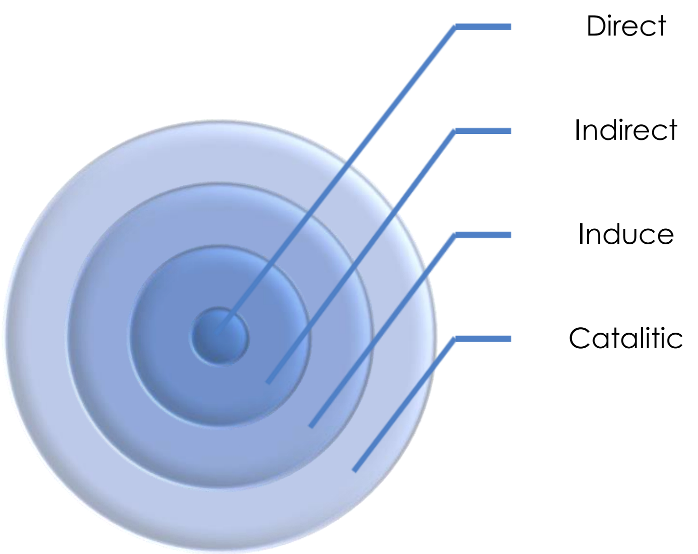
# CHAPTER 3

# ECONOMIC BENEFITS OF AVIATION

## 3.1. The aviation sector and its economic footprint

The air transport industry has become a major driver of the global economy, supporting nowadays nearly 63 million jobs worldwide and 2.7 trillion USD in global GDP[34] through four distinct channels: direct, indirect, induce and catalytic.

Figure 3. Four dimensions of economic impact of aviation.




Source: Own Work.

[34] ATAG, *Aviation: Benefits beyond borders*, 2016.

**Direct impact**

This category includes employment in companies in the aviation sector, such us airports, airlines, civil aerospace, or air navigation service providers. According to the ATAG around 9.9 million people work directly[35] in the air transport industry, including:

- Airport operators: 447,500 employees;
- Other on-airport: 5,468,000 employees;
- Airlines: 2,669,000 employees;
- Civil aerospace: 1,101,000 employees;
- Air navigation service providers: 224,000 employees.

Examples of these sectors:

- ✓ Airport operators – all people working directly for the airports operators;
- ✓ Other on-airport jobs – all people working directly at the airports (excluding those working for the airport operators): in retail, car rental agencies, government agencies, freight forwarders and catering companies;
- ✓ Airlines (flight and cabin crews, executives, ground services, check-in, training, maintenance staff);
- ✓ Civil aerospace – people hired as engineers and designers of civil aircraft, engines and components;

[35] Ibidem.

- ✓ Air navigation service providers - air traffic controllers, executives.

**Indirect impact**

This category includes employment supported through the air transport supply chain. According to ATAG over 11.2 million indirect jobs globally are supported through the purchase of services and goods by companies in the air transport industry.

Examples in this sector:

- ✓ aviation fuel suppliers;
- ✓ construction firms/companies that build airport facilities;
- ✓ suppliers of sub-components used in aircraft;
- ✓ manufacturers of products and goods sold in airport retail outlets;
- ✓ a wide variety of activities in the business services sector (such as call centers, information technology and accountancy).

**Induce impact**

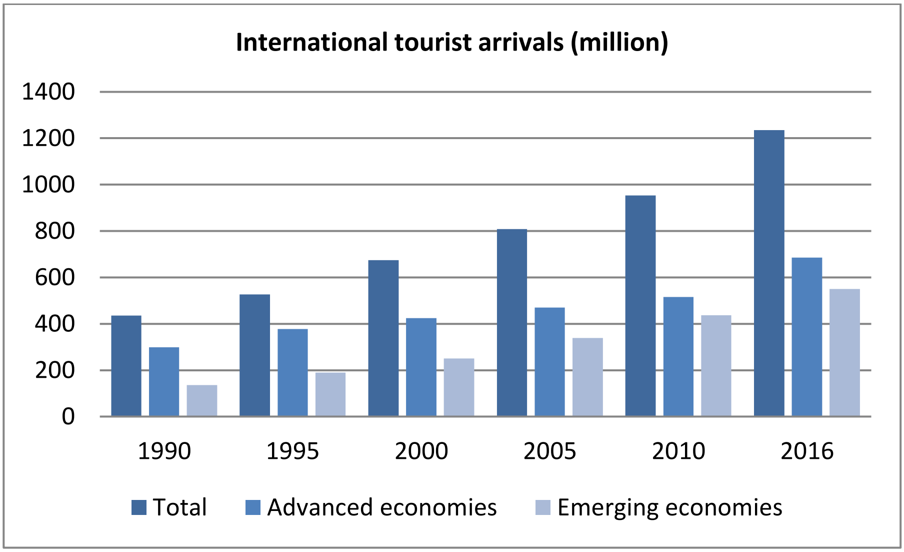
Induce impact can be defined as the buying power of air transport employees, so it covers employment and output supported by the spending of people directly or even indirectly employed in the aviation sector such us hotels, restaurant, banks, etc.

Worldwide, 5.2 million induced jobs globally are supported through employees in the air transport industry (whether direct or indirect) using their income to purchase goods and services for their own consumption.

## Catalytic

Tourism is one of the largest and fastest growing economic sectors. According to UNWTO international tourist arrivals reached in 2016 a total of 1,235 million. Furthermore, the number of international tourist arrival will reach 1.8 billion by 2030[36].

Graph 4. International tourist arrivals (million).




Source: United Nation World Tourist Organization, *Tourism highlights,* 2017 edition.

[36] United Nation World Tourist Organization, *Tourism highlights,* 2017.

As we can see on the graph, the number of international tourists increase year on year, from 435 million in 1990 to 1,3 billion in 2016.

Air service is a fundamental component of tourism, because it provides the link between the origin and the destination. According to the United Nation World Tourism Organization in 2016 nearly 55% of all international tourism travelers use air transport (the most popular means of transport among tourist) and the share of air transport is gradually increasing. ATAG suggest that the air transport industry supports over 36 million jobs within the tourism industry.

The above examples show us how important a role aviation plays in job creation; thus this role as we can see below will be even more important in the future. In 2034, the total number of jobs generated by air transport (direct, indirect, induce and catalytic) will reach 99 million.

Table 6. Aviation global employment impact – 2016 vs 2034.

<table>
<tr><th></th><th>2016</th><th>2034</th></tr>
<tr><td>Direct</td><td>9.9 million</td><td>14.9 million</td></tr>
<tr><td>Indirect</td><td>11.2 million</td><td rowspan="2">39.6 million</td></tr>
<tr><td>Induce</td><td>5.2 million</td></tr>
<tr><td>Catalytic</td><td>36.3 million</td><td>99.1 million* (including direct, indirect, induce employment impact)</td></tr>
<tr><td>TOTAL</td><td>62.7 million</td><td>99.1 million*</td></tr>
</table>

Source: Own work based on ATAG, *Aviation benefit beyond borders,* https://aviationbenefits.org/economic-growth/the-future/.

Aviation not only stimulates job creation but also contributes 2.7 trillion dollars (3.5%) to the world's GDP. What is more, those numbers will increase by 2034 up to the 5.9 trillion USD, as we can see in the table below.

Table 7. Aviation global employment impact – 2016 vs 2034.

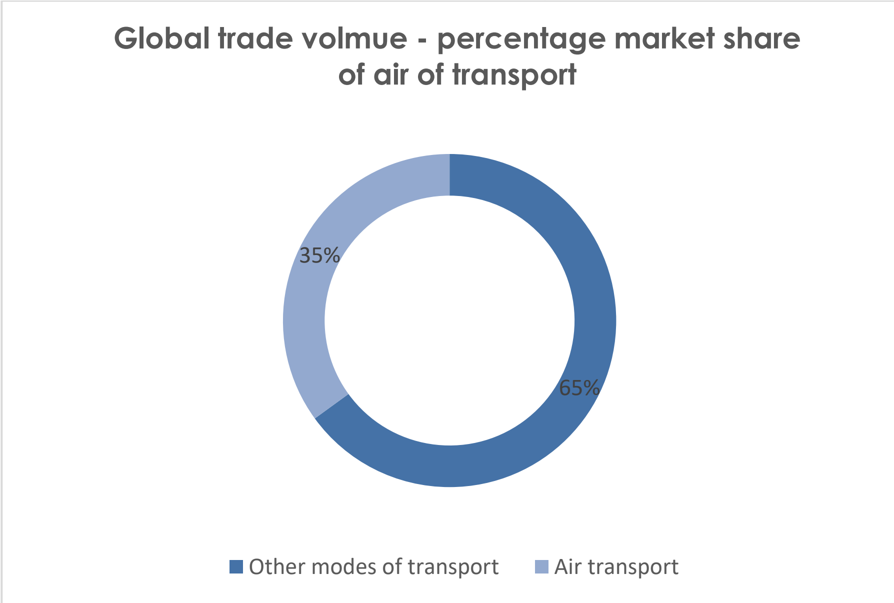
| | 2016 (GDP benefits) | 2034 (GDP benefits) |
|---|---|---|
| Direct | 664.4 billion USD | 1.5 trillion USD |
| Indirect | 761.4 billion USD | 3.9 trillion USD |
| Induce | 355 billion USD | |
| Catalytic | $892.4 billion USD | 5.9 trillion USD * (including direct, indirect, induce employment impact) |
| TOTAL | 2.7 trillion USD | 5.9 trillion USD |

Source: Own work based on ATAG, *Aviation benefit beyond borders,* https://aviationbenefits.org/economic-growth/the-future/.

Global trade has played a key role in supporting economic development and making countries become more productive – supporting income growth and poverty reduction. In 2016, airlines transported 53.9 million metric tons of goods, representing about 35% of global trade by value[37] and 1% of global trade by volume.

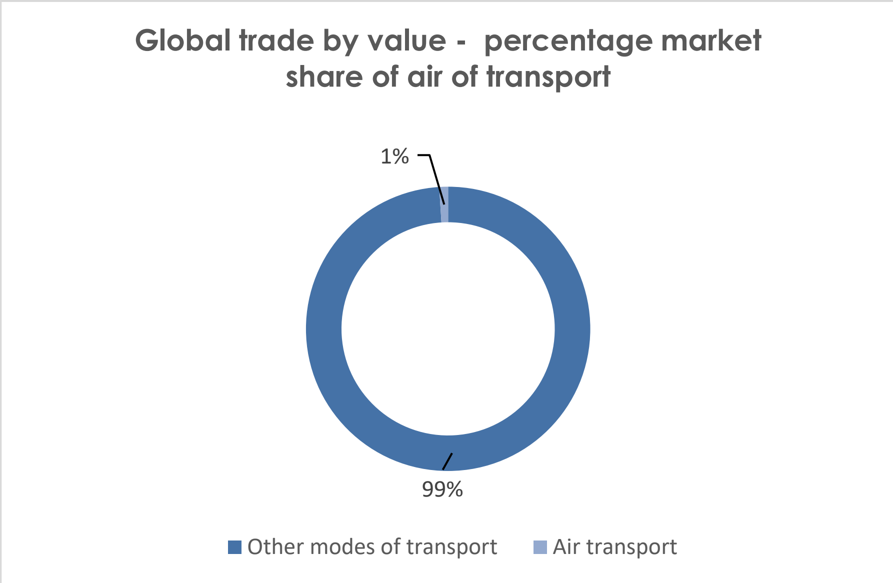
[37] IATA, *Annual review 2017,* p. 48.

Graph 5. Global trade by volume and value - percentage market share of air of transport.




Source: IATA, *Annual review 2017.*

Graph 6. Global trade by volume and value - percentage market share of air of transport.




Source: IATA, *Value of air cargo: air transport and global value chains,* 2016.

# CHAPTER 4

# AVIATION AND SOCIAL DEVELOPMENT

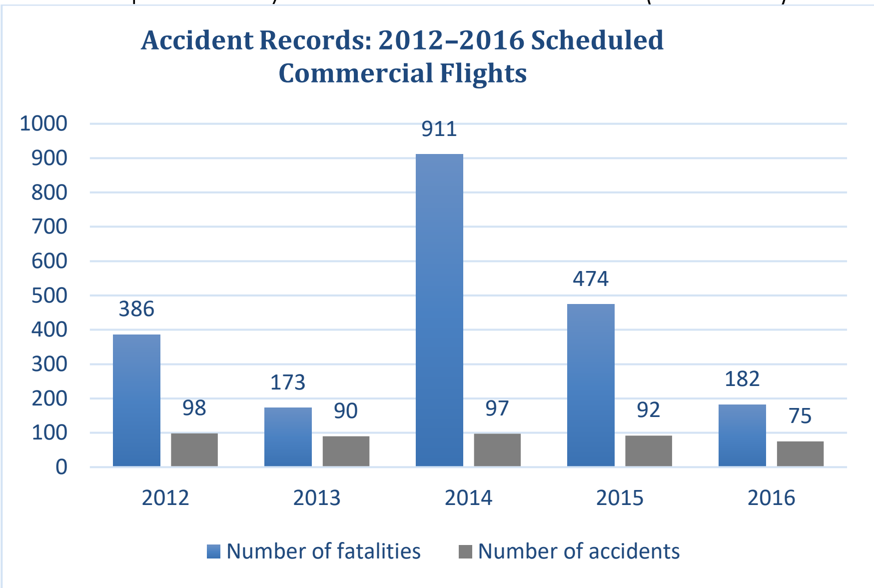
Aviation brings the people and cultures of the world together like no other form of transport. A safe, fast and reliable air service is allowing people to experience the world and supporting tourism. In this chapter the authors will examine the behavior of air travelers – their wants, needs and expectations concerning air travel. The authors strongly believe that only understanding customers' behavior will allow aviation to grow in a sustainable way. Although we have to keep in mind that the factors are complex and numerous.

## 4.1. Accessibility and trust: the two dimensions of passengers' perception on sustainable aviation

Safety is the most important aspect of air travel from the passengers' perspective. That is why ensuring the safety of air transport has become a major priority since the industry began.

ICAO accident records for the last five years (2012-2016) show a decrease in the number of accidents and global accident rate. In 2016, ICAO reported 182 fatalities in 75 commercial air transport accidents. The two intervening years (2014 and 2015) had seen a spike in fatalities (911 in 2014 and 474 in 2015) due to a number of acts of unlawful interference. However, in 2016 only 75 accidents occurred, and it was the lowest rate since 2012.

Graph 7. Safety statistic – accident records (2012-2016).




Graph 8. Safety statistic – aviation global accident rate (2008-2016).


Sources: *Safety report,* ICAO (2017, 2013).

According to ICAO, there is a downward trend in the global accident rate. The reduction in the accident rate, measured in accidents per million departures, is from 4.8 (in 2008) to 2.1 (2016) representing the lowest rate ever.

Graph 9. Accident records – air, railway, road transport in UE (2015).

| Metric | Year | Number of fatalities |
|---|---|---|
| Total number of persons killed in road traffic accidents UE-28 | 2015 | 28 000 |
| Persons killed in railway accidents in the EU | 2015 | 962 |
| Commercial Air Transport number of persons killed in air transport accidents, EU-28 territory, regardless of country of aircraft registration | 2015 | 125 |

Source: Own work based on data from Eurostat (Air safety statistics in the EU, Rail accident fatalities in the EU, Road safety statistics at regional level).

As the data above suggests, aviation is the safest means of transport, although we can notice that a percentage of air passengers or potential passengers do not fully trust this way of traveling. One of the reasons for this is the psychological impact of an aircraft incidence or accident, that often attracts overwhelming public interest and generates mistrust of the system (e.g. airlines, airport operators, regulators, etc.). Below some chosen situations

- A series of four coordinated terrorist attacks, where extremists hijacked four planes that were flying above the US and crashed into World Trade Centre and the Pentagon, located in New York City, USA (11 September 2001, or 9/11);
- Missing of the Malaysia Airlines Flight MH370 flying from Kuala Lumpur in Malaysia to Beijing (2014);
- Shooting down of Malaysia Airlines flight MH17 over Ukraine (2014).

have an immediate and substantial impact on aviation. What is interesting, is the fact that the impact of such a situation does not include only the passengers and aircrew on board, their families, relatives, close friends or community residents in the area where the disaster has occurred, but also part of and, sometimes, even the whole world population. The effect of a terrorist attack, accidents, missing planes or hijacks, the demand for air travel collapses and the aviation sector experiences an immediate drop in departures and arrivals statistics. ICAO report *"The Impact of 11 September 2001 on Aviation"* implies that the impact of this particular event cost the industry three years of growth and, for good, a change in passenger perceptions of air travel".

For the reason mentioned above, aviation safety has been and remains a central public policy concern. One of the most important institutions that promote the safe and orderly development of worldwide civil aviation is ICAO (safety is one of the strategic objectives of the organization). The organization strongly focuses on working with its member states and industry groups:

a) to reach consensus on international civil aviation *Standards and Recommended Practices* (SARPs) and global policy guidance (e.g. the *Procedures of Air Navigation Services* (PANS),
b) to monitor safety trends and indicators,
c) to implement targeted safety programs,
d) to give an effective response to disruption of the aviation system created by natural disasters, conflicts or other causes.

ICAO is the primary forum for co-operation among its 191 Member States in all fields of safety issues. However, international efforts still require governmental (state-level) enforcement to be effective.

Consumers' behavior: Accessibility

Another very important expectation from the passengers' perspective is the possibility to have access to a wide network scope, being able to get a flight ‘from anywhere to anywhere’. To fulfill this primary need, aviation stakeholders operate many strategies.

The best example of this is the liberalization process in the aviation industry. The main aim of liberalization is to remove barriers to the internal market and the creation of unfettered competition. Liberalization in the airplane market has become a global phenomenon and forced airlines, due to increasing competition to operate more efficiently[38]. The origin of the liberalization process in the aviation sector was in the United States. Signed in 1978, The Airline Deregulation Act changed the aviation market for good. Deregulation, in the most simplistic terms can be defined as the situation where government removes certain regulations on business to encourage industry. The premise behind deregulation is that with fewer regulations impeding operations, businesses will become more competitive"[39]. The purpose of the law was to remove restrictions on the setting up of air carriers for air services to selected routes. The new regulation resulted in increased competition and thus decreased prices. A few years after the deregulation processes in the USA, Europe also started to liberalize its air transport sector by adopting three aviation packages:

- The first "package", adopted in 1987 started to relax the established rules giving carriers some flexibility concerning seat capacity by limiting government interference.

[38] P. Belobaba (ed.), *The global airline industry,* WILEY, West Sussex 2009, p. 30.
[39] K. Wylie, *Air transportation deregulation,* GRIN, Phoenix, 2004, p. 2.

- The second "package" adopted in 1990 opened up the air market much further and allowed for the more flexibility over the setting of fares and capacity-sharing.
- The "third package" included harmonizing requirements for an operating license for European union carriers and introduced full freedom with regard to fares[40].

Increased access to the world market for air service providers is the key aim for open-skies agreements, due to the market encouraged by removing restrictions on route rights. Open skies agreements, according to ICAO are defined as "an international policy for the liberalization of the rules and regulations of the international aviation industry - concerning operating without restrictions on the frequencies, capacities, and aircraft types between both parties of agreement"[41]. Nowadays the largest number of open skies agreements has been signed by the United States. Since 2010, the United States has concluded such agreements with countries around the world, including Japan, Canada, India, Brazil, Peru, Chile, Columbia, 28 members of The European Union, as well as few countries in Asia and Africa.

However, not all areas of the world are as open as those described above. While air traffic in the Asian and Pacific market

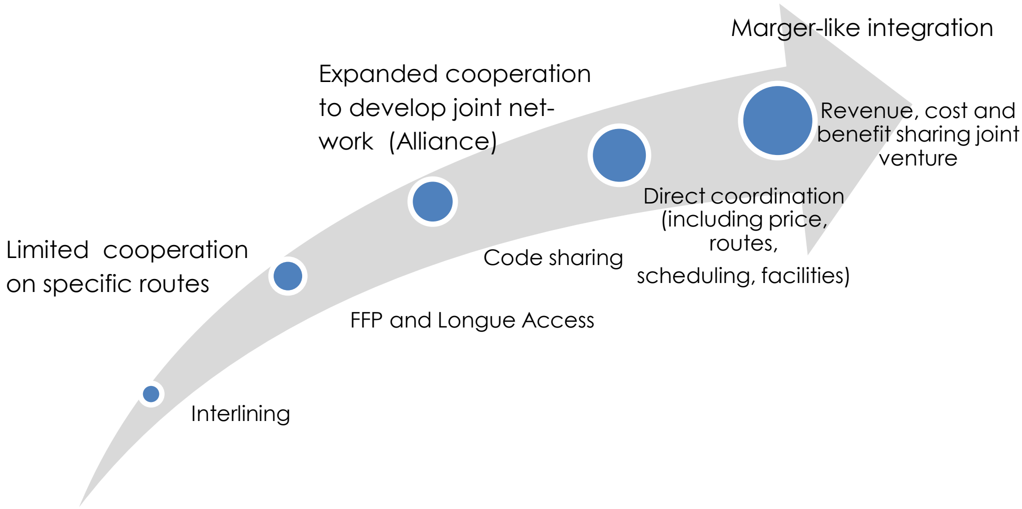
[40] M. Żylicz, *Prawo lotnicze międzynarodowe, europejskie i krajowe,* LexisNexis, Warszawa 2011, p. 66-67.
[41] R. Doganis, *The airline Business*, Routledge, New York 2006, p. 32.

has grown dramatically over the past decade, the region remains relatively regulated. A challenge for the future is, also, to increase access to the highly regulated markets such us China, Hong-Kong, Mexico, Russia and Argentina or Middle East country. Efforts to change the situation in the Asia Pacific region was made by The Association of Southeast Asian Nations (ASEAN). The organization consists of ten member states, including the most important southeast Asian economies such as Indonesia, Malaysia, Philippines, Singapore and Thailand who decided to sign the declaration for a *Single Aviation Market* (ASEAN-SAM) - an initiative that is aiming to fully liberalize air travel between member states. However, all those countries should also start thinking beyond national borders and enhance cooperation between airlines, airports and aviation authorities worldwide. The next aspect of the liberalization policy (needs of harmonized and simplified procedures) should include visas, security procedures, air traffic control and many other issues.

Meeting passengers' demands for network scope that allows flying ‘from anywhere to anywhere’ can involve airlines in differing degrees of cooperation. Alliances and various other forms of partnerships and agreements are becoming more important on a global field. They aim to create cost synergies, marketing benefits and offer a wider network. Moreover, it is an effective way to comply with the various operating and regulatory regimes of individual countries, when foreign ownership rules would prevent an airline from buying controlling stakes in other airlines.

According to the IATA the lowest level of airline co-operation is Interlining, because this term describes the situation when "passengers buy a single ticket for an itinerary on two or more independent airlines, if the airlines have signed multilateral or bilateral airline agreements to accept other airlines' customers". The basic advantages of this situation for customers are lower fares compared to the fares bought through each individual airline, and much more convenient. A higher quality service for passengers is provided through code share agreements. This type of cooperation occurs when an airline places its code and sells seats operated by the partner airline. The main benefit of this situation includes offering passengers a more seamless service with coordinated scheduling, access to business and first class lounges and FFP and close proximity of gates for connections. The closest co-operation and integration of air service can be observed in the example of 'joint venture' (JV), where airlines agree to share revenues and cost on an international route.

Figure 4. The spectrum of airline co-operation.




Source: IATA Economics briefing, *The economic benefits generated by Alliances and joint ventures,* www.iata.org/economics.

Alliances are one of the most popular forms of cooperation between airlines, bringing considerable benefits, including[42]:

1. Lower fares for interlining passengers;
2. Lower fares resulting from economies of traffic density;
3. Passengers are able to combine more easily fares in an itinerary;
4. Airlines are able offer passengers a much wider range of schedules;

[42] IATA, IATA Economics Briefing, *The economic benefits generated by alliances and joint ventures,* 2012.

5. Seamless service and similar/standardize products thanks to harmonizing customer service standards.

There are three major international airline alliances: Star Alliance, Sky Team and Oneworld, called the global airline alliances (GALs), launched between 1997 and 2001. The underpinning of those arrangements was the expansion of air traffic, routes and passengers, as well as the enhancement of consumer choice.

Figure 5. Global Airline Alliance Membership.

| ONEWORLD MEMBERS | SKY TEMA MEMBERS | STAR ALLIANCE MEMBERS |
|---|---|---|
| American Airlines | Aeroflot | Adria Airways |
| British Airways | Aerolíneas Argentinas | Aegean Airlines |
| Cathay Pacific | Aeromexico | Air Canada |
| Finnair | Air Europa | Air China |
| Iberia | Air France | Air India |
| Japan Airlines | Alitalia | Air New Zealand |
| LATAM | China Airlines | All Nippon Airways |
| Malaysia Airlines | China Eastern Airlines | Asiana Airlines |
| Qantas | China Southern Airlines | Austrian Airlines |
| Qatar Airways | Czech Airlines | Avianca |
| Royal Jordanian | Delta Air Lines | Brussels Airlines |
| S7 Airlines | Garuda Indonesia | Copa Airlines |
| SriLankan Airlines | Kenya Airways | Croatia Airlines |
| | KLM | EgyptAir |
| | Korean Air | EVA Air |
| | Middle East Airlines | Ethiopian Airlines |
| | Saudia | LOT Polish Airline |
| | TAROM | Lufthansa |
| | Vietnam Airlines | SAS |
| | Xiamen Airlines | Shenzhen Airlines |
| | | Singapore Airlines |
| | | South African Airways |
| | | Swiss International Air Lines |
| | | TAP Portugal |
| | | Thai Airways International |
| | | Turkish Airlines |
| | | United Airlines |

Source: Own work based on Global Airline Alliances' websites (March 2018).

Star Alliance was founded in 1997 by United Airlines, Air Canada, Lufthansa, Scandinavian (SAS), and Thai Airways, and currently has the largest network, serving more than 1317 destinations worldwide (in 98% of the world's countries) and transporting about 725 million passengers every year[43]. This alliance is characterized by the largest number of members (28) within the industry alliance. It could be argued that as an alliance increases in size, on the one hand the competitive pressure is reduced and costs are decreased through economies of scale and scope, but on the other hand, the more diluted the brand becomes, as quality and quantity do not usually go hand in hand very well.

*Oneworld* alliance was formed in 1998 and is now a group of four airlines, Qantas, Cathay Pacific, American Airlines, British Airways, although, originally with Canadian Airlines (which later withdrew following its merger). It is considered to be a typical marketing alliance with a focus on joint advertising, joint sales and shared FFP[44]. Since *Oneworld* has a more liberal approach, as its members are not as strictly bound by exclusivity stipulations as Star members, the alliance exercises a value on flexibility, a very attractive characteristic for Middle East airlines.

The third major global alliance is SkyTeam (20 members), that started its cooperation in 2000 with Air France, Aeromexico, Delta Air Lines and Korean Air being the founding members. The vision of the group is to remain small in terms of members and to

[43] B. Kleymann, H. Seristö, *Managing strategic airline alliances*, Ashgate, 2004, p. 14.
[44] Ibidem.

concentrate on high quality services. Today the alliance offers access to 1,074 destinations worldwide (in 177 countries).

The matter of joining or not joining an alliance depends on whether such a move would contribute towards the creation of a long lasting, effective, viable and competitive system for the future. Tight integration into an alliance implies both opportunities, yet some threats for airlines. There are basically two reasons which explain why major airlines decide to remain unaligned; firstly, there are those which have not decided which alliance would best fit their interest and those which perceive joining an alliance as a loss of individual sovereignty.

Customer behavior: cost of air transportation

Another important aspect from the passengers' perspective can be connected to cost of air transportation. According to the IATA, the real cost of air travel has been reduced by over 60% between 1970-2010.

Below the most important airline costs are presented:
1. Jet fuel is the largest single cost item for the global airline industry, and it accounts for over one third of the average operating costs. Nowadays, it is considered one of the highest threats within the aviation industry as each 1USD variation in the oil price is reflected in a USD 1.6 billion change in operating profit and cash flow for the airline industry[38]. Historically, fuel has accounted

for only 15% of the industry's total operating costs. By taking a longer-term perspective of its price movement, one could easily conclude that a further price spike could easily push the industry into major losses.

However, the jet fuel cost expressed as a percentage of total operating costs differ from airline to airline, and it is mainly determined by actual fuel price, aircraft fuel consumption, as well as the respective network strategy.

2. Airline fleet planning is one of the most important strategic decisions for an airline because it is a huge capital investment with a long-term horizon. Nevertheless, airlines are currently forced to make long-term decisions regarding major capital investments (fleet planning) based on business plans, which are subject to a large number of uncertainties. Moreover, the fleet structure and aircraft ownership have a critical impact on the context of network design and scheduling, as well on the overall costs to the airline with regard to fuel consumption, crew training, maintenance, depreciation and leasing costs.

3. Airport charges include all charges and fees related to air transport operations that are levied against the air carrier for services provided at the airport and it includes:

- Landing charges;
- Passenger and cargo fees;
- Security, parking and hangar charges;

- Other related traffic operation changes.

The airport industry has experienced tremendous transformation that has driven the market towards higher competition.

4. Staff are the biggest asset to an aviation organization and managing this resource effectively translates into major reduction in operational costs, as employees represent the single largest flexible cost to an airline. However, civil aviation belongs to the service industry, where employees play a fundamental role in customer choice[45]. There are several factors that determine the labour costs such as staff numbers, prevailing wage rates in the airline's home country, training policies, and the extent of outsourcing[46]. However, one of the most important drivers influencing the labour environment of a company is the labour law regulatory system.

Customer behavior: Demand elasticity (air travel prices and incomes), the substitute product and quality of service.

Demand for air travel is sensitive to changes in air travel prices and incomes. The degree of sensitivity will vary according to different situations. To ensure that air transport policies are effective, reliable estimates dedicated to demand elasticity are essential.

[45] G. Harvey, *Management in the airline industry* (R. Delbridge, E. Heery eds.), *Routlege research in employment relations,* Abingdon 2007, p. 125.
[46] S. Holloway, *Straight and level. (3rd ed.),* Ashgate, Aldershot 2008, p. 308.

Demand elasticities measure “the change in the quantity demanded of a particular good or service as a result of changes to other economic variables, such as price, the cost of competing or complementary goods and services, income levels or taxes. They provide a key insight into the proportional impact of different economic actions and policy decisions”.

The income elasticities of demand can be define as follows:

$$\begin{aligned} &\mathit{Income\ elasticity\ of\ demand} \\ &\quad = \frac{\mathit{percentage\ change\ in\ quantity\ demanded}}{\mathit{percentage\ change\ in\ income}} \\ &\quad = \frac{\%\ \Delta Q/\bar{Q}}{\%\ \Delta Y/\bar{Y}} \end{aligned}$$

$\bar{\mathrm{Q}}$ average quantity demanded, $\bar{\mathrm{Y}}$ average income

Most of the goods and services have positive income elasticities. As the studies point out the holiday or vacation demand is more income-elastic than demand of VFR group. What is more, the demands of holiday and vacation passenger is the most income-elastic. Conversely, we could point out that income demand connected for business purposes is relatively inelastic[47].

[47] A. Graham, A. Papatheodorou, P. Forsyth (ed.), *Aviation and tourism. Implication for Leisure Travel,* 2010.

$$\text{Own price elasticity of demand} = \frac{\text{percentage change in quantity demanded}}{\text{percentage change in price}} = \frac{\%\,\Delta Q/\bar{Q}}{\%\,\Delta P/\bar{P}}$$

$\bar{Q}$ average quantity demanded, $\bar{P}$ own price of the product

Own price elasticity is usually negative, it means that there is an inverse relationship between travel and the demand for it.

Air fare elasticity: when we compare long-haul business fare elasticity to short-haul business fare elasticity we can notice that long-haul is generally less fare–elastic. The main reason for this can be explained by the fact that business people place an especially high value of time. They are willingly to pay high fares to save time. In the case of long-haul flights most book tickets in advance (due to the quite high cost), but in the case of short-haul trips there are numerous so called must-go situations - arising in the course of business dealings. The other reason why business-man are able to pay much more for an international flight than for domestic and short-haul is that, in the domestic market finding substitute modes of transport is much easier. The main competitor on the domestic and short haul market for the air transport is rail transportation, especially high speed train (HSR). Railways are well suited and comfortable for passengers over relatively short distances. The global HST high speed rail network is rapidly expanding worldwide. However, many companies will agree to pay much more for the flight ticket for someone who is responsible for signing a contract and closing a multi-million dollar deal, due to the fact that the high air fare now seems low, when compared to the overall value of the trip. However, we have to keep in mind that price elasticity can differ due to different circumstances, it can be quite different when we compare price elasticity for company businessmen and a businessman who is paying for himself.

When we analyze price elasticity for leisure passengers we can notice that this segment is characterized by higher elasticity concerning price change. People who are going on vacation are much more price elastic - when the price of an air ticket increases, demand decrease. We can see this clearly when we analyze the short-haul or domestic flight. Even a small change in price will discourage passengers to travel by air. They will look for another airline or substitute modes of transport.

Although the cost of transportation has been decreasing during the past years and air travel has nowadays become available to a majority of people, the expectations of the passengers are constantly increasing.

The quality of service has an indirect effect on the decision of a passenger whether to use air transport or not. Strong competition between airlines and airports all over the world provide air travelers with an increased expectation to the quality of service. Airlines and airports nowadays are forced to evaluate the passenger’s perception on air transport service in order to meet passengers' satisfaction. A low quality of service in aviation will result in inconvenience for air travelers, and as an effect will decrease the numbers who will choose that carrier again.

To help airlines and airports in satisfying consumers’ needs, IATA publish, each year, a Global Passenger Survey, that list their findings on behavior and preferences of air travelers relating to their air journeys.

# LIST OF FIGURE, TABLES, GRAPHS AND PICTURES

# BIBLIOGRAPHY

**Books**


1. Belobaba P., et., *The global airline industry,* WILEY, West Sussex 2009.
2. Bor R., *Passenger behaviour,* Ashgate 2009.
3. Doganis R., *The airline business,* Routledge, New York 2006.
4. Graham A., et. all, *Aviation and tourism: implications for leisure travel,* Ashgate, 2010.
5. Holloway S., *Straight and level. (3rd ed.),* Ashgate, Aldershot 2008.
6. Howarth D., .et. all, *Sustainable Aviation Futures,* Emerald Group Publishing, 2013.
7. Janic M., *The sustainability of air transportation: A quantitative analysis and assessment,* Ashgate 2007.
8. Karakoc T., et. all, *Advances in sustainable aviation,* Springer, 2018.
9. Kleymann B., Seristö H., *Managing strategic airline alliances,* Ashgate, Aldershot 2004.
10. Kossmann M., *Delivering excellent service quality in aviation: a practical guide for internal and external service providers,* Aldershot, England, Burlington, VT: Ashgate 2006.
11. Millbrook A., *History of aviation,* JEPPESEN, Englewood 2006.
12. Peoples J., *The Economics of international airline transport,* Emerald Group Publishing, 2014.
13. Rhoades D., *Evolution of international aviation: phoenix rising,* Aldershot, England, Ashgate 2008.
14. Upham P., et. all, *Towards sustainable aviation,* Routledge 2003.
15. Wylie K., *Air transportation deregulation,* GRIN, Phoenix 2004.
16. Yenne B., *The story of the Boeing Company,* MOTORBOOKS INTL, Minneapolis 2005.
17. Żylicz M., *Prawo lotnicze międzynarodowe, europejskie i krajowe,* LexisNexis, Warszawa 2011.

**Publication**

1. ACI, *The social and economic benefits of airports,* 2004.
2. Airbus, *Airbus' global market forecast 2017-2036.*
3. ATAG, *Air transport and the sustainable development goals,* 2017.
4. ATAG, *Aviation: benefit beyond borders – global summary,* 2016.
5. ATAG, *Aviation: benefit beyond borders,* 2016.
6. Boeing, *Current market outlook 2017-2036.*
7. Eurocontrol, *Defining sustainability in the aviation sector (EEC/SEE/2004/003),* 2004.
8. IATA Economics briefing, *The economic benefits generated by Alliances and joint ventures,* 2012.
9. IATA, *Annual review,* 2017.
10. IATA, *Value of air cargo: air transport and global value chains,* 2016.
11. ICAO, *Aviation and sustainability: determining the complex environmental, social and economic impacts that are defining aviation's future* (The ICAO Journal, Volume 66, Number 6, 2011).
12. ICAO, *Safety reports,* 2013.
13. ICAO, *Safety reports,* 2017.
14. United Nation World Tourist Organization, *Tourism highlights,* 2017.

**Web pages (selected one)**

- www.atag.org
- www.ec.europa.eu
- www.EPA.gov
- www.EUROCONTROL.int
- www.faa.gov
- www.fican.org
- www.iata.org/Pages/default.aspx
- www.icao.int
- www.npi.gov.au/reducing-pollution
- www.oneworld.com
- www.skyteam.com
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