**Environmental impact of air transport - case study of Krakow Airport**

Civil aviation is one of the fastest growing global industries. The intense stimulation of economic development and employment growth in the sector and associated sectors are positive effects of air transport expansion. Aviation, as every type of transport, is responsible for a number of negative external effects that are not neutral to the environment. Risks associated with air transport are mainly air pollution (especially greenhouse gases), excessive noise from aircrafts at airports and their surroundings, incidental soil and water pollution, waste generation with high share of hazardous wastes and change of land use. The rapid growth of air traffic forces modernization and development of airports, especially these as important as Krakow Airport. Established development strategies allowing to maximize efficiency in economic terms not only should have an approval of the local community but also must take into account environmental issues. The paper presents an analysis of the growing influence of the air transport in Krakow on the environment. The methods of reducing the impact of aviation on the environment were also analyzed. Among others, inclusion of aircraft operators into the European Union Emissions Trading System was presented.

1. INTRODUCTION

Civil aviation is one of the fastest growing global industries. The intense stimulation of economic

development and employment growth in the sector and associated sectors are positive effects of air

transport expansion. The liberalization of the global air transport market was a key issue for the

development of the aviation sector. In the 90' the European Union legislation in this area was still a

barrier to integration and economic development. Therefore, also in the EU, the process of

liberalization of passenger air transport was carried out. Since 1997, the market of air services in the

EU has been almost completely liberalized and harmonized. The new organization of the market

enables every carrier to operate on any flight route within the EU. It allows them also to establish their

own tariffs provided that the principles of fair competition are observed. The dynamic development of

flight connections and the decrease in ticket prices are the result of the liberalization of regulations

governing air transportation. The increase in demand for air services was a further consequence of

these changes. Reduction of air fares, increasing the availability of air services and quick growth of

network connections were consequences of the development of competition as a result of changes in

EU legislation. Almost all airlines in Europe began to develop rapidly; in particular, the low-cost

carriers offering short and middle distance flights [16]. In the years 2001-2010 the low-cost carriers

increased several times the participation in offering supply of seats in regional flight all over the world.

In case of flights between countries of the European Union this growth increased from 6.0% in 2001

up to 37.9% in 2010 [2].

Report by the World Economic Forum (WEF) and Booz & Company estimates that the number of

passengers traveling by air increased in the last two decades, at a rate of about 5% per year [5]. Air

transport is one of the major contributors to the growth in global gross domestic product. It also

generates significant employment in all countries. Despite the global economic recession and the

apparent crisis in air transport, its growth continues to be a global phenomenon with an average

expected annual growth rate of 4.2 - 5.1% [34]. Report of the International Civil Aviation Organization

(ICAO) shows similar estimates. In this document it is expected that by 2025, air passenger traffic in

the world will increase by 4.6% per year while the total mileage in civil aviation will increase by 4.1%

per year [16] The number of flights will increase three or even four times by 2035 if this rate of growth

of the number of air travelers continues [5].

In Poland in the 90's the share of air transport in passenger transport was marginal. This situation

remained unchanged despite the rapid development of air transport in Europe. However, with the

Polish accession to the European Union, it was necessary to adapt Polish laws to the EU legislation,

which changed the aviation market in Poland. In order to enable the development of the air transport

market in Poland, the most important task was to liberalize the policy on access of foreign air carriers

to the Polish market. As a result of the adoption of regulations included in the so-called “third

liberalization package” all restrictions on free competition in aviation in Poland were removed [11, 19,

26]. The most important Act was Council Regulation (EEC) No 2408/92 of 23 July 1992 on access for

Community air carriers to intra-Community air routes. It covers access for air carriers to intra-

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Community air services. Community air carriers (carriers licensed in accordance with Regulation

2407/92/EC3) may exercise traffic rights between airports or airport systems within the Community

where these are open to civil air services [4]. Many low-cost carriers began providing services in the

domestic market after the Polish accession to the EU. Therefore, the number of passengers served in

2005 as compared to 2004 increased by 30.18%, while in 2006 compared to 2005 by 33.57% [31].

Low-cost carriers mainly use regional airports. In Poland in 1998, regional ports handled only 23% of

the traffic. The dynamic increase in the number of passengers contributed to decisions on the regional

airports development. The share of regional airports in passenger transport in Poland in 2011, rose to

57% [15].

The Krakow Airport is the biggest regional airport in Poland in terms of both: the number of

passengers and the number of flight operations. The rapid growth of air traffic forces modernization

and development of airports, especially these as important as Krakow Airport. Established

development strategies allowing to maximize efficiency in economic terms not only should have an

approval of the local community but also must take into account the environmental issues. The paper

presents an analysis of the growing influence of the air transport in Krakow on the environment. The

methods of reducing the impact of aviation on the environment are also analyzed. Among others,

inclusion of aircraft operators into the European Union Emissions Trading System is presented.

2. DEVELOPMENT OF REGIONAL KRAKOW AIRPORT

In 2004, when Poland joined the EU, Polish airports served nearly 9 million passengers. Last year

(2013), this amount reached nearly 25 million passengers [31, 32]. Currently, dynamics of increase in

the number of passengers on domestic airports dropped slightly. In 2013, they handled 2.2% more than

in 2012. For comparison, the average increase in that time for over 450 European airports belonging to

the Airports Council International was 2.8% [32]. Slowdown in growth of the number of passengers is

only temporary. Mobility ratio of Poles, which is still low, indicates that the passenger traffic at

airports in Poland will continue to rise. This factor expresses the ratio between the number of

passengers at airports in the country to the population of the country. The Polish mobility ratio in 2003

was 0.18 and grew steadily every year. In 2007 it reached 0.45. In 2030 Polish mobility ratio will reach

2.13 according to the forecast by the Civil Aviation Office on the number of passengers using air

transport. That will be the same level as it is now in Germany and France [21, 22, 27]. Poland has one

central Airport Warsaw-Okecie and more than 10 regional airports. Commencement of operations on

the Polish market by low-cost carriers contributed to the rapid development of regional airports. Low-

cost carriers choose regional ports because these are cheaper and less crowded as well as open to

cooperation [1]. Contracts signed by the regional airports with low-fare carriers, the rapid increase in

the number of passengers traveling by air and optimistic forecasts for the incoming years led ports to

make a decision about the expansion and modernization of existing infrastructure. Also the

infrastructure on the areas surrounding airports was constructed or modernized in most airports in

Poland. New parking areas and hotels were built near airports, commuting to the airport have been

improved [29].

The most important and largest of the regional airports is Krakow Airport. This airport is located

in the village Balice, about 10 km from the Krakow city center. Civil airport started its operations in

1964. Earlier in Balice there was only a military airport. Full port name is "International Airport John

Paul II Krakow - Balice Sp. z o.o ". The owners of the different parts of the assets of the company are:

Polish Airports (76.19%), Malopolska Region (22.73%), the Municipality of Krakow (1.04%), the

Municipality Zabierzów (0.04%). In the 60 '- 90' the port handled mainly domestic flights to Warsaw,

Gdansk, Koszalin, Rzeszow and Szczecin. Since 2004, the airport has begun to develop rapidly and its

importance for the country rose. The Krakow Airport is the second biggest airport in Poland in terms

of both: the number of passengers and the number of flight operations. It operates connections with 90

cities in 28 countries. [26, 35]. In Poland, the only larger than the Krakow Airport is the airport in

Warsaw, which in 2013 handled over 10 million passengers. Third place in terms of the size holds

Pyrzowice Airport (2.5 million passengers in 2013). Number of passengers served by Krakow airport

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is constantly increasing. In 2011, for the first time it reached almost 3 million passengers, what was the

maximum capacity of the airport. The rapid growth of air traffic forces modernization and

development of regional airports, especially these as important as Krakow Airport. Therefore, in 2012,

construction works at the new terminal, hotel, railway station began. The expansion of the airport

enabled it to handle 3.63 million passengers in 2013 [33]. Completion of all work is planned for 2015.

After the enlargement the passenger terminal will increase the usable space from the current 15,000 m2

to almost 55,000 m2. It will have a capacity of serving 8 million passengers annually [35].

Airports are no longer places where planes just take off and land but have evolved into major

business enterprises with spatial impacts. Airport led urban development, notwithstanding its

capabilities of employment and generating income, comes with costs and risks: economic, cultural, and

environmental [9, 10, 14]. Undoubtedly, the regional Krakow Airport is an important factor in

economic and cultural development of Malopolska Region. However, handling such a fast growing

number of passengers and aircrafts also increases the inconvenience of airport for both the

environment and local residents.

3. ENVIRONMENTAL IMPACT OF KRAKOW AIRPORT

Aviation, as every type of transport, is responsible for a number of negative external effects that

are not neutral to the environment.

Aviation is responsible for a small extent of a global environmental

pollution, estimated approximately at 2 - 3%. These pollution are generated mainly in the area of

airports [20].

Airports are large area objects of transport infrastructure. Their impact on the

environment is a result of the physical characteristics of objects, such as the size and materials used in

their construction, and on the other hand, their use.

Risks associated with use of airports are mainly air

pollution (especially greenhouse gases), excessive noise from aircrafts at airports and their

surroundings, incidental soil and water pollution, waste generation with high share of hazardous wastes

and change of land use.

An airport is the most intensively used part of air transport infrastructure.

Threats to the environment may result from all activities related to servicing air carriers in port and

functioning of the port. An airport is mainly responsible for pollution from sources such as:

 Flight operations (takeoffs and landings),

 Operations involving the vehicles used by the passengers and airport employees (means of

transport by which they arrive at the airport),

 Cleaning and maintenance of aircraft and ground support vehicles,

 The use of anti-freeze chemicals (to thaw ice on aircrafts and runway),

 Aviation fuel loading and storage,

 Construction and maintenance of airport objects,

 Ground handling of passengers [11, 12, 20, 23, 30].

The expansion of the accompanying infrastructure, construction of access roads system and

encouraging investors to develop other economic activities in the surroundings of the airport are the

examples of Krakow Airport impact. Through its leading position in the local economy of Balice

Municipality the airport contributes directly and indirectly to increase of the pressure on the natural

environment. Construction of the airport in Balice as well as its currently ongoing extension was

associated with changes in the natural environment through a permanent change in use of significant

areas. The area of the airport is approximately 3.4 km2 [30]. The company International Airport John

Paul II uses and manages 270 hectares. The airport is also a major area of impermeable and

biologically inactive surfaces. Concrete runway (length 2550 m, width 60m) has more than 1.5

hectares. Aircraft parking aprons for 17 parking spaces, including one for the Boeing 747, has an area

of 9 hectares. Additionally, three terminals: T1 - International Terminal, T2 - Domestic Terminal and

Cargo terminal as well as the storage hall are located directly at the airport [26].

Extremely high concentration of the emission of pollutants to the environment occurs at airports.

Air and noise pollution are listed as the main. According to the Intergovernmental Panel on Climate

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Control (IPCC) the aviation sector currently produces about 2% of the global anthropogenic CO2

emissions [16]. According to other estimates the aviation sector is responsible for 3.5% of

anthropogenic global greenhouse gas emissions [25]. The road transport is the main source of transport

emissions. However, at about 13%, the share of air traffic in transport emissions is significant [20].

The concentration of pollutants on a small area of an airport is the main problem. At airports most of

the emission comes from taking off and landing aircraft, specifically from their powertrain. In the first

three minutes of take-off a transoceanic passenger aircraft emits a stream of hot exhaust gases with a

volume of about 50 thousand m3 and a temperature of about 800 ° C, containing nearly 2 Mg of

carbon dioxide [11, 12]. Aircraft engine exhaust gases contain nitrogen (75.2 %), oxygen (16.3%) and

exhaust fumes (8.5%) [20]. Exhaust fumes of aircraft engines are a mixture of solid particles and

droplets in the air. These include aerosols, smoke, fumes, ash and pollen. These particles are known as

PM2.5, their diameters are less than 2.5 µm [12]. The exhaust fumes consist of carbon dioxide (72%),

water vapor (27.6%) and the products resulting from the incomplete and complete combustion (0,4%),

which contain nitrogen oxides (84%), carbon monoxide (11.8%), unburned hydrocarbons (4 %) and

trace amounts of soot and sulfur oxides. Nitrogen oxides, mainly NO and NO2, are formed in the

process related to high temperature in the combustion chambers of engines [20]. Activity of airports

require the use of multiple combustion vehicles, also emitting toxic exhaust gases. However, these are

negligible compared to the amount of emission from aircraft jet engines while taking off and landing

[11].

At the Krakow Airport emissions are mainly related to the fuel storage, fuel combustion in engines

of aircraft and vehicles and the work of the heating plant. Local natural gas-fired heating plant is the

only organized source of emission. The main sources of fugitive emissions are:

 combustion of fuel in aircraft engines and vehicles operating on the apron area,

 fuel combustion in engines of aircraft landing and taking off from the airport,

 maintenance of proper technical condition of airport runway, roads and parking,

 cars arriving to the parking.

Beyond parking area, fugitive emissions are spread over a large area [28].

The demand for air transport services tends to increase with the growth of the economy. To

minimize the environmental costs efforts are taken to increase aircraft fuel efficiency. The aviation

industry makes an impressive technical progress. In the last 40 years, the average fuel consumption of

a modern aircraft was reduced by 70% [17]. A modern airplane consumes 3.5 liters per passenger-

kilometers and the newest – ag. the Airbus A380 or Boeing 787 - only about 3 liters [20].

In the European Union, it is estimated that the civil aviation sector produces about 4% of the total

EU carbon emissions [24]. The European Environment Agency says that CO2 emissions in the

European Union from international aviation increased by 96% in the period 1990-2005 [7]. European

Union Emissions Trading System (EU ETS) has been expanded to include emissions from the aviation

sector. This action was taken because of the growing impact of air transport on the natural

environment. Since 2012, all emissions from aircraft arriving and departing from airports in the

European Union are monitored and controlled by issuing emission permits. The aviation sector has

been included in the EU ETS in 2012, thanks to the adopted Directive 2008/101/EC of the European

Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include

aviation activities in the scheme for greenhouse gas emission allowance trading within the Community.

Starting in 2013, the number of emission allowances allocated for aviation began to be reduced [6].

The European Commission estimates that the reduction of CO2 emissions by 2015 would be on the

level of 176 million Mg thanks to the inclusion of emissions from aviation in the EU ETS [24].

Noise disturbance is a second important negative externality of the aviation sector. European

Environment Agency estimates that 6.9 million people in Europe are exposed to aviation noise levels

exceeding 55 dB [8]. Air Transport Action Group (ATAG) indicates that the noise level of a new

aircraft is 20 dB lower than 40 years ago. Thanks to technological progress it is expected that by 2020

the noise during takeoffs and landings will be reduced by 50% [20]. Although individual aircraft

engines are becoming quieter, the level of noise generated by airports grows. This is a result of

intensification of aircraft traffic and expansion of airports.

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Research on noise pollution around Krakow Airport was conducted in 2005 and 2006. The

analysis of the results shows that there are large areas around the airport under acoustic threat. The

increasing frequency of flights over areas of municipalities around the airport additionally adds to the

acoustic nuisance of port. The range of airport noise impact was determined on the base of the research

results and traffic data collected in 2006. Then, the airport management had analyzed a number of

solutions to improve the acoustic climate in the neighborhood of the airport. Among others, changes in

the organization of air traffic were taken into account. It was decided that the flight paths of aircraft

will be carried out in a straight line in order to reduce the area of impact of the strong noise. This

change was approved by the Polish Air Navigation Services Agency [3, 28].

Airport operations, in addition to air pollution and noise, might also cause water pollution.

Maintenance of aircraft, in particular related to the storehouses of fuels and other petroleum products,

the necessity of the use of various chemicals to melt the ice on runway and on aircrafts wings, can be a

source of groundwater contamination. Rainwater and thaw water from the surface of Krakow Airport

apron, aircraft de-icing area, driveways, parkings and technical facilities area are captured and cleaned

of oil pollution. After purification water is drained into the Olszanicki stream flowing near the airport.

The airport has a permit to discharge water into the stream issued by the Wojewoda Malopolski

(President of the Malopolska Region). In recent decades, in the area of the airport there were numerous

failures and leaks of fuel tanks. Groundwater and soil in an area of over 30 hectares has been

contaminated. Currently, the contaminated area is reduced to the close surroundings of fuel depots and

railway ramp thanks to the renovation of fuel storehouses and improvements in safety conditions [3,

28]. Airports also affect the environment through the production of waste resulting from their current

operations. Krakow Airport has a permit of Wojewoda Malopolski for generation of hazardous and

non-hazardous waste. This permit determines the acceptable types and quantities of waste that might

be produced at the airport. These wastes are generated from the exploitation of the airport installations

and operations of the airport. The main sources of waste are: operations and maintenance of the

runway, maneuvering areas and apron, lighting systems in buildings and airport, airport equipment

maintenance, transportation machines and equipment, water treatment, oil separators, Firefighters and

Rescue Service of Airport, Medical Support Service, etc.

Airports directly change the diversity of fauna and flora. These large-area objects have high share

of land covered with concrete or asphalt. Usually the biologically active airport areas are frequently

mown monocultures of grass. In addition to the impact on the fauna by air pollution and noise, airports

take action to deter birds from the area of the port and its neighborhood. Bird deterrence is taken for

security reasons, as bird collisions with aircraft may cause air accidents. One of the most effective

methods is the use of prey birds. This solution is also used in Krakow Airport where trained saker

falcons (Falco cherrug) were brought [30].

4. CONCLUSIONS

Krakow Airport has a strong impact on the natural environment. Changes in the surrounding

environment are caused by both: the size of the port and the specificity of its use. Noise and air

pollution generated by aircraft engines as well as those generated by the operations of the airport have

the most significant impact on the environment. Krakow Airport uses a number of solutions, in order to

reduce these environmental nuisance. In addition, the on-going development of the airport may

contribute to reduction of external effects. Construction of high-speed rail connecting the airport to the

center of Krakow should result in abandonment of cars as a main means of transport.