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Environmental Impact of Air Transport

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Abstract:

Purpose: *The investigations focus on environmental impact of air transport. The main purpose of the study was to present the core actions performed by the Kraków - Balice airport, the first airport in Poland to join the Partnership for implementing sustainable development objectives (2018), in full respect of the principles of sustainable development and the natural environment around the airport.*
Design/Methodology/Approach: *The analysis of the actions pursued by the Polish airport within the framework of sustainable development is based on the available scientific literature and sustainable development reports issued by the studied airport between 2016 and 2018.*
Findings: *Rapid development of air transport over the last 50 years has not gone unnoticed by the natural environment. Studies in the field have demonstrated negative effects both locally, around airports, and globally, considering climate change issues and air pollution.*
Practical Implications: *Continuing developments in air transport entail not only an economic advantage but also stimulated investments in state-of-the-art technologies. With an increased application of know-how and innovative approaches of other sectors, there will be new opportunities to address the issue of environmental impact of air transport. However, the impact of air transport activities on climate change, noise levels, and air quality is deemed to grow year by year, which has an effect on health and life quality of the society.*
Originality/Value: *A presentation of core actions undertaken by the airport to protect the natural environment. The variety of currently introduced activities continue to generate passenger air transport demand, which leads to a general increase of its environmental impact. Given the above, we continue to explore ways to meet environmental challenges, whilst ensuring a long-term success of air transport.*

Keywords: *Sustainable development, Air transport, climate, Environmental Protection.*

JEL Code: *N7, N70, Q54, Q53, R41, R58.*

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1. Introduction

Rapid development of air transport over the last 50 years, in particular in terms of passenger transport, has not gone unnoticed by the natural environment. Studies in the field show its negative effects both locally, around airports, and globally, taking into account climate change issues and air pollution. What is more, over the last 10 years social environmental awareness has surged, which translates into an increased political focus on environmental management. Given the above, environmental protection has become a priority in the aviation industry.

An assessment of the present and, most importantly, future impact of aviation activities on the environment and climate is an arduous and risky task. It is expected that in the future it will grow rapidly because air transport is an amazingly fast developing sector that cannot be restrained. Nonetheless, one must make every effort to reduce its negative impact on the environment, which is a real challenge provided the constant drive to seek new solutions and develop aviation infrastructure (Chakuu, Kozłowski and Nędza, 2012; Zajas and Ozga, 2011).

2. Environmental Protection in Aviation Legislation

Mitigation of climate change is a priority for 21st-century communities. One effective weapon in the war for the natural environment is law. International law plays a key role because the climate convention and the Kyoto Protocol launched certain strategies to combat a climate catastrophe, further pursued under the Paris Agreement. Whereas, bearing in mind the consequences of climate change across Europe, the EU law has not remained aloof. Via its strategies, politics and legislature, the European Union plays a central role in addressing the consequences of climate change at all levels: local, regional, and national (Ciechanowicz-McLean, 2016). Yet another issue is the analysis of regulations concerning environmental protection included in the aviation legislation. The core regulations are presented in Table 1.

***Table 1**. Examples of environmental protection regulations in Polish legislation*

Item	Type of legal act	Where published	Content of the provision
1.	Act of 3 July 2002 - Aviation Law Section III Aircraft and other aviation equipment Chapter 3 Aircraft airworthiness	Consolidated version: J. of Laws 2019, Item 1580	includes a competence regulation of the President of the Civil Aviation Office (ULC) - within a scope non-reserved for EASA[4]the President of ULC shall investigate whether appropriate environmental requirements with respect to protection from noise and earth, water and air contaminants specified by international provisions and the European Union legislation and the provisions issued pursuant to Article 53(5) have been complied with (Article 53(1)).
			The President of ULC shall state the fulfilment of the requirements specified in Para. 1 in a noise certificate issued in the form of an administrative decision - Article 53(2).
			Should an aircraft be destined for export, instead of fulfilment of the requirements specified in Para. 1, a noise certificate may state the fulfilment of corresponding requirements specified by relevant authorities of the country of the importer - Article 53(3).
			The President of ULC, under an administrative decision, shall suspend for a defined period the noise certificate specified in Para. 2, if the requirements set forth in Para. 1 have not been met - Article 53(3a).
			The President of ULC, under an administrative decision, shall revoke the noise certificate specified in Para. 2, if compliance with the requirements specified in Para. 1 is not restored - Article 53(3b).
			The noise certificate should be kept on-board on outbound aircraft - Article 53(4).
			The Minister competent for Transport, bearing in mind EASA's airworthiness and environmental requirements and having due regard to the need to ensure safe operation of aircraft, shall establish by Ordinance the requirements aircraft should meet due to protection of the environment from noise and earth, water and air contaminants - Article 53(5).
	Section IV, Aerodromes, airstrips, and aerodrome equipment - Chapter 2 - Aerodrome operation		The President of ULC, at the request of aerodrome operator or at the request of a Voivod locally competent for a given aerodrome, specified in Article 2(2) of the Regulation (EU) No 598/2014 of the European Parliament and of the Council of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC (OJ L 173, 12.6.2014, p. 65), may introduce by an administrative decision operating restrictions specified in Article 2(6) of the said Regulation at an aerodrome - Article 71a(1).
			At aerodromes of public use, with issue related to the protection of the environment against excessive noise, an aerodrome operator may set surcharges to the airport charges specified in Para. 1 or set a separate noise charge. In any such case, the aerodrome operator has a duty to create a targeted fund of collected surcharges or charges related to environment protection against excessive noise, intended solely to cover the cost of environmental protection associated with the measurement of harmful emissions, preventive actions, and dealing with the consequences of the noise impact on the environment - Article 75(4).
	Section VI Air navigation - Chapter 1 - Principles of air space use and air		It includes an optional mandate for the Minister competent for Transport in agreement with the Minister competent for Climate and the Minister competent for the Environment, by Ordinance, to introduce flight restrictions or bands for aircraft non-compliant with noise-related

[4]EASA (European Aviation Safety Agency) under Regulation (EC) No. 1592/2002 of the European Parliament and of the Council of 15 July 2002 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency (Official Journal L 240, 07/09/2002).

	traffic organization		environmental requirements and the conditions and methods of introducing the said bans, having regard to combating environmental impact of civil aviation and the requirements under international legislation - Article 119(5).
2.	Act of 12 February 2009 on the special rules for the preparation and implementation of investment in aerodromes of public use.	Consolidated version: J. of Laws 2009, Item 340 as amended	

Source:[*http://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20190001580/U/D20191580Lj.pdf*](http://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20190001580/U/D20191580Lj.pdf)

The essence of the Balanced Approach is to choose methods and measures aimed at a reduction of noise at and around airports involving:

- reduction of noise emitted by airplanes;
- suitable spatial planning and development;
- suitable air traffic management aimed at a reduction of noise pollution at and around airports;
- introduction of restrictions and bans on air operations at a given airport.

Further considerations to be considered when choosing between different alternatives and measures are:

- the principle of nondiscrimination of air carriers and aircraft manufacturers;
- the use of restrictive measures at a given airport required under environmental protection (Biskup and Bukowski, 2015).

3. Materials and Methods

The investigations focus on the environmental impact of air transport. The main purpose of the study was to present the key operations of the Polish Kraków - Balice airport, the first airport in Poland to join the Partnership for implementing sustainable development objectives (2018), fully respecting the principles of sustainable development and the natural environment around the airport.

The presented research goal led to the following research problems: What is the environmental impact of air transport? Which measures are taken at the Polish airport within the framework of sustainable development? Data sources are sustainable development reports issued by the studied airport in the period 2016-2018, legal acts, books and online publications relating to the operation of the air transport sector and its impact on the environment.

To enhance our understanding of the issue of environmental impact of air transport and to attain the research goal, the research process comprised two main stages. The

first step was to indicate the negative factors of air transport sector operations and their impact on the natural environment in contrast with the presentation of actions undertaken by the Kraków-Balice airport for the benefit of the environment. The collected data were tabulated and analysed.

4. Major Environmental Risks Posed by Airport Operations and the Methods of their Mitigation

Business activities of the Cracow airport are pursued in compliance with the principles of sustainable development. With increasing concern for the natural environment surrounding the airport, the aerodrome conducts the following actions:

- introduces programs of airport acoustic impact reduction;
- runs a program of selective waste collection around the airport;
- runs a program of continued retrieval of secondary raw materials from waste generated by the airport;
- applied energy-saving solutions at the stage of new investment implementation or modernization of existing facilities;
- conducts environmental awareness raising actions among employees.

What is more, the Cracow airport performs activities presented in Table 2 aimed at:

- protection against noise pollution;
- protection of air;
- rational management of hazardous waste and non-hazardous waste;
- rational water and sewage management;
- sustainable landscape management.

5. Noise Management

The Kraków-Balice airport is one of the military airports which, under the Agreement of 17 November 2004 between the Minister for Infrastructure and the Minister for the National Defence on the Operator of the Kraków-Balice airport, is managed by a civil unit. *Międzynarodowy Port lotniczy im. Jana Pawła II Kraków – Balice Sp. z o. o.* and the Military unit no. 1158: 8th Base of Transport Aviation in Cracow are its co-users.

The main types of aircraft used at the Cracow airport are civil aircraft (amongst others: Airbus, Boening, Cesna, Bombardier, Cirrus) and military aircraft (amongst others: CASA, PZL Mielec). The only runway at the Kraków-Balice airport is the one situated at an angle of 78 to 258 degrees. Aircraft operations, take offs and landings, are typically performed upwind. The prevailing winds at the airport are west winds, therefore the majority of aviation operations of aircraft are performed at the 258° direction. Aircraft operations i.e. take-offs, flights, landings, and ground operations of aircraft are the main source of noise at the airport.

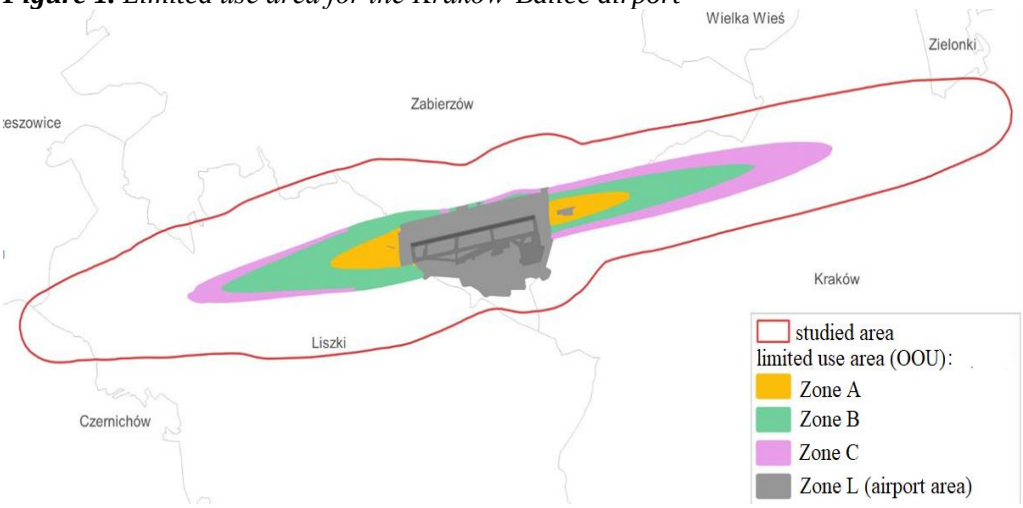
Table 2. *Airport's actions to preserve the natural environment*

Item	Objective	Action
1.	Noise abatement	Continuous monitoring of aviation noise; Implementation of anti-noise pollution procedures conducted in cooperation with external bodies; Implementation of new solutions and programs to reduce the acoustic impact of the airport.
2.	Air protection	Monitoring of the quantity of emitted gases or particles from exhaust gases; Monitoring of actions an individual work posts with respect to correct operation of machines and equipment in terms of effective reduction of emissions.
3.	Rational management of hazardous waste and non-hazardous waste	Monitoring of the quantity and quality of generated waste; Reducing amount of generated waste; Fitting waste generating posts with suitable environmental equipment.
4.	Rational water and sewage management	Monitoring the quality and quantity of water collection and release of sewage into the water or onto the land; Retrofitting of the rainwater sewage system via an implementation of state-of-the-art technical and organizational solutions protecting against contamination.
5.	Sustainable landscape management	Quantitative and qualitative monitoring of wooded lands and green areas; Cleaning and maintenance.

Source: *Own study compiled on the basis of: https://www.krakowairport.pl/pl/lotnisko,c94/media,c106/nasze-publikacje,c108/raport-zrownowazonego-rozwoju-krakow-airport,c467/raport-zrownowazonego-rozwoju-krakow-airport-2017,a3049.html.*

As environmental standards on the maximum sound levels in the environment had not been met, on 25 May 2009 the Little Poland Assembly (*Sejmik Województwa Mazowieckiego*) adopted a resolution no. XXXII/470/09 on the creation of an area of limited use for the Kraków-Balice airport, managed by *Międzynarodowy Port Lotniczy im. Jana Pawła II Kraków – Balice Sp. z o.o.*

Figure 1. *Limited use area for the Kraków-Balice airport*



Source:
http://www.gios.gov.pl/images/dokumenty/pms/monitoring_halasu/stan_srodowiska/Ocena_stanu_akustycznego_malopolskie_2018.pdf.

The limited use area was divided into three zones:

1. Zone A – an area between the border of the land managed by the airport and the line at which noise level is LN = 50 dB or LDWN = 60 dB,
2. Zone B – an area between the external border of Zone A and the line at which noise level is LDWN = 55 dB,
3. Zone C – an area between the border of Zone B and the line at which noise level is LN = 45 dB. – Figure 1.

When sketching the acoustic map, an area of 45.67m2 covering the lands located across the Zabierzów, Liszki, Kraków, Czernichów, Zielonki and Krzeszowice communes was considered. In order to reduce aviation noise propagation, the Cracow airport undertakes the following actions:

1. Noise abatement procedures:

- aircraft operators carrying out aircraft operations at the Cracow airport are obliged to comply with the procedures of noise abatement relevant for a given aircraft type. In the absence of the above procedures, it is recommended that take offs are performed following an example procedure of noise abatement during take-off (initial climb) – Annex to Chapter 3 ICAO Doc 8168 Procedures for Air Navigation Services – Aeroplane Operating Procedures, Vol. 1 – Flight procedures, Part 1, Section 7.
- For the departure climb straight along the roadway (RWY) axis, as far as it is practicable, up until 600 m, then turn as authorized by the traffic services.
- Smooth approach to landing;
- Limitations between 22:00 hrs. and 6:00 hrs. from sunset to sunrise descent with RWY07 visibility is prohibited. Air traffic control tower (TWR) does not issue descent permits with RWY 25 visibility.

2. In 2017, the document entitled "Politics of reducing the environmental acoustic impact of the Kraków-Balice airport (EPKK)". Under the above document, the following actions have been initiated:

-A pilot "Program for the improvement of acoustic climate" oriented at the inhabitants of the limited use area. The primary objective was to finance the works related to the application of increased acoustic insulation in houses and flats where environmental quality standards were not met.
-A partner program of the Cracow airport and local governments around the airport oriented at airport acoustic climate improvement.
- adoption of the document entitled "Politics of reducing the environmental acoustic impact of the Kraków-Balice airport (EPKK)" - with a joint initiative of the Company involving inter-sectoral work for acoustic climate improvement of real estate outside the airport (https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2018_flipbook_v1/

http://www.gios.gov.pl/images/dokumenty/pms/monitoring_halasu/stan_srodowiska/Ocena_stanu_akustycznego_malopolskie_2018.pdf).

Such a rational use of the environment by the Cracow airport is associated with development and delivery of reports on:

- amount of generated waste;
- gases or particles from exhaust gases emitted from boilers fired with gaseous fuels;
- groundwater abstraction and groundwater recharge with rainwater sewage.

The above reports constitute the foundation for the payment of legal fees, such as the summary fee for environment use which in the studied period amounted to, respectively:

- in 2016 – 58,889.92 zł;
- in 2017 – 59,656.00 zł;
- in 2018 – 3,472.00 zł
(https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2016_flipbook_v1/;
https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2017_flipbook_v1/;
https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2018_flipbook_v1/).

Air Protection:
Some potential sources of air pollution around the airport include:

- boiler plants fired by natural gas;
- mechanical ventilation installations;
- passenger cars, special vehicles, specialist vehicles, power-generating units, mechanical vehicles, road transport means, other equipment – Table 3.

Table 3. *Fuel use over the period 2016-2018*

Years	**Fuel**		
	ON	**EURO 95-Pb**	**Methane-rich natural gas**
2016	95,000.00 liters	50,500.00 liters	797,700 m3
2017	78,792.22 liters	45,162.16 liters	1,125,481 m3
2018	89,370.74 liters	41,100.30 liters	1,061,135 m3

Source: *Own study compiled on the basis of 2016-2018 sustainable development reports by the Cracow airport.*

Within the airport, there are other cooperating operators, i.e. airlines, state administration services, handling agents, cleaning companies, transport companies, and air fuel suppliers, also responsible for gas and particle emissions. However, these bodies are themselves accountable for and comply with the law on their own.

Since August 2017, as part of minimization of reduction of the negative environmental impact, six hybrid cars driven by the so-called "marshals" cross the aerodrome. In addition to the concern for the environment, they were selected because of the absence of failing parts, i.e. alternators and starters.

What is more, the Cracow airport maintains a procedure for systemic register of gases and particles of exhaust gases emitted during fuel combustion processes in the engines of combustion engine vehicles. The procedure serves the purpose of developing official reports following the statutory obligation and fee payment, as previously highlighted.

Management of hazardous waste and non-hazardous waste:

As part of waste management, the Cracow airport bases its work on the process of waste segregation and reduction. Recycling of secondary raw material reduces the quantity of generated municipal solid waste – Table 4. Proper segregation, and then sale to external bodies, is not only cost-effective but it also increases environmental awareness of the airport staff.

Table 4*. Waste management over the period 2016-2018*

QTY of municipal solid waste		**Put to recycling**				**Waste (paper and cardboard packaging) sale profits**
		Paper and cardboard packaging	**Plastics**	**Metal**	**Glass**	
2016	8,161 m3	Over 42 tons				15,000.00 zł
2017	8,448 m3	52 t	2.6 t	1.7 t	0.8 t	18,282.25 zł
2018	8,891 m3	57,890 t	1,240 t	0 750 t	1,550 t	17,200.00 zł

Source*: Own study compiled on the basis of 2016-2018 sustainable development reports by the Cracow airport.*

Water and sewage management:

The main source of potable water for the Cracow airport is water delivered by the Municipal Service Company (PUK) in Zabierzów, and two extra sources are two deep water wells. Water abstraction in the studied period is shown in Table 4.

Table 4. *Water abstraction over the period 2016-2018*

Item	**Year**	**Water supply network**	**Deep water wells**	**Military unit (supplies LSR-G and PKB)**	**Total water abstraction**	**Total sewage volume**
1.	2016	32,415 m3	36,900 m3	-	69,315 m3	101,409 m3
2.	2017	33,993 m3	37,176 m3	1,334.5 m3	72,503.5 m3	71,531 m3
3.	2018	52,957 m3	35,953 m3	1,864.5 m3	90,774.5 m3	no data

Source: *Own study compiled on the basis of 2016-2018 sustainable development reports by the Cracow airport.*

The underlying element conditioning effective airport operation is rainwater drainage. Rainwater is collected in tanks and then transported to the water treatment plant of the Cracow Municipal Water Supply and Sewage Company (MPWiK). Retention tanks, rainwater and sewage treatment sub-plants are treated on a regular basis. Rainwater from the airport surface is naturally drained into the Olszanicki Stream, a part of which flows through the airport in a closed manner.

Nowadays, in compliance with the currently binding law, rainwater is drained from the airport surface via a modernized and complex storm-water drainage system fitted with suitable environmentally friendly equipment (tanks, petroleum substance separators, and reservoirs). The system of storm-water drainage as part of water and soil environmental protection and anti-flooding support in case of excessive rainfall is subject to continuous monitoring of the quality and quantity of water abstraction and release of sewage into the water or onto the land; Moreover, as part of airport development, spatial development plans are made regarding a construction of a treatment plant and development of an alternative method of rainwater drainage. In 2018, airport authorities completed an investment regarding the real control over and balancing of waters incoming intro the airport form outside areas, i.e. at the entry of the Olszanicki Stream. Given the dynamic increase in air traffic in the years to come and investment plans, efforts are being made to better the protection of the Olszanicki Stream against potential contamination from the airport area by a selection of effective treatment technologies and work organization mitigating any adverse environmental impact.

Landscape management:
The Kraków-Balice airport and surrounding areas require a special approach to issues concerning wooded lands and green areas. Therefore, bearing in mind the provisions of the law on nature protection, the aviation law regarding the provision of operational safety, at and around the airport works have been performed for several years now aimed at rational flora development and good landscape management (tree and bush maintenance). Compensation actions, in turn, comprise the planting of new trees and bushes across and around the airport (https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2016_flipbook_v1/,
https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2017_flipbook_v1
/https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2018_flipbook_v1/).

6. Conclusions

Airport operations in harmony with the natural environment did not pose a problem for many years. The issue was marginalized since airports were located away from human settlements. A pressing problem was underinvestment of facilities with respect to combating natural environment degradation, inappropriate use of

equipment, and risk unawareness among those responsible for organizational operations and use of equipment and devices contaminating the environment.

A clear change in the approach to this grave issue could be observed post 1980, i.e. upon an adoption of the Law on environmental protection and development. At that time, a clear guidance was introduced regarding airport design, which consequently prevented further natural environment degradation at aerodromes. However, environmental operations and the condition of airports continued to be unsatisfactory.

There is a myriad of things everyone can do to save our natural surroundings. Without a doubt, environmentally friendly airport operations are feasible, and we should do everything to make airport operations as little invasive for the environment as possible. With respect to excessive noise, one can create acoustic green strips, design maps of noise pollution with protecting strips for all airports, and then use the said maps for the spatial development of the areas adjacent to airports.

Harmonious co-existence of airports and the environment depends also on suitable prevention against soil and groundwater contamination. Thanks to ongoing maintenance of treatment facilities, fittings can remain in the best possible condition, thus reducing the risk of spills into soil or groundwater. These operations can be supported by periodic testing of waters abstracted from airport areas, the analysis of test results, and fitting fuel distribution posts with special draining equipment. As part of actions which can help protect nature, one may also introduce constant supervision over compliance with the principles of use of aviation and distribution equipment.

All in all, it can be claimed with certainty that contemporary airports and aviation operations greatly contribute to natural environment degradation. Nonetheless, in the age of transport development and immense popularity of air communication, there are sound reasons to believe that all actions associated with air operations will be oriented at environmental protection. New Directives, Regulations and Laws are being adopted imposing compliance with certain principles of aviation operations, which will allow poeple to live and function in harmony with nature (Zajas and Ozga, 2011, Jeż, 2009).

References:

Biskup, K., Bukowski, Z. 2015. Działalność lotnicza w Polsce. Wydawnictwo Uniwersytetu Kazimierza Wielkiego, Bydgoszcz, 106-108.

Chakuu, S., Kozłowski, P., Nędza, M. 2012. Podstawy transportu lotniczego. Konsorcjum Akademickie, Kraków-Rzeszów, Zamość, p. 214.

Ciechanowicz-McLean, J. 2016. Prawo ochrony klimatu. Powszechne Wydawnictwo Prawnicze, Warszawa, p. 12.

Jeż, M. 2009. Transport lotniczy a zrównoważony rozwój, Biblioteka Naukowa Instytutu Lotnictwa, Warszawa, p. 35.
Zajas, S., Ozga, D. 2011. Lotnictwo a środowisko naturalne, AON, Warszawa, pp. 7-8.

Internet sources:

http://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20190001580/U/D20191580Lj.pdf
http://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20090420340/U/D20090340Lj.pdf
https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2016_flipbook_v1/
https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2017_flipbook_v1/
https://krakowairport.pl/multimedia/balice_raport_zrownowazonego_rozwoju_2018_flipbook_v1/
http://www.gios.gov.pl/images/dokumenty/pms/monitoring_halasu/stan_srodowiska/Ocena_stanu_akustycznego_malopolskie_2018.pdf