ASSESSMENT OF NOISE IMPACT OF AIRCRAFT OPERATIONS AROUND PODGORICA AIRPORT

Nikola Lukačević
University of Belgrade, Belgrade, Serbia

Emir Ganić
University of Belgrade, Belgrade, Serbia

Bojana Mirković
University of Belgrade, Belgrade, Serbia

ABSTRACT

This paper analyses the impact of aircraft noise on community around Podgorica Airport, Montenegro. The airport is located 12 km from the city centre of the Montenegro capital, Podgorica. It served 1.3 million passengers and 7.5 thousand operations in 2019. The noise impact assessment is conducted in IMPACT web-based modelling platform using the distribution of operations by aircraft types, time of the day, and radar tracks for the busiest day (August 15) in 2019. Noise contours are assessed for Lden and Lnight indicators. They were merged with the Global Human Settlement Layer to assess the number of people exposed to different noise levels. In addition, based on the World Health Organization recommended exposure levels related to their health implications, the percentages of the population highly annoyed and highly sleep-disturbed are estimated. Furthermore, facilities of public importance (schools, hospitals, churches, etc.) are assessed against compatibility with the requirements set for the Zones with increased noise protection in national regulations. The results show that the exposure of community around Podgorica Airport to aircraft noise is still not a serious

issue. The near vicinity of the airport is industrial zone and the number of people highly annoyed by noise is approximately 3.2% of the total city population. Nevertheless, it is crucial to draw attention to planners to preserve airport neighbourhood from potential inhabiting, to avoid problems that some airports in the region are facing nowadays.

KEYWORDS: aircraft noise modelling, noise impact assessment, population noise exposure, noise contours, noise annoyance

1. INTRODUCTION

The aviation industry was and will be continuously challenged to reduce environmental impact in the face of constant (although temporarily interrupted) increase in demand [1]. In 2017, The European Commission (EC) defined Flight Path 2050 strategy [2], which represents the vision of air traffic systems and the aviation industry in 2050. This strategy sets important safety, infrastructure, operational, environmental protection, and others goals. Flightpath 2050 sets the goal to reduce the perceived noise emission of flying aircraft by 65%, relative to typical new aircraft in 2000.

Aircraft noise is considered to be disturbing to population who live around airports. Increasing the number of take-off and landing operations may lead to increased resentment of the population, which may result in limiting the further development of the airport. Airports are facing a constant struggle to reduce the harmful effects of noise on the surrounding population to a minimum. Otherwise, air traffic may jeopardize its own development due to noise problems.

For decades, the industry has been working to reduce noise and numerous decisions have been made to mitigate negative impact of noise. The

International Civil Aviation Organization (ICAO) has defined "Balanced approach" [3] to aircraft noise management. The Balanced Approach identifies the noise problem at a specific airport and analyses various measures available to reduce noise, which can be classified into four principal elements: Reduction of Noise at Source (Technology Standards), Land-use Planning and Management, Noise Abatement Operational Procedures, and Operating Restrictions.

At the European level, Environmental Noise Directive 2002/49/EC (END) [4] has been introduced for the assessment and management of environmental noise. The Directive introduced the obligation of strategic noise map development and subsequently implementation of noise action plans. In course of that, numerous studies have been conducted to meet these requirements. Following the European Noise Directive, Ozkurt et al. [5] assess the level of aircraft noise exposure around İstanbul Atatürk Airport. In [6] noise levels for the day, evening and night time slices around İzmir Adnan Menderes Airport were calculated, showing that about 2% of the resident population was exposed to noise levels of 55 dB(A) or higher during day-time in Izmir. Study on Aircraft Noise for Athens International Airport [7] based on 2006 and 2011 Strategic Noise Maps (SNM) and Noise Action Plans for the EU indicators L_{den} and L_{night}, has been done. In [8] a complete Strategic Noise Mapping research and Action Noise Plans assessment and evaluation, for the Larnaka International Airport in Cyprus, were presented and aimed to access land use management as an effective tool for protection from aircraft noise. In [9] the noise impact produced by the airport Galileo Galilei in Pisa, Italy, was estimated and exposed population were evaluated.

This paper examines the noise impact on community around Podgorica Airport in Montenegro. The analysis was done in the IMPACT web-based modelling platform, for the day with the largest volume of traffic (August 15) in 2019.

The paper is organized as follows. Section 2 provides some general information about Podgorica Airport, including location of the airport, the number of passengers and aircraft operations, the airlines that operate at the airport, etc. Section 3 provides methodology together with information about IMPACT software and required input data for noise impact analysis. Section 4 summarizes the results on noise exposure analysis for the Podgorica Airport case study. Noise contours were assessed for L_{den}, as well as for L_{day}, $L_{evening}$ and L_{night} indicators and the number of people highly annoyed and highly sleep disturbed by the aircraft noise, was estimated. Section 5 contains conclusions and ideas for future works.

2. PODGORICA AIRPORT

The main goal of this study was to analyse impact of aircraft noise on community around Podgorica Airport. Podgorica Airport (ICAO: LYPG) is an international airport located 12 km south of the capital of Montenegro, Podgorica, and together with Tivat Airport (ICAO: LYTV) is one of the two civil airports in Montenegro. The airport is located next to the main roads E65 and E80, which connects Podgorica with the coast via Skadar Lake and the Sozina tunnel.

Podgorica Airport has one runway 2500 m long and 45 m wide, with a north-south orientation 180°/360°. The airport has ICAO classification 4E/ILS CAT I, though ILS landing is only possible on runway 36. The northern approach to runway 18 is visual only, possible under visual meteorological conditions (VMC). This is due to the proximity of the Dinaric Alps on the north.

International flights and domestic flights within Montenegro take place from Podgorica Airport. Due to the proximity of LYPG and LYTV, there are no

scheduled flights, only charter flights. At Podgorica Airport, the number of flights depends on the time of year. Some of airline companies that use Podgorica Airport are: Montenegro Airlines, Air Serbia, Wizzair, Ryanair, Alitialia, Turkish airlines, Austrian airlines, etc. In the summer months there is an increase in traffic, and companies flying to Podgorica are: Lot Polish Airlies, Enter Air, Rossiya Airlines, Tui Fly Belgium, Aegean Airlines, etc.

During the period from 2014 to 2019, the number of passengers at Podgorica Airport was constantly increasing, Figure 1. Podgorica Airport handled nearly 1.3 million passengers in 2019, which was an increase of 85.7% compared to the number of passengers in 2014 (0.7 million) [10].

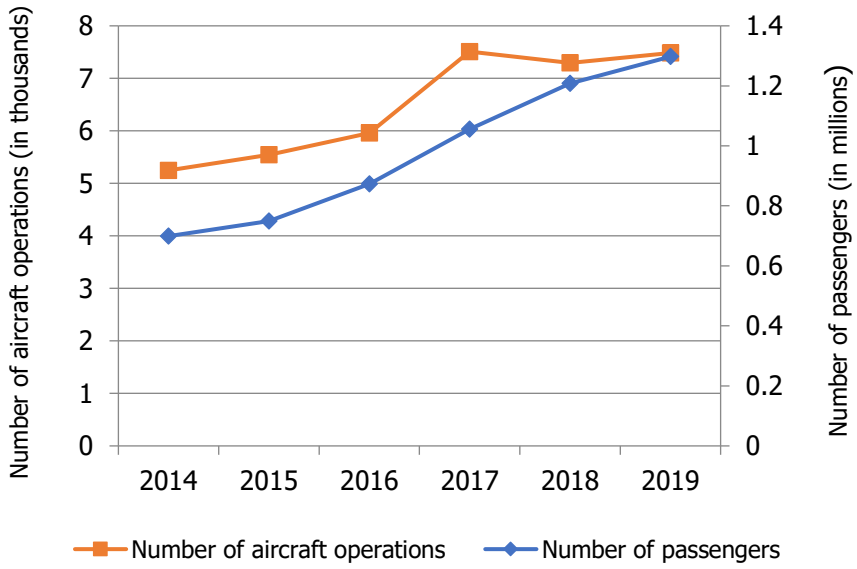

Figure 1. Total number of passengers and aircraft operations at Podgorica Airport

From 2014 to 2017, the number of aircraft operations was constantly increasing, while in 2018 there was a slight decline [10]. In 2019, the number of aircraft operations increased again and it was around 7500, which was an increase of 42.6% compared to number of aircraft operations in 2014 (around 5250).

3. METHODOLOGY

To analyse the impact of aircraft noise on community around Podgorica Airport, several steps were performed. In the first step, the software for noise prediction and mapping were chosen. Subsequently, all required input data, such as number of aircraft operations, aircraft types, arrival and departure routes, runway in use, meteorological data (temperature, atmospheric pressure, relative humidity, headwind speed), population data, terrain data were collected and used by software for the noise contours calculation. The obtained noise contours and the collected population data were used for noise exposure analysis. A brief description of the software that has been used for noise contours modelling and collected input data is given bellow.

3.1. Impact Software

There are many different noise prediction and mapping software that could be used to calculate noise exposure around an airport. For the purpose of making this study IMPACT (Integrated aircraft noise and emission platform) software was used.

IMPACT [11] is a web application for assessing the impact of civil aviation on the environment in terms of noise and gaseous/particulate emissions. IMPACT produces noise maps around airports according to widely used and recognised noise metrics such as LA_{eq}, L_{den}, LA_{max}, and SEL. It calculates the area of each noise contour and the number of people living within it. IMPACT uses reference data such as the Aircraft Noise and Performance database (ANP) [12] and/or the Base of Aircraft Data (BADA) [13]. ANP is a database that accompanies the ECAC Doc 29 [4] and ICAO Doc 9911 [14] guidance documents on airport noise contour modelling. ANP provides reference data for the modelling of departure and approach flight phases, as well as for

determining noise levels. BADA is an aircraft performance database and model that provides all the required parameters to calculate the 4D trajectory of an aircraft by using the Total Energy Model. IMPACT takes into account the fact that different aircraft types overfly locations at different altitudes and thrust settings.

3.2. Input Data

Traffic data were collected for the day with the highest number of aircraft movements in the 2019 (August 15th). During the observed period, there were 64 operations, out of which 33 departures and 31 arrivals. The runway 18 was used for 28 operations (44%), while the runway 36 was used for 36 operations (56%). Since departing and arriving aircraft vectoring is mostly in place at Podgorica Airport, actual radar data (Figure 2) [15] were used for departure/arrival route modelling instead of Standard Instrument Departure (SID) and Standard Arrival Routes (STAR). The blue colour in Figure 2 indicates departure routes, while arrival routes are marked in red.

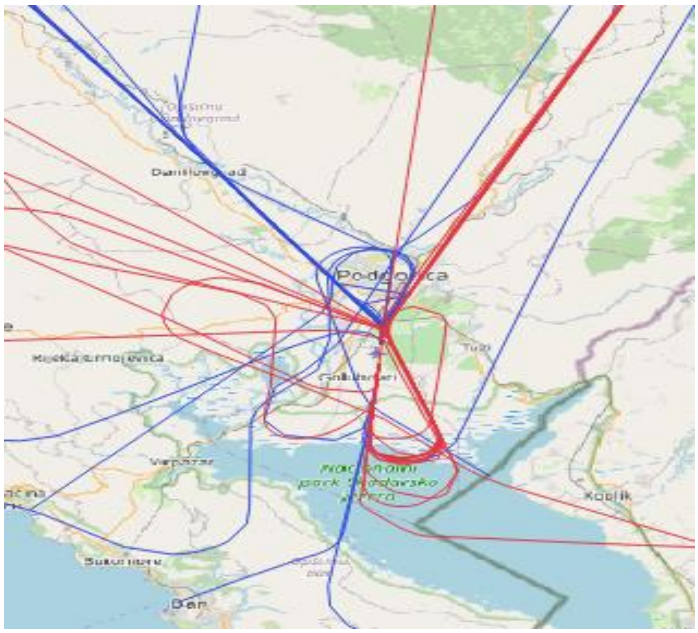

Figure 2. Departure and arrival routes (source: Flightradar24.com)

The fleet mix consisted of 12 different aircraft types: Dornier 328, Fokker 100, Embraer 175, Embraer 195, Bombardier CRJ700, ATR 72, Airbus A320, Airbus A319, Boeing 737-800, Boeing 737-300, Cessna 550 Citation Bravo and Cessna Citation Excel 560. The frequency of occurrence of each type of aircraft is shown in Table 1.

On August 15, 2019, three quarters of all operations (48) were performed during the day, 14% (9) in evening and 11% (7) night flights. This flight schedule at Podgorica Airport was favourable from the standpoint of noise because the least number of operations was during the night period. However, 11% of the total number of operations is not negligible and night noise, associated with the highest sensitivity of the population, might be serious problem.

Terrain data were obtained from the NASA SRTM (Shuttle Radar Topography Mission) database [17], which contains high-resolution digital topographic database of Earth.

Population data for each location around Podgorica Airport was obtained from the Global Human Settlement Layer [16]. This spatial raster dataset depicts the distribution and density of residential population, expressed as the number of people per cell. The data obtained are very detailed with a resolution of 100 m. According to this data source, there are 177,803 inhabitants in the municipality of Podgorica.

Table 1. Aircraft frequency at Podgorica Airport (August 15th, 2019)

Aircraft type	Number of departures	Number of arrivals	Total number of operations	Frequency
Boeing 737-800	9	9	18	28.1%
Airbus 320	4	4	8	12.5%
Fokker 100	4	3	7	10.9%
Embraer 195	4	3	7	10.9%

Aircraft type	Number of departures	Number of arrivals	Total number of operations	Frequency
Boeing 737-300	3	3	6	9.4%
Embraer 175	2	2	4	6.3%
Cessna 550 Citation Bravo	2	2	4	6.3%
Dornier 328	1	1	2	3.1%
Bombardier CRJ700	1	1	2	3.1%
ATR 72	1	1	2	3.1%
Airbus 319	1	1	2	3.1%
Cessna Citation Excel 560	1	1	2	3.1%
Total	33	31	64	100%

Figure 3 shows the population distribution of the municipality of Podgorica relative to Podgorica Airport. To estimate the noise exposure of inhabitants living within each cell, for each population grid cell (100 m x 100 m) noise levels were calculated at the cell's centroid.

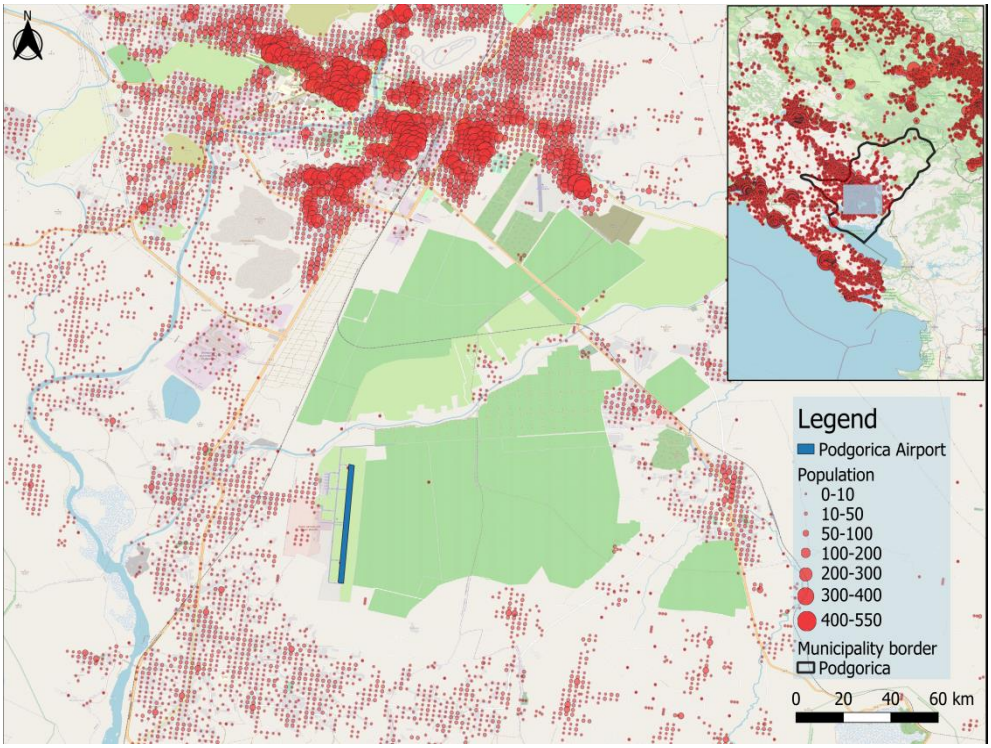

Figure 3. Population in the municipality of Podgorica

Meteorological data were collected from the Iowa Environ Mesonet [18] reports for Podgorica Airport. Average temperature in Podgorica, on 15.08.2019. was 25.57 °C. Average relative air humidity was 46.30%, the average atmospheric pressure was 29.86 inHg, while the average headwind was 6.73 kt.

4. RESULTS AND DISCUSSION

4.1. Noise Exposure Assessment

Noise contours are assessed for L_{den}, as well as for L_{day}, $L_{evening}$ and L_{night} indicators separately, according to [4] and [19]. L_{den} and L_{night} noise contours are given in Figure 4 and Figure 5, respectively. In order to assess the number of people exposed to different noise levels, noise contours were merged with the Global Human Settlement Layer [16]. The A-weighted equivalent sound pressure level in dB (L_{Aeq}) has been calculated for each period and for each location nearby Podgorica Airport. The population at locations within the same noise contours was summed and presented in Table 2 as the number of people exposed to different noise level range.

Table 2. Total number of people exposed per each noise band

	Number of people exposed per each noise band (dB)					
	<40	**40-45**	**45-50**	**50-55**	**55-60**	**>60**
L_{day}	71,686	69,500	7,380	1,178	30	5
$L_{evening}$	84,829	12,524	1,261	497	4	4
L_{night}	66,543	25,391	594	1	5	0

Only five people were exposed to noise greater than 60 dB during the period of the day and four during the period of evening. No one was exposed to noise above 60 dB during the period of the night. Thirty people was exposed

to noise between 55 dB and 60 dB during the period of the day (7 am to 7 pm), four during the period of the evening (7 pm do 11 pm), and five people during the period of the night (11 pm to 7 am). For night period, lower limits are usually set than the ones for day and evening periods.

Table 3 shows limit values for outdoor noise indicators for different zones and land use in Montenegro [19]. The homogeneous acoustic zones are characterised by different noise limit values in three periods (day, evening, and night). The limit values refer to overall noise from all sources in the considered area. Indicators listed in this table (L_{day}, $L_{evening}$, L_{night}) are defined as average values of the yearly noise level during the period of the day they represent. For residential areas, legal noise limit value of 55 dB (A) was used for day period and evening periods, while noise limit value of 45 dB was used for night period.

Table 3. Limit values for outdoor noise indicators in Montenegro

Acoustic zone	**L_{day}**	**$L_{evening}$**	**L_{night}**
Quiet zone in nature	35	35	30
Quiet zone in the agglomeration	40	40	35
Zone of increased noise protection mode	50	50	40
Residential areas	55	55	45
Mixed use zone	60	60	50
Zones under the strong influence of noise from air traffic	55	55	50
Zones under the strong influence of noise from road traffic	60	60	55
Zones under the strong influence of noise from railway traffic	65	65	60
Industrial zone	Noise must not exceed the limit value of the neighbouring area.		
Mineral exploitation zone			

From Table 2 it can be seen that 35 people is exposed to noise greater than 55 dB during the day, and less than 10 (8) people during evening period. As for the night periods, 600 people are exposed to noise above set limit of 45 dB.

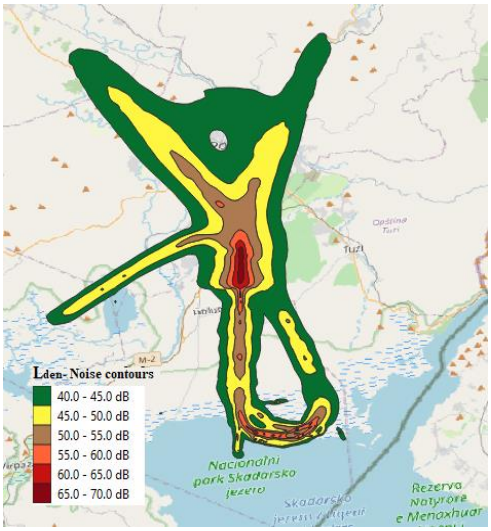

Figure 4. L_{den} – noise contours

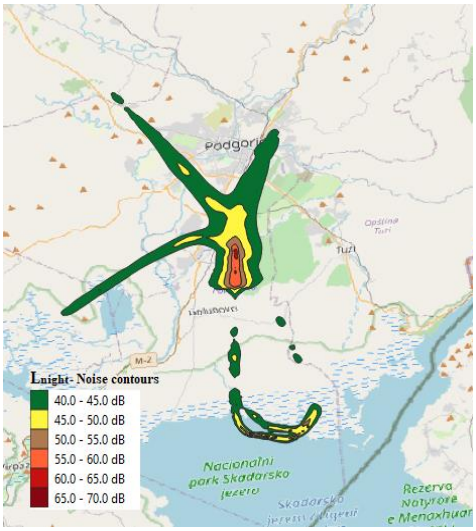

Figure 5. L_{night} – noise contours

4.2. Assessment of Harmful Effects

In order to assess the annoyance and harmful effects of aircraft noise to population, dose-effect relation is used, concerning the following (European Commission, 2020) [20]:

- the relation between high annoyance and L_{den} for air traffic noise,
- the relation between high sleep disturbance and L_{night} for air traffic noise.

For the calculation of the absolute risk (AR) with respect to the harmful effect of high annoyance (HA), defined as occurrence of that harmful effect in a population exposed to a specific level of environmental noise, the following dose-effect relations shall be used:

$$\mathrm{AR}_{HA} = (-50.9693 + 1.0168 \cdot \mathrm{L_{den}} + 0.0072 \cdot \mathrm{L_{den}}^2)/100 \quad (1)$$

For the calculation of the AR, with respect to the harmful effect of high sleep disturbance (HSD), the following dose-effect relations shall be used:

$$\mathrm{AR}_{HSD} = (16.7885 - 0.9293 \cdot \mathrm{L_{night}} + 0.0198 \cdot \mathrm{L_{night}}^2)/100 \quad (2)$$

The given equations are precise enough for practical use and are used as facilitation and replacement for assessment based on empirical data (such as surveying the population around the airport). Using the equations (1) and (2), based on the values of the noise indicators L_{den} and L_{night}, population data for each location and the World Health Organization recommended exposure levels related to their health implications [21], the number of people who may be highly annoyed and sleep disturbed by air traffic noise was estimated. The number of people who may be highly annoyed by air traffic noise were 5687, while the number of people who may be highly sleep disturbed were 3248.

According to the recommendations of the World Health Organization (WTO), the noise limit value for the day period is 45 dB, while the noise limit for the night period is 40 dB [21]. For this reason, in calculation of number of people highly annoyed and highly sleep disturbed, only locations exposed to noise greater than or equal to 45 dB during the period of the day and evening and locations exposed to noise greater than or equal to 40 dB during the night period, were taken into account.

4.3. Assessment of Noise Levels at Facilities of Public Importance

Figure 6 shows locations of some of the facilities of public importance (schools, hospitals, churches, museums, etc.) in the municipality Podgorica. According to national regulations of Montenegro [19] these facilities are defined as Zones with increased noise protection. That means that the noise in their surroundings must not exceed the limit value of 50 dB for the period of day and evening, and 40 dB for the night period. In order to examine whether the limit values are exceeded, it was necessary to calculate noise exposure for each of these locations.

During the day (7-19h) and in the evening (19-23h) none of the locations were exposed to noise greater than 50 dB. During the night period (23-07h) location such as Church of the Holy Great Martyr George (Crkva Svetog

Velikomučenika Georgija) one in Vojvodjanska Street and the other in Vladike Danila Street, Dajbabe Monastery, elementary school "Marko Miljanov", kindergarten "Artić Pinokio", and health center "Konik" were exposed to noise greater than 40 dB. Since the working hours of these institutions are during the day, the impact of noise was considered to be insignificant.

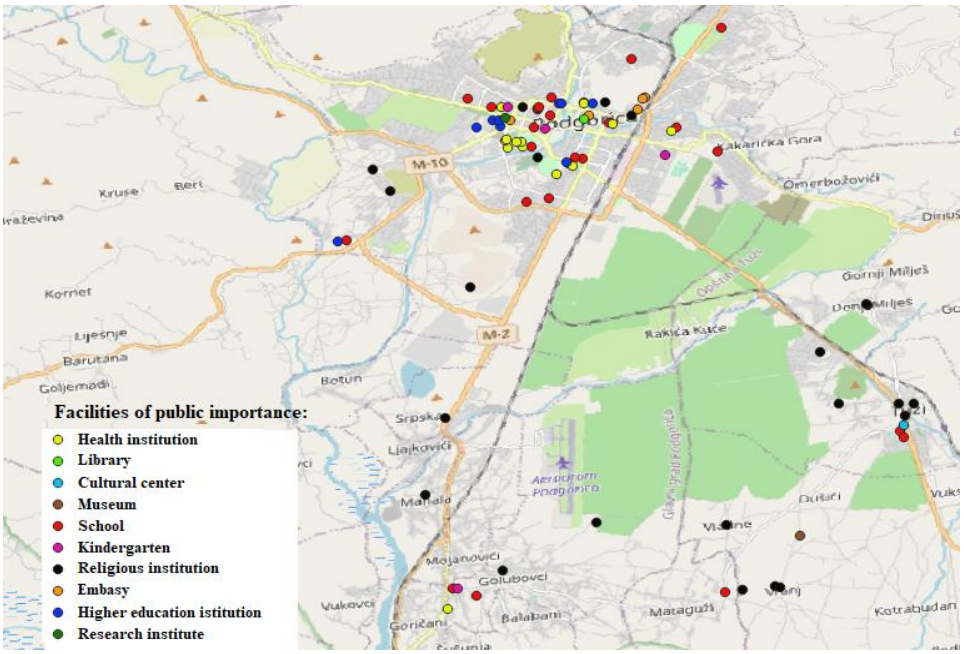

Figure 6. The facilities of public importance in the municipality of Podgorica

4. CONCLUSION

In this paper, the impact of aircraft noise on community around Podgorica Airport was analysed. The day with the largest volume of traffic was observed and it consisted of 64 aircraft operations. Noise contours around the airport were calculated and the number of people who may be highly annoyed and highly sleep disturbed by the aircraft noise was estimated.

The results show that the exposure of community around Podgorica Airport to aircraft noise is still not a serious issue. There are no larger settlements in the vicinity of the airport, the area is mostly uninhabited or there are industrial

zones. The number of people highly annoyed by noise is approximately 3.2% of the total city population, while the number of people highly sleep disturbed is approximately 1.82%. Nevertheless, it is crucial to draw attention to planners to preserve airport neighbourhood from potential inhabiting, to avoid problems that some airports in the region are facing nowadays.

Acknowledgments

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia. The authors would like to express their gratitude to Podgorica Airport for providing the data.

REFERENCES

[1] Ganić E, Ivošević J, Mirković B, Impact of aircraft noise on communities near Belgrade Airport, Promet – Traffic & Transportation, 2021, 33(3): 323-335, DOI: 10.7307/ptt.v33i3.3692

[2] European Commission. Flightpath 2050 - Europe's vision for aviation: Report of the High-Level Group on Aviation Research. Luxembourg: Publications Office of the European Union, 2011 p. 1–32. Available from: https://tinyurl.com/2u5xutvs

[3] ICAO - International Civil Aviation Organization. Doc 9829 - Guidance on the balanced approach to aircraft noise management, 2nd Edition. Montreal, Canada, 2008.

[4] ECAC - European Civil Aviation Conference, Doc. 29: Report on Standard Method of Computing Noise Contours around Civil Airports, 4th Edition, Vol. 1 - Applications Guide, 2016.

[5] Ozkurt N, Sari D, Akdag A, Kutukoglu M, Gurarslan A. Modeling of noise pollution and estimated human exposure around İstanbul

Atatürk Airport in Turkey. The Science of the Total Environment, 2014, 482–483: 486–492, DOI: 10.1016/j.scitotenv.2013.08.017

[6] Ozkurt N, Hamamci SF, Sari D. Estimation of airport noise impacts on public health. A case study of İzmir Adnan Menderes Airport. Transportation Research Part D: Transport and Environment, 2015, 36: 152–159, DOI: 10.1016/j.trd.2015.02.002

[7] Vogiatzis K. Assessment of environmental noise due to aircraft operation at the Athens International Airport according to the 2002/49/EC Directive and the new Greek national legislation. Applied Acoustics, 2014, 84: 37– 46, DOI: 10.1016/j.apacoust.2014.02.019

[8] Vogiatzis K. Airport environmental noise mapping and land use management as an environmental protection action policy tool. The case of the Larnaka International Airport (Cyprus). The Science of the Total Environment, 2012, 424: 162–73, DOI: 10.1016/j.scitotenv.2012.02.036

[9] Licitra G, Gagliardi P, Fredianelli L, Simonetti D. Noise mitigation action plan of Pisa civil and military airport and its effects on people exposure. Applied Acoustics, 2014, 84: 25–36. DOI: 10.1016/j.apacoust.2014.02.020

[10] Montenegro Airports, https://montenegroairports.com/ (accessed 30.06.2021).

[11] EUROCONTROL, Integrated aircraft noise and emissions modeling platform – IMPACT User Guide, release 3.36, version 1.0, June 2020

[12] The Aircraft Noise and Performance database – ANP, https://www.aircraftnoise model.com, (accessed 25.05.2021)

[13] The Base of Aircraft Data - BADA, https://www.eurocontrol.int/model/bada (accessed 25.05.2021)

[14] ICAO - International Civil Aviation Organization, Doc. 9911: Recommended Method for Computing Noise Contours Around Airports, 2nd Edition, Montreal, Canada, 2018

[15] Flighradar24, https://www.flightradar24.com (accessed:01.04.2021)

[16] S. Freire, M. Halkia, M. Pesaresi, GHS population grid, derived from EUROSTAT census data (2011) and ESM R2016. European Commission, Joint Research Centre (JRC), 2016, [Dataset] PID: https://tinyurl.com/26f8hukk (accessed April 2021)

[17] NASA SRTM (Shuttle Radar Topography Mission), https://www2.jpl.nasa.gov/ (accessed 01.04.2021)

[18] Iowa Environmental Mesonet, Iowa State University, https://mesonet.agron.iastate.edu (accessed 01.04.2021)

[19] Government of Montenegro, Rulebook on environmental noise limit values, manner of determining noise indicators and acoustic zones and methods of assessing the harmful effects of noise ("Official Gazette of Montenegro", No. 60/11)

[20] European Commission. Directive 2020/367, of 4 March 2020 amending Annex III to Directive 2002/49/EC of the European Parliament and of the Council as regards the establishment of assessment methods for harmful effects of environmental noise, Official Journal of the European Communities, March 5, 2020: 132–136.

[21] World Health Organisation, Environmental Noise Guidelines for the European Region, 2018, https://tinyurl.com/mv9sz9bc (accessed July 2021)

AUTHORS' BIOS

Mr **Nikola Lukačević** is a first-year PhD student at the University of Belgrade - Faculty of Transport and Traffic Engineering (Serbia). He received a bachelor's and master's degree in Traffic Engineering from University of Belgrade. He is interested in areas of Airports and Air Traffic Safety. Email: nikola.lukacevic@sf.bg.ac.rs

Dr **Emir Ganić** is a Research Associate at the University of Belgrade – Faculty of Transport and Traffic Engineering, Serbia. His scientific and professional interests, reflected through numerous publications and research and consulting projects conducted, are in the areas of environmental protection, sustainable aviation, noise and emission reduction and environmental quality management. Tel: +381113091352, Email: e.ganic@sf.bg.ac.rs

Dr **Bojana Mirković** is an Associate Professor at the Division of Airports and Air Traffic Safety, University of Belgrade - Faculty of Transport and Traffic Engineering (Serbia). She is a leading lecturer for four courses related to airport planning, design, operations and management, and actively takes part in a number of research and consulting projects. Tel: +381113091231, Email: b.mirkovic@sf.bg.ac.rs