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Effects of the COVID-19 Pandemic on the noise exposure of population around Split Airport

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Abstract

Airports negatively affect the environment by generating annoying aircraft noise. In practice, negative noise effect due to constant increase of air traffic is being compensated for through improved approach and departure procedures as well as new methods of noise reduction, mainly at the noise source itself. The emergence of COVID-19 pandemic significantly reduced air traffic throughout the world, which had a positive effect on the noise exposure of the people living around airports. This research is analyzing the effect of the COVID-19 on the noise exposure of the population living around Split Airport. The analysis was conducted based on the comparison of the noise maps for the peak days of 2019 and 2020, created in the Integrated Noise Model. The estimated number of inhabitants exposed to noise levels above 55 dB during the 2020 peak day was reduced by 22.7% compared to 2019, while the estimated number of inhabitants exposed to noise levels above 40 dB during the night decreased by 49.4%.

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Keywords: aircraft noise; air traffic; Split airport; COVID-19; Integrated Noise Model; noise map.

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1. Introduction

As a part of air transport, airports negatively affect the environment by generating aircraft emissions – exhaust gases, as well as noise. Although increased traffic at the airport can improve quality of life by increasing employment and attracting new business, it goes without saying that generated noise will have adverse effects on the people living close to airport. There are various ways to reduce noise in air traffic. Some of them are noise source related, some are spatial planning and others might be related to aircraft operational procedures. Introduction of restrictive measures and new technologies indicates that aviation is moving towards sustainable development. In order to assess the exposure of the population to aircraft noise, strategic noise maps that show data on existing or projected noise using noise indicators are created.

Although air transport makes up a small part of GDP, it has a strong connection to airports, aircraft manufacturing and many other sectors. It goes without saying that many economic activities within various industries are driven by the aviation. Due to the COVID-19 related restrictions, demand for air transport of passengers has plummeted, threatening the sustainability of many air transport carriers and other associated parties in the aviation sector. Even though government policies often target aviation industry, according to ACI (2021), the COVID-19 crisis has triggered a series of new loans, wage subsidies and capital injections, raising concerns about competition and efficient use of government funding.

Having in mind that the well-being, health, and safety of passengers and employees is an imperative of the aviation industry, airports have introduced many related measures to ensure and achieve that goal. Airports and airlines are working with the industry to be ready to restart global connectivity as soon as the epidemiological situation allows. According to OECD (2020), one of the keys of support to continued recovery is the establishment of an interoperable health data trust framework to promote the safe reopening of borders and cross-border travel.

The global pandemic has caused the shutdown of airports around the world, resulting in losses in the number of passengers and revenues in all regions. Although many countries started the gradual opening of many branches of the economy, which directly affects air traffic, unfortunately some of them were forced to face several waves of infection and a large number of countries decided to re-introduce partial or complete quarantines.

The goal of this research is to analyze the effects of COVID-19 on the noise exposure of the population using the noise maps created in the Integrated Noise Model (INM) software. The analysis was conducted based on the comparison of the noise map for the peak days of 2019 and 2020. The paper also explains how the COVID-19 pandemic affected the reduction of the population's exposure to noise.

The impact of the COVID-19 pandemic on air traffic is explained in the next chapter. The methodology is given in the third chapter, where the process of aircraft noise modeling is explained in more detail. The fourth chapter presents the characteristics of the case study for Split Airport. The analysis of the effects of the COVID-19 pandemic on the noise exposure of the population around Split Airport is presented in the fifth chapter, where the statistically processed results are presented by tables and graphs. Concluding considerations are given in the last, sixth chapter.

2. Impact of the COVID-19 pandemic on air traffic

The COVID-19, also known as the coronavirus pandemic, currently covers all countries of the world and is therefore also called a global pandemic. It is caused by severe acute respiratory syndrome coronavirus 2, which was first identified in December 2019 in Wuhan, China. More than 548 million cases have been confirmed and this number is increasing every day.

In addition to the human tragedy, this crisis also caused enormous damage to the global economy, trade and liquidity. Due to the COVID-19 restrictions, the demand for air transport of passengers has fallen sharply, threatening the viability of many companies in the aviation sector and other sectors of the aviation industry.

2.1. Air traffic in 2019

Before the COVID-19 pandemic, 2019 was the busiest year in air traffic history. According to EUROSTAT (2021), the total number of passengers who traveled by air in the European Union was 1.034 million, which was an increase of 3.8% compared to 2018. The area studied by EUROCONTROL measures a positive growth trend in the number of
flights of 0.8% in 2019 compared to 2018, which is not a big increase compared to the annual growth in the last few years. However, if we compare the year 2013, when the increase in the number of air passengers began, in 2019 there were 1.5 million more flights, or in other words, there was a growth of 15.4%. Along with the increase in the number of flights, it is important to note other growth variables in air traffic. For example, in 2019 compared to 2018, the average size of aircraft was higher by 1.7% and the distance traveled also increased by 1.7%. Consequently, although the number of flights grew by only 0.8%, the number of air passengers in 2019 was 3.2% higher than in 2018, according to EUROCONTROL (2020). The fact that 2019 was the busiest year in air traffic is also supported by the fact that on July 24, 2019, there was a record number of flights in the amount of 225,000 in one day, as stated in Slotnick (2019).

2.2. Air traffic during the COVID-19 pandemic

Changes in air passenger behavior caused by the COVID-19 crisis, travel bans and restrictions, and consequently the worldwide economic crisis, have caused a drastic drop in air traffic demand. In April 2020, the International Air Transport Association (IATA) recorded a 90% drop in Revenue Passenger Kilometers (RPK) within a one-year period. The mentioned drop in August 2020 was also very high compared to 2019, more precisely 75% higher, according to ACI (2021).

A comparison of the actual traffic with the baseline forecast for the year 2020 made before the coronavirus pandemic indicates a loss of 1 billion air passengers. In other words, passenger traffic was actually lower by 64.6% than the forecasted figure for 2020. The actual number of passengers achieved in 2020 compared with the 2019 shows a decrease of 63.3% in total, according to OECD (2020).

Statistical data on the number of passengers transported at airports in the Republic of Croatia is shown in Table 1. The sharpest drop in the number of transported passengers is evident at Pula Airport, i.e. -89.7%. The second largest drop was recorded for Dubrovnik Airport, which in 2019 had 2,880,505 transported passengers, and in 2020 only 326,789 passengers. The smallest drop in the number of transported passengers is recorded at Mali Lošinj Airport.

| Airport              | Number of passengers | Percentage of change |
|----------------------|----------------------|----------------------|
| Zagreb Airport       | 3,419,338            | 920,069              | -73.1% |
| Split Airport        | 3,271,731            | 659,351              | -79.9% |
| Dubrovnik Airport    | 2,880,505            | 326,780              | -88.7% |
| Pula Airport         | 764,871              | 78,493               | -89.7% |
| Zadar Airport        | 777,662              | 110,227              | -85.8% |
| Osijek Airport       | 46,361               | 6,625                | -85.7% |
| Rijeka Airport       | 200,184              | 27,190               | -86.4% |
| Brač Airport         | 25,339               | 4,250                | -86.2% |
| Mali Lošinj Airport  | 6,495                | 3,214                | -50.5% |
| Total                | 11,392,486           | 2,136,199            | -81.3% |

2.3. Air traffic forecast

The recovery of air traffic and the aircraft industry still has many uncertainties. EUROCONTROL has published three scenarios that contain certain assumptions necessary to form possible directions for the recovery of the aviation industry.

The first and the optimistic scenario is a complete recovery by 2024, which is achievable if the vaccines are effective and if a sufficient number of people receive the vaccine. This scenario relies on strained assumptions about
the demand effect and is characterized as optimistic because there is a high probability that it will not materialize in the specified period.

The second scenario assumes that humanity is vaccinated in 2022 and that the air traffic in 2024 reaches 95% of the traffic in 2019. The realization of this scenario largely depends on the measures that certain countries will implement to make travel easier on a global scale. The above scenario is taken as the scenario that will most likely succeed because the prerequisites for its realization are set in realistic possibilities.

The last and the pessimistic scenario assumes that air traffic in 2024 will reach only 74% of the traffic in 2019, and that a full recovery of air traffic will not be possible before 2029. According to EUROCONTROL (2021b), this scenario predicts persistent restrictions in the coming years, new waves of infection, the emergence of new virus strains, insufficient vaccination, and ultimately the loss of travelers’ confidence and enthusiasm for travel.

If the optimistic scenario becomes a reality, an increase in air traffic is expected, resulting in an increase in noise levels in the vicinity of airports. This will increase the number of vulnerable residents. However, if the pessimistic scenario comes true, the number of residents exposed to noise will still grow, but over a longer period of time, which will provide additional possibility to implement new noise reduction regulations and technological methods.

3. Methodology

The analysis of the effects of the COVID-19 pandemic on the population noise exposure was carried out based on the results obtained by modeling aircraft noise and the number of people living in the close proximity of the airport. The INM program was used to create the noise maps.

By modeling aircraft noise in the INM program, noise maps were created for the year 2019 (before the onset of COVID-19) and the year 2020 (during COVID-19). In the analysis, the obtained data were statistically processed and the difference in the obtained results was explained in more detail. The process of aircraft noise modeling was done gradually with several steps and by collecting the following data: airport and runway data; terrain data; meteorological data; population and location data; aircraft data; departure and arrival routes; and distribution of flight operations.

Study Setup is the first step towards developing noise contours in INM, where geographical data for the airport including runway physical characteristics are required. The next step is to setup different cases with actual meteorological data (temperature, pressure, humidity, and headwind) for the airport for different years.

Terrain elevation data provide a terrain contour layer which INM uses to adjust observer-to-aircraft distances when computing noise levels. To calculate noise at some specific points such as schools, hospitals, religious buildings, etc, the coordinates for each location point must be provided. In addition, population points should also be created to calculate the number of people inside noise contours.

Grid setup defines locations where noise is calculated, and it can be different for each scenario. Grid type can be different for contours, populations, and locations. For each scenario it must be defined what noise metric will be calculated along with the contour spacing and number of grid points.

Selection of INM standard civil airplanes for the study is based upon aircraft type data provided by the airport. If some airplane is not on the list, the FAA approved substitutions that are associated with INM standard airplanes should be selected based on the aircraft performance including MTOW (Maximum Take-off Weight), type and number of engines as well as thrust setting.

Necessary air traffic data for each flight operation include the type of operation (departure or approach), airports from which aircraft arrive and to which they depart, actual time of take-off and arrival, type of aircraft, and runway designator. Ground tracks and vertical flight profiles that make unique arrival and departure routes need to be modelled for each runway. Aeronautical Information Publication (AIP) contains data from which these tracks can be modelled, or they could be obtained through radar/ADB-S data. Obtained flight operations must be distributed over tracks and runways separately for departures and arrivals and for each time period (day, evening, night).

In order to assess the noise at each location, we calculated the most commonly used indicators in Europe which are Lden and Lnight as defined in European Commission (2002). These indicators represent yearly averaged noise values designed to express the environmental noise exposure from different transport sources and industry, as well. In the Republic of Croatia, the state default values for periods used to calculate Lden and Lnight are as follows: the period of day is from 07:00 to 19:00, the evening period is from 19:00 to 23:00, while the night period is from 23:00 to 07:00, all local time.
The following phase includes calculating the cumulative noise impact through estimation of the population exposed to calculated \( L_{\text{den}} \) and \( L_{\text{night}} \) noise levels at each location. Furthermore, adverse effects of aircraft noise in terms of annoyance and sleep-disturbance can be estimated through dose-effect relations, as explained in Commission Directive (EU) 2020/367 amending Annex III to Directive 2002/49/EC, by European Commission (2020).

4. Case study for Split Airport

Analysis of the impact of the COVID-19 pandemic on the population's exposure to noise was conducted using the example of Split Airport. Split Airport is in the center of the central Dalmatian region and covers air traffic needs of the coast, from Makarska to Šibenik, the islands of Hvar, Brač, Šolta, etc. It is situated six kilometers from the city of Trogir, and twenty kilometers from the city of Split.

It was opened on November 25, 1966. The planned number of 150,000 passengers per year was already exceeded in 1968, while in 2019 the total number of passengers was 3,301,930, according to Split Airport (2021). Apart from the drop in traffic caused by the political crisis in 1988 and the closure of Split Airport to all traffic due to the war in 1991, as well as the world economic crisis in 2009, Split Airport recorded an increase in the number of passengers year after year, until 2020, the year when the COVID-19 followed.

Split Airport is located at 43.538889° North latitude and 16.297778° East longitude. The runway is positioned in the direction of 052.57° and 232.59°, and thus the thresholds of USS 05 and 23 are assigned. The length of the runway is 2550 m. For the analysis carried out in this work, it is important to point out that the peak day of 2019 was August 3, while in 2020 it was August 8. Meteorological data necessary for noise modeling were collected from the Iowa State University (2021). Table 2 compares average values of meteorological data for the peak day of 2019 and of 2020.

| Year | Temperature (°C) | Air pressure (kPa) | Relative humidity (%) | Headwind (kt) |
|------|------------------|--------------------|-----------------------|--------------|
| 2019 | 25.7             | 101.3              | 53.6                  | 3.1          |
| 2020 | 29.4             | 100.9              | 42.0                  | 7.9          |

On August 3, 2019, according to the realized flight schedule, which was delivered from Split airport itself, there were a total of 212 operations, 107 of which were take-off operations and 105 were landing operations. On the other hand, on August 8, 2020, there were 171 operations, 86 of which were take-off operations and 85 were landing operations. A drop in traffic by 19.3% is obvious at first glance. Given that each type of aircraft has different performance which affects the noise of the aircraft itself, it is important to highlight which aircraft had the most operations on the observed peak day. So, on 2019 peak day, the Airbus A320 aircraft performed the largest number of operations - 74. Then comes the Boeing 737-800, which had 37 operations, etc.

Figure 1 shows all aircraft types with assigned numbers of operation, i.e., Figure 1a) for the 2019 peak day and Figure 1b) for the 2020 peak day. The comparison of the two peak days reveals similarities in the types of aircraft, such as Airbuses, Boeings, some Cessnas, Bombardier Dash and Dassault Falcon that can be found both in 2019 and 2020. Airbus A320, likewise in 2019, performed most operations (63). Unlike in 2019, the Bombardier Dash 8 Q400 was the second, with 23 operations, followed by Airbus A319 and Boeing 737-800, while other aircraft types had four or fewer operations in the observed time.
To analyze the noise exposure of the population, it is essential to define the area of interest around the airport. We downloaded a set of raster data with population density and distribution, which is expressed as the number of people on a certain surface, which depends on the resolution of the raster data. The data were taken from the EUROSTAT census data (2011) and ESM R2016, as state in Freire et al. (2016). Then, within QGIS, the area of interest was reduced to a radius of 50 km centered on Split Airport. The radius was chosen arbitrarily, because the authors believe that outside this area, aircraft noise has no significant impact on the population. Population points represent a network of 100 m² areas and the noise levels for each location are calculated at the centroids of these areas. Finally, it was calculated that 372,727 inhabitants live in the observed area of interest.

Initially, the creation of routes was attempted within the NEST program, but due to imprecise results, four approach and four departure routes from eAIP were chosen as representatives of the routes that were used for modeling. The three selected approach routes are assigned to runway 05 (TORPO4C, SIPAL5G and VAPUP2A), while only one is assigned to runway 23 (OXLAX3D). Three departure routes belong to runway 23 (TORPO8E, KEMIX3A and SIRM12E) while only route TORPO7D is assigned to runway 05. In addition, in INM, the dispersion of the created routes is automatically performed, which is used to model deviations from the nominal flight path, which distributes the noise over a larger area than a single path provides. It should be noted that actual lateral dispersion, which was not available for this research, could provide more precise results. Furthermore, conventional SID/STAR procedures flown manually or with RNAV systems may result in significative differences on lateral dispersions. Therefore, the modelled routes in this case study should be considered more as a theoretical one rather than as actually flown. Nevertheless, the use of these routes is justified as they will be considered in this research only for comparison purposes between two peak days of pre-COVID and during the COVID. Figure 2 shows the created approach (red color) and departure (blue color) routes. After creating the routes, it is necessary to assign the corresponding route to the individual flight depending on the geographical position of the airport which the aircraft arrives from, or departs to, Split Airport.

![Fig. 1. (a) Number of movements per aircraft type for 3 August 2019; (b) Number of movements per aircraft type for 8 August 2020.](image-url)
Therefore, flights coming from the following countries were added to the outgoing route TORPO7D: the United Kingdom, Italy, France, Switzerland, Austria, Ireland, Czech Republic, Russia, Norway, Finland and Germany. TORPO8E is an outgoing route with the following destination countries added: Netherlands, United Kingdom, Italy and France. Furthermore, the KEMIX3A route is characterized by outbound flights to Spain and Italy. Flights to the Czech Republic, Germany, Sweden and the cities of Zagreb and Zadar are assigned to the SIRM12E route. SIPAL5G was assigned flights from Turkey, Romania and the city of Dubrovnik. OXLAX3D is the only approach route with runway 23 active so all aircraft landing in the direction of USS 23 belong to that route. VAPUP2A contains flights from Italy and France, specifically Rome, Naples and Cannes. All listed countries that belong to the outgoing route TORPO7D also belong to the incoming route TORPO4C. Figure 3 shows a comparison of the number of flights on the peak day of 2019 and 2020 assigned to the previously mentioned routes. For the purposes of this work, standard flight profiles were used. Each flight is assigned a route, a procedural profile, a runway and the number of day, evening, and night flights for each aircraft. For both peak days, two scenarios were created, one for L_{den} and the another for L_{night}.
5. Results and discussion

5.1. Noise exposure of the population around Split Airport

The analysis of the effects of the COVID-19 on noise exposure of population is based on a comparison of the obtained results of the noise contours of that population, i.e., the sum of all residents within the observed area who are exposed to different noise levels. Figure 4 shows L_{den} noise contours on peak days in 2019 and 2020, which represent the noise level for the whole day. On the other hand, Figure 5 shows a comparison of the L_{night} noise contours for the same peak days only for the period during the night. For L_{den}, the lower limit is 40 dB, and the upper limit is 85 dB, while for the L_{night} parameter, the limits are 35 dB and 80 dB.

Due to the COVID-19 pandemic, there were fewer aircraft operations on the 2020 peak day than on the 2019 peak day. A larger difference was expected but considering that the peak day is in the month of August, which represents the heart of the tourist season, a smaller difference in the number of operations is justified. The difference can be seen just by comparing the figures, although it can be seen more clearly in Table 3, where the numbers of residents exposed to different noise levels on the peak days of 2019 and 2020 are shown.

The largest relative change in the number of residents exposed to noise on the peak day of 2019 is manifested in noise levels from 65 dB to 70 dB, where this value decreases by 85.4%. On the other hand, the greatest relative reduction during the night is manifested in the range from 50 dB to 55 dB and reaches a value of 81.5%.

On the peak day of 2019, the number of people highly annoyed was 8,859, and on the peak day of 2020, this number decreased to 7,594. The difference between these values is 1,265 or -14.3%.

On the peak day of 2019, the number of people highly sleep-disturbed was 3,776, and on the peak day of 2020, this number decreased to 1,422. The difference between these values is 2,254 or -62.3%. The large drop in the number of people highly sleep-disturbed is supported by the fact that in 2020 there were significantly fewer night operations. It is also reflected in the comparison of the noise maps for 2019 and 2020. The contour area of aircraft noise during the night on the 2019 peak day is much smaller than the contour area on the 2020 peak day.
Given that the limit values of the permitted noise levels for each zone are known, a comparison was made between the peak day of 2019 and the peak day of 2020 according to the number of inhabitants exposed to noise levels above the limit values. Hereby it is possible to find out if there is a problem that requires implementation of measures related to aircraft noise. It is important to note that the limit values refer to an average day for the whole year, and for this analysis the peak day was taken into consideration. For this reason, it is realistic to expect noise levels to be lower on an average day. Thus, during the peak day in 2019, 16,050 inhabitants were exposed to noise levels above 55 dB, and in 2020, this number was 10,239, which was 36.2% less. During the night in 2019, 34,783 inhabitants were exposed to noise levels above 40 dB, and in 2020, only 17,609 inhabitants, which is 49.4% less.

5.2. Assessment of noise levels at facilities of public importance

For the purposes of noise analysis at facilities of public importance, it is first necessary to choose institutions where people are expected to stay for a long time. These are primarily institutions where specific activities are carried out, such as hospitals, health centers, schools, kindergartens, etc. It is pivotal that such institutions are in areas where the impact of noise is negligible. Therefore, 113 points were chosen, shown in Figure 6. Some of them are Diocletian's Palace, Split Health Center, Faculty of Law, Poljud Stadium, Marjan Park, Petar Berislavić Primary School, Church of John Paul II, Catholic Faculty of Theology. In addition, the noise levels on the peak day of 2019 and the peak day of 2020 at those locations were compared.

The analysis showed that there are many locations that exceed the limit values of the prescribed noise levels. For example, in the Elementary School Bijači Kaštel Novi in 2019, the measured noise level was 60.1 dB, which exceeded the limit value, and in 2020 it was 57.1 dB. This apparent decrease can be attributed solely to the decrease in traffic during the COVID-19, but the noise values measured at that location in 2020 are still not acceptable. Likewise, at the location of Hotel Resnik, the noise level on the peak day in 2019 is 62 dB, and in 2020 it was 58.3 dB. It can be concluded that for some locations near the airport, the noise levels did not become acceptable even during the COVID-19.
6. Conclusion

Aircraft noise, along with the emission of gases from aircraft engines, have a harmful effect on the environment, and various methods are used to reduce their negative effect. Just as they have a bad impact on the environment, they also have a negative impact on humans. This negative influence can be manifested in the psychological and physiological aspects of life. For this reason, various research was initiated in the past that contributed to this area. One of the ways of evaluating the exposure of the population to aircraft noise is to create strategic noise maps. By comparing the strategic noise map of an area of interest and conflicting noise maps, ways of noise reduction can be devised.

For the purposes of analyzing the impact of COVID-19 on the population's exposure to noise in the vicinity of Split airport, the noise contours of the area of interest were developed and the residents affected by aircraft noise have been estimated. Given that there were 212 operations on August 3, 2019, and 171 on August 8, 2020, the decrease in traffic amounts to 19.3%. In summary, analysis of the research results shows that the total population affected by adverse effects of aircraft noise on the peak day of 2020 is significantly lower than on the peak day of 2019 due to the COVID-19 pandemic.

Furthermore, the analysis showed that a certain number of residents lives in settlements that are exposed to noise above the limit values. During the 2019 peak day, 16,050 inhabitants were exposed to noise levels above 55 dB, and in 2020, this number was 10,239, which is 22.7% less. During the night in 2019, 34,783 inhabitants were exposed to noise levels above 40 dB, and in 2020, this number was 17,609, which is 49.4% less. Limit values refer to an average day for the whole year, and for this analysis the peak day was taken into consideration. For this reason, it is expected that the number of inhabitants exposed to unallowed noise levels is lower. Future research can be based on the determination of noise contours based on an average day for the whole year. Also, the actual number of exposed people can be considered due to the large number of tourists in the summer months.

Some European airports invest heavily in research and development activities aimed at reducing the impact of noise on residents living near the airport. Passive measures, such as sound insulation or spatial planning of populated areas, are effective measures that contribute to reducing the noise impact. By involving the community, airports can investigate the problem in more detail. For this reason, it is recommended that the authorities communicate better with citizens by providing live data on flying planes, the measured noise levels, and the health consequences of aircraft noise.
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