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The Impacts of Climate Change on Aircraft Noise Near Airports

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Abstract This paper presents the impacts of climate change on aircraft noise at Chios Airport in Greece. Departure noise contours are generated using the IMPACT assessment tool for the A320 and B737-800 aircraft. Since 1974, observed climate data shows that the average minimum temperature has increased by 0.75°C per decade and the average windspeed has decreased by 2.26 knots per decade. Since 1997, the degraded take-off performance has expanded the 60dB L_{den} noise contour area by up to 4.8%, increasing the population exposure to aircraft noise. Further research about the local climate impact on aircraft noise at busier airports is recommended.

Key Words *Aircraft Noise, Climate Change, Airports, Environment.*

1. Introduction

This paper provides details of the first known study on how climate change has had an impact on aircraft noise close to an airport. Chios Airport in Greece is used as a focus of the study as local historical climate data show that the airport has experienced both an increase in temperatures and a decrease in wind speed since 1974 (Gratton et al. 2020). Both temperature and wind speed are known to impact aircraft performance and vertical trajectories and therefore impact the level of noise experienced by communities living close to the airport. Two short-haul, narrow body jet aircraft, the Airbus A320-232 and Boeing 737-800 are capable of operations at Chios Airport and are used in this study to assess their noise impact.

Since the 1950's, improvements in aircraft and engine technology have significantly reduced the environmental impact of flights. However, in that time, the number of flights has increased dramatically and continues to do so (Lee et al. 2001). The International Air Transport Association (IATA) forecasts, even despite the interruption caused by Covid-19, that over the next two decades, passenger numbers will grow at an annual compound growth rate of 3.7%, doubling the number of passengers from current levels (IATA, 2020). Aviation's contribution to noise and air pollution and long-term climatic variations through the release of greenhouse gases is now widely accepted. Aircraft noise and its impact on communities living close to airports is a major environmental issue. While aircraft have become quieter and cleaner in the last few decades, environmental concerns continue to slow down European airport expansion and EASA (2019) suggests that 60% of the 100 busiest airports in Europe now apply an environmental charge to aircraft operators. In 2012, the European Commission formed the Noise Expert Group which has enabled 'detailed discussions with Member States and stakeholders on environmental noise policy issues.

The issue of aircraft noise is more than just a nuisance to residents. Several published studies have indicated that noise pollution has contributed to a reduced quality of life, poor health and a subsequent increase in the risk of medical conditions. Stansfeld et al. (2005) studied 2,844 children exposed to aircraft noise across three European countries. They concluded that noise from aircraft could impair cognitive development in children, specifically reading comprehension. Hansell et al. (2013) showed statistical evidence that high levels of aircraft noise were associated with increased risks of stroke, coronary heart disease and cardiovascular disease for both hospital admissions and mortality near Heathrow Airport in London. The societal impacts of aircraft noise has led aircraft and engine manufacturers to develop more quieter aircraft and the rate of progress has been rapid. For example, ICAO (2010) highlighted that aircraft then were 15% more fuel-efficient than a decade previous and that noise levels had reduced by more than 90% since jet aircraft were introduced in the 1950s.

In addition to the negative environmental impact of aircraft noise, the aviation industry is also a major contributor to climate change due to various direct and indirect sources of greenhouse gas emissions. The contribution of the industry to climate change has been widely studied over the last few decades. However, recent research studies (Burbidge, 2018; Thompson, 2016) have also highlighted that the aviation industry will need to adapt to the consequences of climate change. Many of the known impacts of climate change on aviation are provided in a review by Ryley et al. (2020). For example, some studies have shown that higher temperatures impact aircraft take-off performance due to increasing take-off distances (Gratton et al. 2020; Coffel et al. 2017). This has a commercial impact on aircraft operators due to the requirement to offload weight, usually payload. In another example, Williams (2017) suggests that the prevalence of clear-air turbulence will increase as the climate changes. This represents a potential increase in safety-related incidents in the future. The purpose of this paper is to build on existing research into the how the changing climate impacts the aviation industry. This study presents results for Chios Airport in Greece showing the changes in aircraft noise exposure for communities living close to the airport since 1974 due to changes in the local climate.

2. Methodology

2.1. IMPACT Noise Assessment Model

Prior to the development of any new or existing airport, there is often a requirement to conduct an environmental impact assessment study. As a result, a number of models and tools have been developed which estimate aircraft noise and emissions at and close to airports. This study makes use of the IMPACT model (version 3.36) developed and maintained by EUROCONTROL which can quantify noise and emissions for a range of commercial aircraft. The IMPACT model is approved for conducting assessments for the Modelling and Database Group (MDG) of the ICAO Committee on Aviation Environmental Protection (CAEP). The model is also compliant with the European Civil Aviation Conference, ECAC Doc 29 detailing the standard method of computing noise contours around civil airports. The model makes use of user-input data such as airport, runway, aircraft type and operator procedure information to construct a vertical, lateral and temporal trajectory of the aircraft for various phases of flight such as departure, climb, cruise, descent and approach. The 4D aircraft trajectory is determined using the Base of Aircraft Data (BADA) aircraft performance model (version 4.2) developed and maintained by EUROCONTROL. The BADA model assumes an aircraft as a point and equates the rate of work done by forces acting on the aircraft to the rate of change in potential and kinetic energy. The propulsive force is used to determine the mass fuel burn and emissions. Further details of the BADA model and an overview of the modelling approach is provided in Nuic et al. (2010). Once a 4D flight trajectory is determined, the Noise Calculation Module (NCM) within IMPACT uses the Aircraft Noise and Performance (ANP) Database (version 2.2) to calculate aircraft noise indices and generates noise contour maps around the airport. Only aircraft noise is simulated, and any background noise from other sources does not contribute to the noise contours. Further details of the IMPACT noise and emissions model is provided in EUROCONTROL (2020). The vertical atmospheric conditions within IMPACT are based on the variations in the International Standard Atmosphere (ISA). The atmospheric parameters at the airport are set by the user for temperature, pressure, relative humidity and headwind component (being the component of total wind resolved parallel with the take-off runway, assuming that an aircraft will always elect to take off into the prevailing wind, or at worst with a 90° crosswind, which would be zero headwind). For the purpose of this study, the relative humidity was set at a model default value of 76.5% for all cases.

2.2. Chios Airport and Local Climate Data

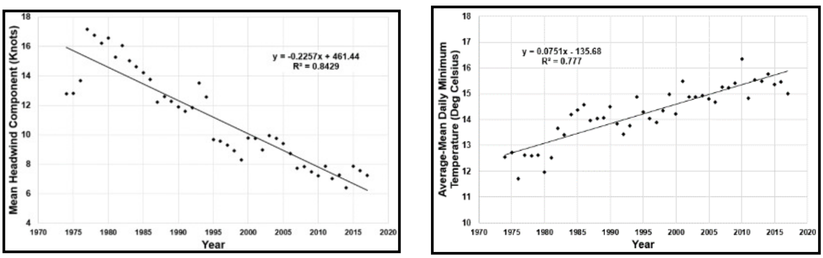
The study was conducted for Chios Airport, on the island of Chios in Greece. Information about the airport including the declared runway distances and the elevations were taken from the Aeronautical Information Services (AIS) documents published by the Hellenic Civil Aviation Authority. A summary of the airport data is provided in Table 1.

Airport ICAO/IATA Code	**LGHI/JKH**
Airport Elevation (metres above mean sea-level)	4.42
Runway Numbers	01/19
Runway Length (m)	1511
Runway Alignment	006°
Runway Slope	0°
Runway 01 Threshold Location	38° 20' 16" N 26° 08' 22" E
Runway 19 Threshold Location	38° 20' 56" N 26° 08' 30" E

Table 1: Chios Airport Data.

Climate data for the airport was determined from historical records from the period 1974 to 2017. The data consisted of the average-mean daily minimum temperature for each year and the mean headwind component (parallel with the runway in use). The lower daily temperature (usually during the night) is used in the study as it is shown to be the best indicator of local climate change (Davy et al. 2017) and has the lowest day-to-day variation (Munasinghe et al. 2012).

Figure 1a and 1b show the trend in the average-mean daily minimum temperature and mean headwind component from the period from 1974 to 2017. For both the trend in temperature and wind presented in Figure 1, the p-values are 0, indicating that the trends are statistically significant. Figure 1a shows that at Chios Airport, the mean daily minimum temperature has on average increased by 0.751 degrees Celsius per decade. In the same period, Figure 1b shows that the mean headwind component has on average decreased by 2.26 knots per decade.



(a) (b)

Figure 1: The trend in (a) average-mean daily minimum temperature and (b) mean headwind component for Chios Airport, Greece from 1974 to 2017.

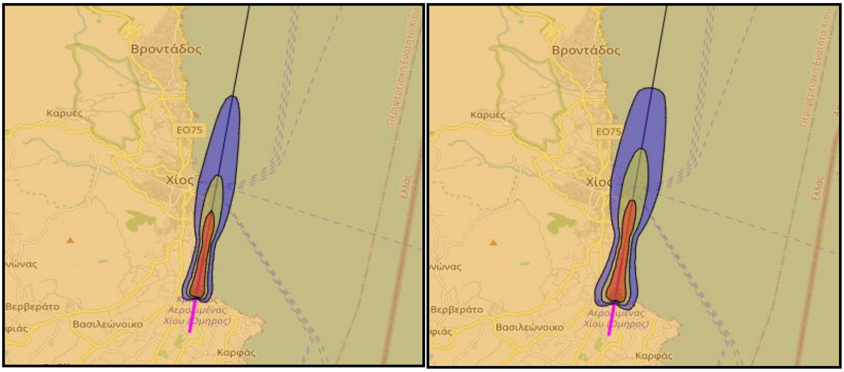
2.3. Aircraft and Departure Procedures

The aircraft chosen for this study were the Airbus A320-232 and Boeing 737-800. Both aircraft are narrow-body aircraft usually operated for short-haul flights. The A320-232 was first certified in 1993 and is fitted with IAE V2527-A5 engines. The Boeing 737-800 conducted its maiden flight in 1997 and is fitted with CFM56-7B engines. Due to the relatively short length of the runway at Chios Airport, both aircraft are unable to take-off at maximum take-off weight (MTOW). Therefore, the maximum permissible take-off weight for mean conditions in the overall period of consideration was used for the study. The aircraft take-off weight is represented in the IMPACT model based on the stage length of the flight with longer stage lengths corresponding to a heavier aircraft. For both aircraft, the stage length of the flight was set at 3500nm. This corresponded to a maximum permissible take-off weight of 77,020kg for the Airbus A320-232 and 76,022kg for the Boeing 737-800 aircraft.

Aircraft operators have adopted their own take-off departure procedures based on environmental, cost and safety considerations. Take-off departure procedures can significantly impact noise on the ground in the vicinity of the airport and therefore, the International Civil Aviation Organisation (ICAO) has established two noise abatement departure procedures (NADP), named NADP1 and NADP2 to minimise noise on the ground. The details of each procedure are outlined in ICAO (2018). NADP1 is used by aircraft operators to minimise noise close to the airport, by climbing quickly to a higher altitude (3000ft) before reducing the climb gradient. NADP2 is used to alleviate noise further afield by climbing relatively slowly early on in the departure before increasing the climb gradient upon reaching 3000ft altitude. For both aircraft, the NADP1 and NADP2 departure procedures were simulated. The study was conducted for departures from runway 01 and 19, with a straight-out departure with no turns. Due to a climb decrement for turning aircraft, the straight-out departure represents the best case scenario for noise levels at ground level and represents a realistic scenario immediately after take-off when aircraft noise levels are at their highest before aircraft begin to follow the Standard Instrument Departure (SID) track.

3. Key Findings

For each simulation run, the noise contour area, in square kilometres, was determined for the L_{den} noise metric, measured in decibels (dB). The L_{den} noise metric is a European standard noise descriptor of noise level based on energy equivalent noise level over a period of 24 hours. The noise level periods are separated into day (07:00 to 19:00 hours local time), evening (19:00 to 23:00 hours) and night (23:00 to 07:00 hours), with a 10dB penalty for night-time noise and a 5dB penalty for evening-time noise. Based on average 2017 traffic levels at Chios Airport, the number of aircraft departures during the day, evening and night was 4, 2 and 0 respectively. The L_{den} noise contour areas were determined at the 50dB, 55dB and 60dB noise levels. Figure 2 shows the noise contour levels for an Airbus A320-232 and a Boeing 737-800 departing from Runway 01 at Chios Airport. Table 2 provides the results of all the simulation runs for 1974 (the earliest climate data available for Chios), 1997 (the earliest year that both aircraft were conducting regular commercial operations) and 2017 (the most recent climate data available for Chios). The noise contour areas are given in square kilometres. The IMPACT modelling tool can also estimate the population contained within each noise contour level, to determine the number of people exposed to a particular noise level. The population data is derived from a population density raster dataset provided by the European Environment Agency (EEA). The dataset is based in the 2001 Census data compiled by Eurostat.



(a) (b)

Figure 2: L_{den} Noise contours for departures from Runway 01 at Chios Airport for (a) an Airbus A320-232 aircraft and (b) a Boeing B737-800 aircraft using NADP2. The contours are based on 2017 temperature and wind data. (50dB – Blue, 55dB – Yellow and 60dB – Red).

For this study, we assume a static population and do not account for changes in population density due to the relocation of residents. According to the Hellenic Statistical Authority (2020), the average permanent population of Chios Island between 1991 and 2017 was 52,952 with a standard deviation of 416. Thus, the population of the island has remained relatively constant during this period and changes in population density are likely to be negligible. Table 2 shows that the noise footprint area of the Boeing 737-800 is larger than that of the Airbus A320-232 aircraft by approximately 61% for NADP1 and 52% for NADP2, under similar scenarios. This is due to different engine types and the better climb performance of the A320-232 aircraft. From 1974 to 2017, the climate data in Figure 1 shows that on average the temperature has increased and the mean headwind component has decreased. Higher temperatures and lower windspeeds reduce the climb performance of aircraft due to a lower true airspeed and lower air density which reduce the lift force and engine performance. The result is a vertical trajectory that is closer to the ground and therefore a larger noise footprint occurs for the same L_{den} noise level. Table 2 shows that for each aircraft and both noise abatement procedures, the noise contour areas at all levels increase from 1974 to 2017. The percentage change in the noise contour areas between the two departure procedures NADP1 and NADP2 is a maximum of 0.69% for the Airbus A320-232 and an average difference of 0.24%. Similarly, for the Boeing 737-800 the maximum percentage difference is 0.24% with an average difference of 0.06%. Thus, it can be concluded that neither considered departure procedure is significantly impacted more or less by the changing climate at Chios Airport. Since 1974, the average noise contour area for L_{den} 60dB would have increased by up to 10.7% for an Airbus A320-232 and by up to 10.3% for a Boeing 737-800 had the aircraft been flying since then. Since 1997, both aircraft have been in regular operation and the noise contour area for L_{den} 60dB has increased by up to 4.8% for an Airbus A320-232 aircraft and up to 4.7% for a Boeing 737-800 aircraft, due to the changing climate. At lower L_{den} levels the minimum increase in noise contour area since 1997 has been 3.1%. Figure 3 shows the percentage change in noise contour areas averaged for both runway departures and noise abatement procedures for each aircraft type. While the Boeing 737-800 has a larger noise footprint area than the Airbus A320-232, the percentage change in noise contour area is slightly higher for the Airbus A320-232 aircraft at all L_{den} noise levels. A clear trend is that the percentage change in noise contour area increases for louder L_{den} noise levels between 1974 and 2017 and 1997 and 2017, though for the latter period the change is approximately half. The increase in the noise contour areas close to the airport due to a changing climate has an inevitable impact on the numbers of people exposed to aircraft noise.

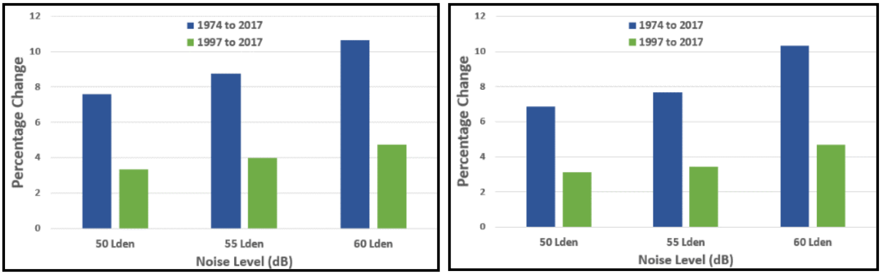
Figure 4 shows the percentage change in the number of people contained within each noise contour level for departures from runway 01 and 19 for the periods 1974 to 2017 and 1997 to 2017. The percentage changes are averaged for aircraft type and the noise abatement departure procedures. Figure 3 and Table 2 show that the area of each L_{den} noise contour increases in all cases with a changing climate. However, this does not always result in an increase in the numbers of people contained within a noise contour. Figure 4 shows that at the 50dB L_{den} noise contour, the population exposed to aircraft noise decreased for runway 01 departures, for the period 1974 to 2017. This is due to the geographic spread of the residential area and its population close to the airport. At Chios Airport, the noise contours resulting for departures from runway 01 are spread across both the land and sea surface. On average the expansion of the noise contour was greater over the sea than the land and therefore less people were contained within this noise level contour. Lower L_{den} noise contours have a greater geographical extent than higher L_{den} noise levels and therefore changes in the number of people exposed to lower L_{den} noise contours noise has a greater dependence on the local geographical spread of the population.

Aircraft Type	Year	Mean Minimum Temperature (Celsius)	Mean Headwind Component (kts)	Noise Abatement Procedure	L_{den} Noise Contour Area (km^2)			Population Contained Within Noise Contour Area		
					50dB	55dB	60dB	50dB	55dB	60dB
Airbus A320-232	1974	12.4	15.9	NADP1	3.83	1.64	0.675	2530	675	38
	1997	14.1	10.7		4.00	1.72	0.714	2520	796	41
	2017	15.6	6.20		4.14	1.79	0.748	2400	795	44
	1974	12.4	15.9	NADP2	4.87	1.68	0.674	2530	676	38
	1997	14.1	10.7		5.06	1.76	0.713	2525	796	41
	2017	15.6	6.20		5.23	1.83	0.746	2400	795	44
Boeing B737-800	1974	12.4	15.9	NADP1	6.20	2.74	1.00	4010	1550	60
	1997	14.1	10.7		6.42	2.85	1.06	3770	1430	61
	2017	15.6	6.20		6.62	2.95	1.11	3640	1420	180
	1974	12.4	15.9	NADP2	7.40	2.84	1.00	4130	1550	60
	1997	14.1	10.7		7.67	2.95	1.06	3770	1430	61
	2017	15.6	6.20		7.91	3.05	1.11	3640	1420	180

Table 2: Noise contour area and population impacted for aircraft departures from Runway 01 at Chios Airport.

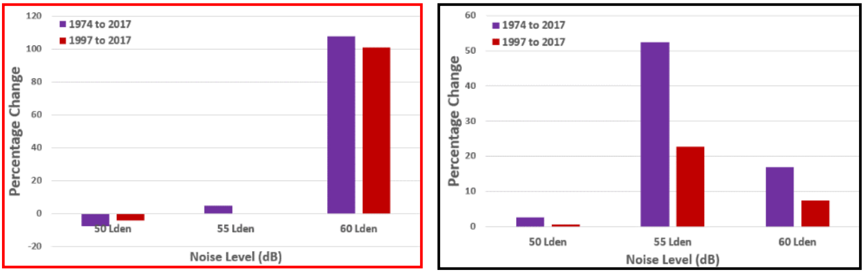
Aircraft Type	Year	Mean Minimum Temperature (Celsius)	Mean Headwind Component (kts)	Noise Abatement Procedure	L_{den} Noise Contour Area (km^2)			Population Contained Within Noise Contour Area		
					50dB	55dB	60dB	50dB	55dB	60dB
Airbus A320-232	1974	12.4	15.9	NADP1	3.83	1.64	0.673	1580	105	30
	1997	14.1	10.7		3.99	1.72	0.710	1640	107	34
	2017	15.6	6.20		4.13	1.78	0.744	1650	158	37
	1974	12.4	15.9	NADP2	4.87	1.68	0.672	1690	107	30
	1997	14.1	10.7		5.06	1.76	0.709	1750	156	34
	2017	15.6	6.20		5.22	1.82	0.743	1760	204	37
Boeing B737-800	1974	12.4	15.9	NADP1	6.19	2.74	1.00	1850	841	48
	1997	14.1	10.7		6.42	2.85	1.06	1870	1210	50
	2017	15.6	6.20		6.62	2.95	1.11	1900	1310	53
	1974	12.4	15.9	NADP2	7.40	2.84	1.00	1970	1170	48
	1997	14.1	10.7		7.67	2.95	1.05	1970	1270	50
	2017	15.6	6.20		7.90	3.05	1.10	1970	1320	53

Table 3: Noise contour area and population impacted for aircraft departures from Runway 19 at Chios Airport.



(a) (b)

Figure 3: Average percentage change in L_{den} noise contour areas from 1974 to 2017 and from 1997 to 2017 for (a) Airbus A320-232 and (b) Boeing 737-800 at Chios Airport.



(a) (b)

Figure 4: Average percentage change in the population exposed to aircraft noise from 1974 to 2017 and from 1997 to 2017 for (a) Runway 01 and (b) Runway 19 departures at Chios Airport.

For runway 19 departures, Figure 4b shows that the number of people contained within all noise level contours increased from 1974 to 2017. For these departures, the noise contours and their expansion due to climate change, are all over land. The largest increases were at the L_{den} 55dB contour level, where on average the population exposed at this noise level increased by 52% and 23% for the period 1974 to 2017 and 1997 to 2017, respectively. For runway 01 departures (Figure 4a), the average increase in population exposure at L_{den} 60dB more than doubled for both time periods, assuming the population remained constant during these periods. In the specific case of a Boeing 737-800 departures from runway 01, the number of people contained within the 60dB L_{den} noise contour increased from 61 to 180 people, in the period 1997 to 2017. This represented a three-fold increase in the population exposed to aircraft noise due to the changing climate.

4. Conclusion

The results of this study show that for the specific case of Chios Airport in Greece, the increase in local temperature and the decrease in local windspeed from 1974 to 2017 has resulted in aircraft trajectories remaining closer to the ground during the departure phase of flight. This in turn has resulted in an expansion of the L_{den} noise contour areas at 50dB, 55dB and 60dB noise levels. Where the expansion of noise contours has been over land occupied by local residents, the numbers of people exposed to higher L_{den} noise levels has increased. In some cases, the population exposure has tripled. Therefore, on average, the changes to the local climate are shown to have an adverse impact on noise levels due to aircraft operations close to an airport. While the results of the present study are only for Chios Airport, it is likely that similar changes in climate at other airports will also have an adverse impact on aircraft noise. Chios Airport is a relatively quiet airport in terms of aircraft traffic and is located in a location with a relatively small population density. At busier airports located in towns and cities with a much greater population density, similar changes in climate in the past and/or future would have a far greater impact on the population. This study has only considered narrow-body, short haul aircraft operations. There would be societal benefits to extend the current research to larger, noisier aircraft operating at major hub airports to assess the impact of noise due to climate change. The current study also emphasises the importance of environmental impact assessment studies for future airport developments to include climate change impacts on aircraft performance and operations and their subsequent impact on local communities.

5. Acknowledgements

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