Citizen Science Study of Overflight Noise from New and Old Generation Aircraft at London City Airport

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Key Points:

- Study finds only modest overflight noise reduction with new generation planes. They were louder in some areas; among the loudest overall.
- Airport stakeholders must convey uncertainties around noise and avoid potentially misleading terms like ‘quieter new generation aircraft’.
- Real-world noise monitoring, both formal and citizen-led, is essential for transparency and trust in airport management and policymaking.

Abstract

This study employs a citizen science methodology to compare the overflight noise of the Embraer E190-E2 with the older Embraer E190 aircraft at London City Airport. The study assesses whether new generation aircraft are quieter in a real-world overflight scenario away from the immediate take-off and landing area. The study uses six monitoring sites, which are an average of 9km from the airport runway and underneath the easterly wind arrivals flight path. The data was gathered using the Explane smartphone app that has a 2dB margin of error. Results from the study indicate a modest 1.7dB noise reduction in new aircraft, with instances of newer models being louder in certain locations and some of the loudest overall. This raises doubts whether a shift towards the new aircraft would create any meaningful reduction in aircraft noise for the communities overflown at London City Airport. It also raises questions about the airport expansion noise models, which are premised on the assumption that the new generation aircraft are significantly quieter. This study argues that airport stakeholders bear the obligation of conveying public environmental information with greater precision and nuance, both in terms of what is established and what remains uncertain concerning noise. They should avoid universalising and potentially misleading phrases like 'cleaner, quieter new generation aircraft.' The study suggests a need for a larger follow-up study of real-life noise monitoring at London City Airport using formal and citizen science methods to foster transparency and trust in airport management and policymaking.

Plain Language Summary

This research is a collaboration between community and professional scientists aimed at exploring if newer planes are quieter than older ones at London City Airport when they fly over houses and not only during take-off or landing as normally measured by the airport. The team used a smartphone app to collect the noise data. Measurements were made at six places not too close to the runway where planes come in from the east. The study found that the newer planes are a little quieter, but sometimes they can be noisier in some spots. The study says the airport should be clearer about what they know and don't know about airplane noise and refrain from using catchy phrases like 'cleaner, quieter new generation aircraft' because they are not always true. There should be another bigger study to keep track of the noise at London City Airport in real-life situations. This study should involve experts and members of the public working together to better understand airplane noise.

1 Introduction

Concerns about aircraft noise affecting public health and wellbeing date back to the early 1960s with the introduction of turbo-jet aircraft where they triggered some of the first studies into aircraft noise impact (Nold, 2017). Over the decades these studies have developed technical metrics that capture the public annoyance and impact of aircraft noise and some of these metrics have been integrated into regulations for planning and operations of airports across the world. This study concentrates on a specific case that contributes to the literature around public noise as well as the application of citizen science to urban studies (Vanoutrive & Huyse, 2023). It examines the introduction of new aircraft models in conjunction with the advent of citizen science technologies, both of which are redefining the relationship between airports, policymakers, and the public.

This study originates from the concerns of four individuals affected by noise from London City Airport (LCA), who posed a straightforward question: Do newer aircraft produce less noise compared to older ones? The research team conducted noise measurements during July and August 2022, as well as September 2023, collecting a total of 291 measurements from six monitoring locations. What distinguishes this investigation is that the citizen researchers gathered the data themselves using a smartphone application while working in collaboration with two scientists who validated the overall research study and its findings. This paper makes two significant contributions. Firstly, it establishes a real-world comparison between the noise generated by new and old-generation aircraft at LCA. Secondly, it serves as an example of citizen science (Haklay, 2013) that is initiated and led by citizens and has direct relevance to policymaking. In this way, the study contributes to discussions about how to govern airport noise using citizen involvement.

1.1 Expansion Plans for City Airport

The context for this study is the proposed expansion of LCA. Although it is a relatively small airport, it is situated within the densely populated part of East London, near two of its financial hubs, and residential areas. In the proposed expansion the airport wants to boost the annual passenger capacity from 6.5 million to 9 million, expand morning and Saturday flights, and remove the existing Saturday flight curfew established in 1986, which currently halts all airport operations at 12:30pm (Fiaz, 2023). The primary point of dispute for residents is the noise impact of these additional Saturday flights and the overall increase of flights.

1.2 The argument of ‘cleaner, quieter, new generation’ aircraft

The proponents for airport expansion argue that one of the key mitigations that will address the noise impact of these increased number of flights is that they will be a new generation of quieter aircraft. In formal planning application documents, the airport argues that “*the accelerated transition to quieter new generation aircraft in the [Development Case] scenario is expected to lead to a reduction in air noise*” (Pell Frischmann, 2022, p. 32). Since its beginning, LCA limited its environmental impact by only allowing specific types of aircrafts to be used. This is also the case in the new application, in this application, LCA refer specifically to the Airbus A220-100 and the Embraer E190-E2 which is a newer version of the Embraer E190. Table 1 is reproduced from the LCA Benefits and Mitigation Statement (London City Airport, 2022a, p. 18).

Aircraft Type	Change in the noise level SEL compared to the Embraer E190, dB (A)	
	Arrivals	Departures
Airbus A220-100	-2.8	-5.1
Airbus A220-300	-2.0	-4.0
Embraer E190-E2	-3.2	-5.4
Embraer E195-E2	-2.9	-4.6

Table 1. The noise of the new generation aircraft compared against the old Embraer E190 - reproduced from the LCA Benefits and Mitigation Statement (London City Airport, 2022a, p. 18).

This reduction of noise is built into the future projections produced by the airport. The LCA Master Plan Noise Assessment Report states that the new planes "*are significantly quieter than the current generation aircraft they replace, particularly on departure. […] Allowances have been made in the production of the noise contours for the expected lower noise levels of these aircraft types*." (Bickerdike Allen Partners, 2020, p. 14). This means the notion that these new aircraft are significantly quieter is already built into the technical noise contours projections produced by the airport to predict how many people will be significantly affected by noise.

The focus on these new aircraft is also a significant part of how LCA communicates the expansion proposal to the public and in policy discussions. In the formal planning application (Pell Frischmann, 2022) and statements by the airport Chief Executive (BlueSky Aviation News, 2021), the aircraft are repeatedly referred to as 'cleaner, quieter new generation aircraft'. The airport's newsletter 'Inside E16' that is used to inform residents about changes at the airport makes the even larger claim that the Embraer E190-E2 *"is 14dB quieter – the quietest single-aisle jet in the world"* (London City Airport, 2019, p. 6).

The starting point for this study is that the four citizen researchers who initiated this research had doubts about the noise reduction claims around these new aircraft. While the airport and aircraft manufacturers suggest the new aircraft are quieter during take-off and landing, there is little information to be found about how loud these aircraft are during normal flight when they are overflying people's homes. Indeed, the airport claims that the aircraft are overall 14dB quieter (London City Airport, 2019, p. 6) seems to contradict the airport's own technical documents which present much smaller figures, see Table 1. The airport have commissioned some ad hoc noise surveys beyond the proximity of the runways (London City Airport, 2022b), yet these do not focus on the new generation aircraft or enable a comparison between the new and old aircraft. For example, the Dulwich study in the south of London, does not include any of the new generation aircraft (Bickerdike Allen Partners, 2018). The absence of clear data to address their research question led the citizen researchers to take matters into their own hands. They decided to conduct their own empirical research to measure the noise of the new aircraft.

1.3 Aircraft Noise and Measurement

It has long been established that environmental noise disturbs sleep (Franssen et al., 2004), increases the onset of cardio disease (Bluhm et al., 2007), impairs the mental health and cognitive ability in children (Lercher et al., 2002), causes psychological distress (Mucci et al., 2020) and disrupts the immune system (Kim et al., 2017). Many authors have studied the impact of aircraft noise in relation to residential areas (Franssen et al., 2004; Hansell et al., 2013; Passchier-Vermeer & Passchier, 2000) and there is an extensive literature about methods of noise mitigation and abatement at airports (Ganic et al., 2016; Licitra et al., 2014). The clear effects of aircraft noise on health, as well as resident annoyance are key considerations when making policy decisions around airport expansion (Fidell, 2003; Suau-Sanchez et al., 2011). Noise data is largely modelled based on the properties of engines and airframes as well as climate and flight paths. These kinds of models require validation using empirical measurement (Filippone et al., 2019). At LCA, there are continuous noise monitoring stations located at either end of the runway as well as near the flyover reference point 6.5 km from start-of-roll (London City Airport, 2017). LCA produces air noise contours annually which are validated by comparing the predicted levels with the noise measured at the airport's noise monitors to make sure the noise contours reflect the noise environment (Bickerdike Allen Partners, 2020). In addition, the airport commissions limited ad hoc aircraft noise surveys that involve moving portable measurement units to target areas beyond the immediate runways (London City Airport, 2022b).

These established procedures of monitoring noise have not changed since the 1970s and have not engaged with the growth of new computational technologies that citizens are comfortable and competent in using every day. While many airports like LCA have procedures for citizen self-reporting of complaints, Fidell argues that noise complaints have been "*difficult to process and systematically compare, largely inaccessible to researchers, and generally awkward to interpret*" (Fidell, 2003, p. 3012). Yet, Fidell argues that the growth in distributed, networked computing devices has made it possible for geographically tagged citizen noise complaints to function as new metrics for resident noise annoyance. With the proliferation of smartphones, citizens now all carry their own "*imager-microphone-wireless-sensor packages*" (Estrin, 2007, p. 3) in their pocket. Radicchi (2017) has identified 28 different apps for measuring noise using smartphones.

1.4 Citizen Science

Citizen science, or the participation of non-professional researchers within a scientific research project (Haklay et al., 2021), has enjoyed a rapid growth of citizen science since the 1990s. Citizen science operates in multiple modes, especially when it comes to the question of leadership and setting the research question. As Shirk et al. (2012) identified, in contributory projects the scientists are setting the research question, while in collegial projects it is the non-professional participants who are leading it, and then verify their results with scientists. The majority of projects are contributory (Land-Zandstra et al., 2021). Beyond this form, Haklay (2013) suggested an extreme citizen science, in which the participants control the whole process, and approach professional scientists only if they feel the need to do so.

The use of community-led forms of citizen science is common in environmental justice issues, where the community is involved in collecting environmental data to have a voice in governance processes (Berti Suman et al., 2023). This is in contrast to the early days of the modern policy response to environmental challenges in the 1970s, where it was assumed that only experts are supposed to create and use environmental information (Haklay, 2016). Over the years, with policy changes such as Principle 10 of the Rio conference in 1992 and the UN Economic Commission for Europe (UNECE) Aarhus convention of 1998, the public gained the right to access environmental information that is held by the authorities. Yet, environmental justice cases demonstrate the urgent need to go further and provide a space for environmental information that is generated by the public. Within these data, noise and air pollution monitoring are two of the largest topics in citizen science and include many examples of both bottom-up and top-down projects (Nold, 2020).

A common concern regarding citizen science revolves around questions of data quality. This concern becomes especially prominent when arguments are raised related to the participants' activism as potentially affecting the credibility of their observations. Substantial research has focused on analysing and quantifying the quality of data gathered through citizen science activities and consistently revealed that citizen science data generated by community members maintains high standards across the spectrum of activities (Balázs et al., 2021; Kosmala et al., 2016). Worries about activism distorting data quality have been shown to be largely unfounded (Davies & Mah, 2020; Kimura, 2019; Ottinger, 2015). Nonetheless, it is crucial for participants to adhere to a detailed and rigorous protocol, accompanied by proper documentation, to ensure the accuracy and impartiality of their observations. Previous studies of citizen noise monitoring have shown that participants are highly focused on research rigour and aim to create high quality data (Nold, 2017; Nold & Francis, 2016). Moreover, the primary objective of citizen science projects focused on environmental justice is typically to inform the relevant authorities and to prompt action based on these findings, rather than replacing official measurements. The goal for citizens is thus ultimately aligned with the governance process in trying to highlight and alleviate environmental harms.

2 Study Design

The citizen research team aimed to determine whether the new Airbus A220-100 and Embraer E190-E2 aircraft produce less noise than old generation aircraft in a real-world overflight scenario away from the runway at LCA. In addition, the study focused on comparing the noise of two generations of the same plane, the older model Embraer E190 with the newer Embraer E190-E2. The citizen research team selected the arrival flightpath at LCA when easterly winds prevailed as their focus.

Due to the study's dependence on smartphones for noise measurement, the study focused on gathering multiple measurements of the same flight to improve accuracy. Consequently, recording the overflights from multiple ground-level monitoring sites was decided upon to aid in the validation of individual measurements. This study design was possible because LCA does not employ a Continuous Descent Approach (CDA) but instead follows a more conventional shelved flightpath where aircraft descend to a low and level altitude for several kilometres before finally descending to land (Eurocontrol, 2011). At LCA this is reinforced by an altitude restriction that prevents LCA planes from interfering with the flightpath of nearby Heathrow Airport, which operates at a higher altitude. Furthermore, the aircraft use Performance-Based Navigation (PBN) to minimise horizontal deviations from a central line to ensure a stable flight path. The flatness and consistency of the flightpath during this shelved segment provide the conditions for measuring and comparing the noise generated by an individual aircraft from multiple ground-level locations.

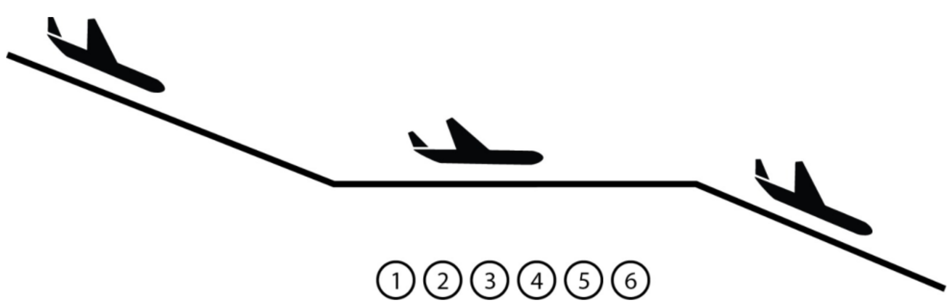

Figure 1. Sideview of the shelved approach flightpath at LCA with the citizen science study monitoring sites (1-6) located underneath the flat segment.

The selection of the volunteers to collect the data was determined by multiple factors. As a prerequisite, these individuals had to live in the shelved section of the arrival flightpath where monitoring sites needed to be established. The volunteers were also required to dedicate their time to data collection, possess an iPhone, and be capable of installing and using the Explane app for taking measurements in the study. Additionally, they needed access to an outdoor area free from noise disruptions, such as traffic, which could interfere with the noise measurements. During an initial briefing session, the team of citizen researchers received comprehensive instructions and support to ensure their familiarity with the function of the Explane app and the correct measurement procedures.

2.1 Methodology & Measurement Protocol

Data collection took place through coordinated team monitoring sessions. These sessions were planned by utilising medium-range weather forecasts to identify periods when easterly wind conditions were expected. The researchers referred to the LCA website to ascertain the anticipated flight arrivals, their scheduled flyover times in the monitoring area, and the aircraft types for each flight. This information was shared with the citizen research team via a dedicated WhatsApp group. In practice, the airport saw only a limited number of new generation aircraft arrivals, usually around two or three per day, primarily originating from Geneva or Zurich during the early morning and early evening hours.

As the time for conducting noise measurements drew near, the team of citizen researchers positioned themselves at their respective monitoring sites and used the FlightRadar and FlightAware aircraft apps to track incoming aircraft as they approached the monitoring zone. The researchers aimed to capture multiple aircraft during each session, with a particular emphasis on recording at least one new generation aircraft.

Figure 2. One of the citizen researchers using the Explane app running on an iPhone. Measurements were taken over 10 seconds with the screen pointing up and the phone held at head height.

As the aircraft approached, the researchers positioned themselves in the centre of the open area, holding their smartphone at head height with the screen facing upward, as illustrated in Figure 2. The measurement process in the Explane app commenced just as the aircraft reached its zenith directly overhead, capturing the maximum noise level during the app's predefined 10-second measurement period. Subsequently, the app transmitted these dBmax measurements to the central Explane repository. Following the monitoring session, each researcher submitted screenshots displaying their own set of data to the team for verification and inclusion in the central study dataset. All the corroborated data was then tabulated in Excel.

2.2 Monitoring Sites

The research team selected six monitoring sites along a 7.8 km section of the easterly wind flight path see Figure 3. Aircraft fly from east to west from Mottingham (SE9) 29km flying distance from landing to Catford (SE6) 26km, and then over the Horniman Museum and gardens (SE23), 22km flying distance from landing. Five of the sites were positioned directly underneath the flight path and one offset by 1km. These sites were fixed so that the altitude of overflights at each site was consistent with minor variation in the angle of overflight from the observer on the ground. Five of the monitoring sites were in private gardens and one in a public park. Postcodes for the sites: Site 1: SE9 3LU, Site 2: SE6 1TD, Site 3: SE6 4EZ, Site 4, SE23 2NN, Site 5: SE23 2QL, Site 6: SE23 3BU.

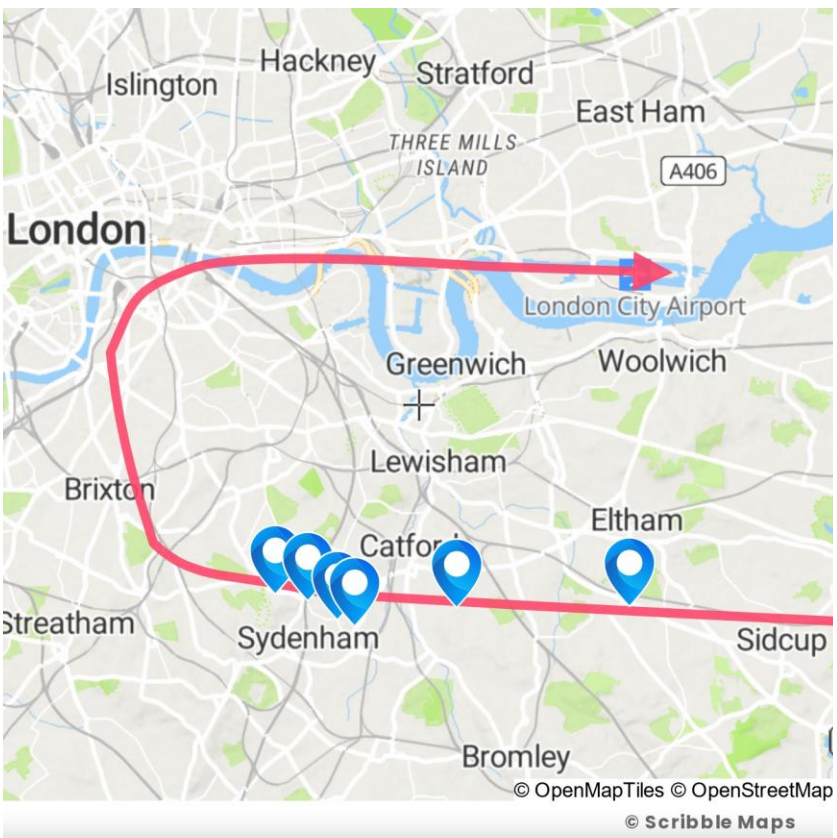

Figure 3. Map of the LCA easterly landing flightpath in red with the six monitoring sites (blue markers) located under the flightpath, 7.5 - 9km from the London City airport runway.

2.3 Monitoring Equipment

The measurements were collected using the freely available Explane noise measurement app, specifically developed for citizen aircraft monitoring in Holland (Explane, 2023b). Explane has been in use for five years since 2018. The app requires access to the smartphone's microphone for measurement purposes as well as the phone’s geographical location and a working internet connection to identify the plane. For the present study, only iPhones were used to create measurements. This is significant because the hardware microphones on these devices are more standardised and tend to be higher quality than on Android phones which use a wide variety of different hardware microphones.

In operation, the Explane app identifies which plane is flying overhead using the Open Sky Network (2023) and then measures for 10 seconds to record the maximum decibel level during this timeframe. When a measurement is complete, the data is uploaded to the central repository where the data is available to publicly view and download (Explane, 2023a). The Explane website provides a page outlining the details of the data it collects (Explane, 2022). It does not describe how the decibel level is calculated and whether any psychoacoustic weighting is being applied to the data. The webpage does not make any claims about the measurement accuracy and displays the sound level as dB using a single decimal point. This lack of specificity is common amongst participatory sensing apps (Nold, 2017). Since Explane is based on a maximum measurement, this study refers to the Explane data as dBmax.

To test the measurement accuracy of the app, the organisation SchipholWatch (2019a) setup a large-scale experiment where hundreds of aircraft measurements were collected with Explane and then compared against the official noise data collected by the Dutch Noise Pollution Foundation (NSG). The study identified that the app data had a maximum ± 2 dB margin of error from the official noise data (SchipholWatch, 2019a, para. 4).

The app’s limitation is that the data it generates cannot be directly compared against existing noise datasets. However, Explane is useful for environmental monitoring in identifying aircraft and creating a relative comparison between the old and new aircraft that were captured using the same app and phone hardware. An analogy might be to say that the app allows us to identify that two children are the same height, but we cannot be certain about how tall they are in centimetres. Explane is powerful in creating relative comparisons between aircraft but there is less certainty about absolute decibel level measurements.

Despite this limitation, the app has been used in relation to other airports in Holland (SchipholWatch, 2019b) and data from a similar app (WideNoise) has been used by the Royal Borough of Windsor & Maidenhead in their submission to the Airports Commission (2013). Studies of the similar NoiseTube app have demonstrated that smartphone apps can be used successfully for environmental monitoring, offering “*concrete proof that participatory techniques, when implemented properly, can achieve the same accuracy as standard noise mapping techniques*” (D’Hondt et al., 2013, p. 681).

According to the Explane website, approximately 550,000 aircraft noise measurements have been recorded in the Netherlands, contributing to a global total of 650,000 measurements. The website states that the app is being used by the Rotterdam city council (SchipholWatch, 2019b) and data has been requested by scientists, as well as the regional Public Health Services and other research institutions. Explane is included in the Dutch National Institute for Public Health and the Environment's 'Samen Geluid Meten' (Measuring Together) program, where Explane is being evaluated alongside other citizen noise monitoring devices (RIVM, 2019).

2.3 Atmospheric Conditions

The measurements for the study were conducted in July and August 2022, as well as September 2023, specifically during arrivals with easterly winds. These monitoring sessions during the summer months were chosen to coincide with extended periods of stable high-pressure systems, resulting in warm and dry conditions. No monitoring was conducted during high wind or rain conditions. Each monitoring session had a maximum duration of 1.5 hours to ensure the stability of atmospheric conditions and enable comparability across the measurements.

2.4 Aircraft Identification

The target aircraft were identified in advance of arrival as described in section 2.1. The Explane app only allows a noise measurement to be created if it can definitively identify the overflying aircraft. The aircraft location and identification details such as flight number and airplane type are taken from the Open Sky Network (2023). If no identification can be made, then the app reports 'No airplane captured' and no decibel data is recorded. To ensure the accuracy of this data, during the study, the Explane readings were cross-checked against the airport's online map-based tracking system TraVis (2023). This ensured that the date and time recorded of each passing aircraft was identified by flight number, which ensured the correct identification of each aircraft.

4 Data

Table 2 provides an overview of the collected data, encompassing a total of 291 data points derived from 193 distinct flights. The primary data collection period spanned from July 21, 2022, to August 13, 2022, with a supplementary data collection session on September 27, 2023. The Embraer E190 emerged as the aircraft most frequently measured during this study which is also the most frequently flown aircraft from the airport (London City Airport, 2022a).

Aircraft	No. Measurements	No. Flights	Average dBmax
Embraer E190	188	131	72.2
Airbus A220-100	44	23	73.7
Embraer E190-E2	27	14	70.5
De Havilland Canada DHC-8	15	11	73.1
ATR 72	7	6	73.8
ATR 42	6	5	72.2
Dassault Falcon 7X	2	1	65.5
Embraer Legacy 450/500	1	1	76.0
Dassault Falcon 900	1	1	62.0
Total	**291**	**193**	

Table 2. Summary of the dataset showing the number of measurements, flights, and average noise level for the different aircraft types.

5 Analysis

The data analysis focused on the three aircraft for which there is the most data available, the Embraer E190, Airbus 220-100 and the Embraer E190-E2. This allows a direct evaluation between the older Embraer E190 and newer Embraer E190-E2 which are directly comparable aircraft with the newer one being claimed to be much quieter.

5.1 The new Embraer E190-E2 is almost as loud as the old Embraer E190 during overflight.

When averaged across all locations, the old Embraer E190 measured 1.7 dBmax louder than the new Embraer E190-E2 during overflights, see Table 3.

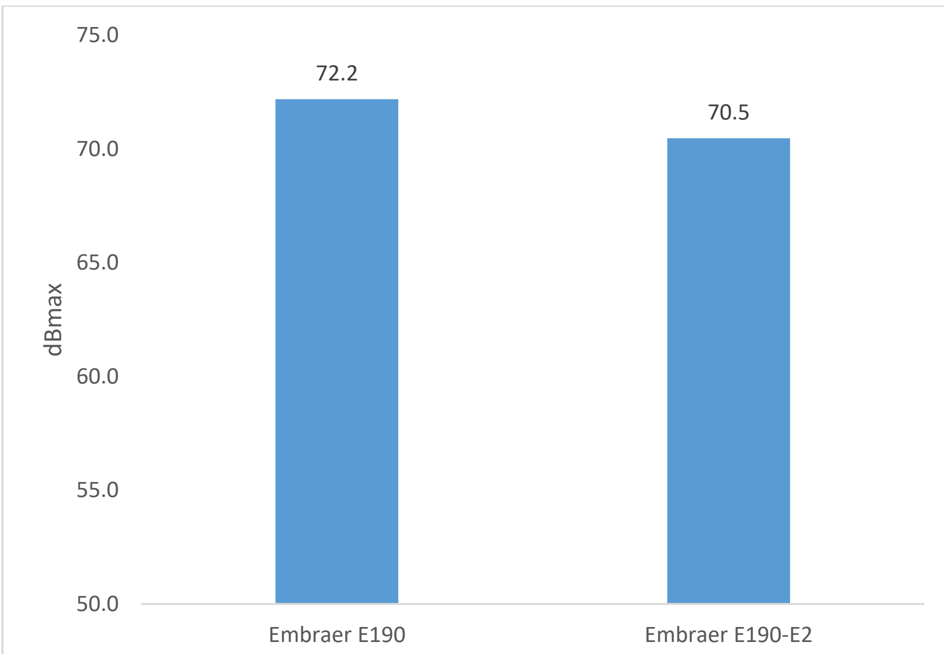

Table 3. Comparison of overflight noise from the old Embraer E190 and the new Embraer E190-E2 averaged across all the monitoring sites.

There are two analytical points to be made. The first point is that this difference is small and might not actually be audible. According to the Civil Aviation Authority's webpage on 'Measuring and modelling noise: How aviation noise can be measured and modelled' "*a change of 3dB has been defined as the minimum perceptible under normal conditions while a change of 10dB corresponds to roughly a doubling or halving of loudness*" (2023, para. 2). This suggests that while 1.7 dB is a measurable difference with a sound level meter, this modest level of difference might not be noticeable to the human ear. The second point is that this 1.7 dB reduction in noise for the Embraer E190-E2 is notably smaller than the airport's claimed reduction of 3.2 dB for arrivals and 5.4 dB for departures, see Table 1 and much lower than their claimed 14dB reduction in noise (London City Airport, 2019, p. 6). Thus, while the new Embraer

E190-E2 may indeed be quieter than the older Embraer E190 during arrivals and departures at the runway, this reduction does not appear to extend to overflight noise, where the ground-level noise impact is similar for the new and old planes.

The importance of this finding lies in the fact that a significantly larger number of individuals are affected by overflights then those few living near to the runways and who are affected by take-off and landing noise. This raises doubts whether the new aircraft would create any meaningful reduction in aircraft noise for most of the communities overflown by LCA aircraft.

5.2 In some locations the new Embraer E190-E2 was louder than the older Embraer E190

An unexpected finding was at a third of the measurement sites, specifically Site 2 and Site 3, the new Embraer E190-E2 aircraft were louder than their older counterparts, see Table 4.

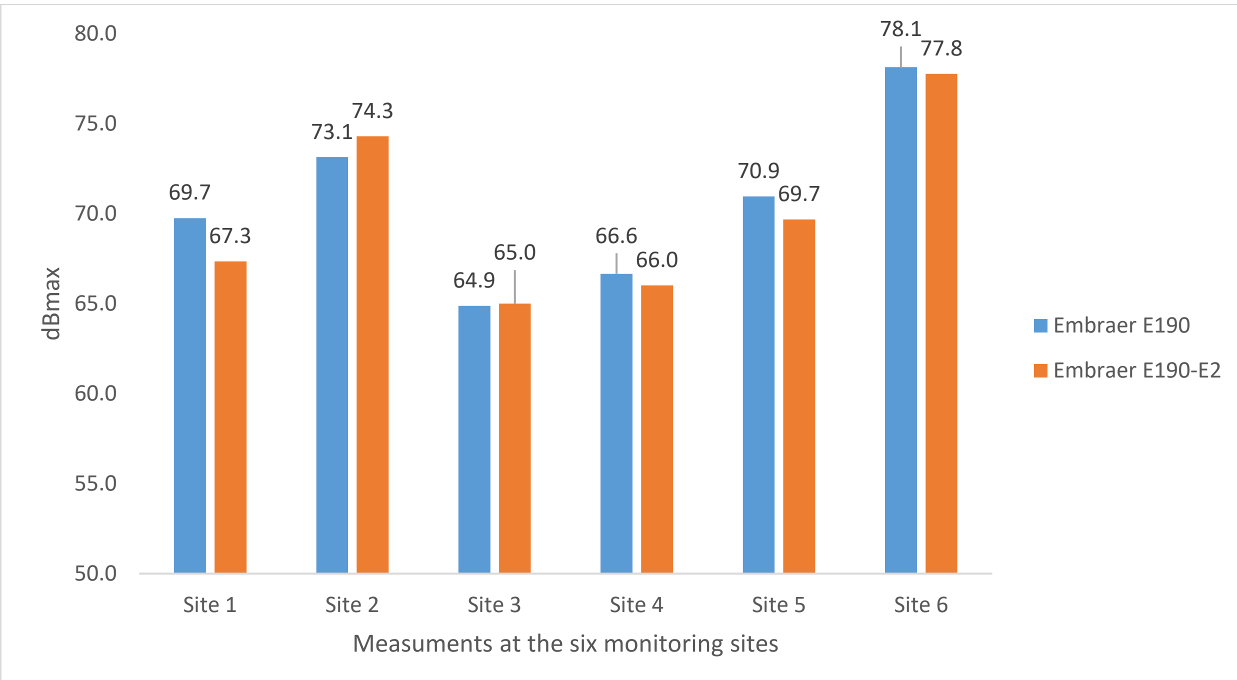

Table 4. Monitoring sites where new generation Embraer E190-E2 were louder than old generation Embraer E190. 3.

Although this variance might stem from factors like user error or ground-level site characteristics, it may be linked to the inherent variability in aircraft noise impacts at ground level, see section 5.4. This observation underscores the minimal noise difference observed between the two Embraer models and the unpredictability of noise measurements in real-life scenarios. Consequently, this observation raises doubts about being able to describe the new Embraer E190-E2 as universally ‘quieter’ than the older Embraer E190.

5.3 The new A220-100 is one of the loudest aircraft overall.

In the dataset the Airbus A220-100 is the third loudest aircraft overall, see Table 5.

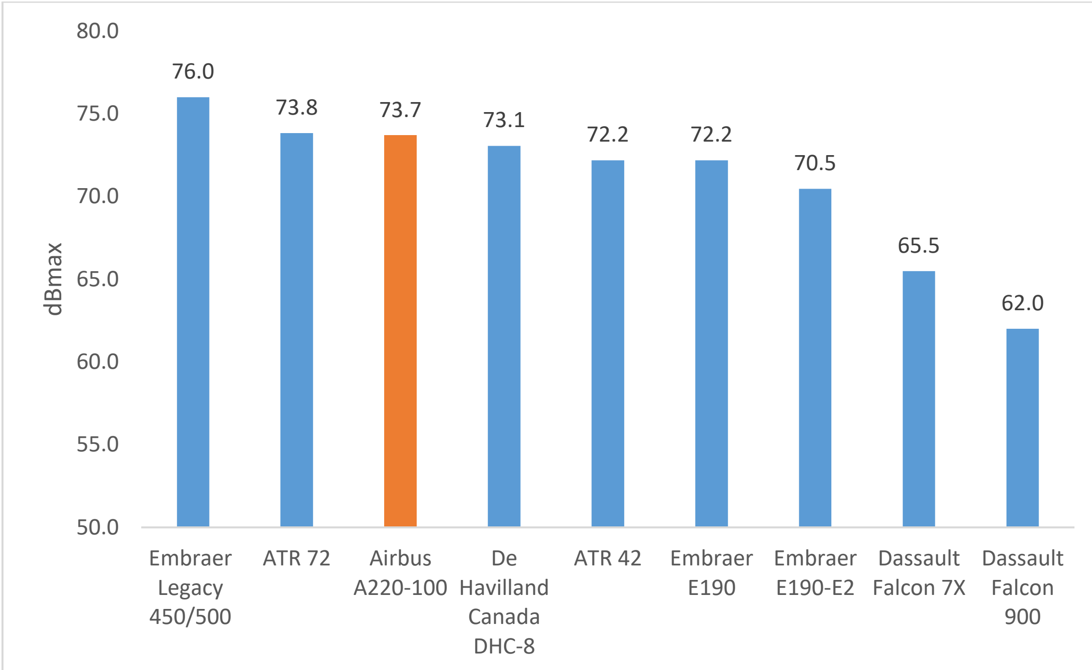

Table 5. Ranking of the noisiest aircraft during overflight. The orange bar is the new generation Airbus A220-100, which is the third loudest aircraft overall.

The data suggests the new generation Airbus A220-100 is louder during overflights than the older Embraer 190. This challenges the data presented by the airport in Table 1, where the Airbus A220-100 is presented as a significantly quieter aircraft than the Embraer 190 during arrival and departure. This data raises questions whether the Airbus A220-100 can be described as a ‘quiet’ aircraft.

5.4 Measurements of the same aircraft vary considerably.

When flights were recorded from multiple monitoring sites, there were often notable discrepancies in the decibel measurements of the same aircraft as it passed overhead. For example, on August 13, 2022, an Airbus A220-100 with the callsign SWR478V, flying at 1653, was measured as 83 dBmax at Site 2 and 69 dBmax at Site 5. This represents a significant 14 dB difference between the highest and lowest measurements. This high level of variation could be attributed to numerous factors, including the possibility of user error or ground-level conditions. Yet, in the Excel spreadsheet, the researcher at site 2 made a note regarding the high 83 dB measurement, mentioning that the aircraft emitted whistling and whale-like sounds. A review of the dataset reveals multiple instances of such notable measurement differences. This is in line with other empirical studies such as Simons and colleagues who identify that “*variability in noise levels for flyovers of the same aircraft type can be as large as 12 dB, hampering noise assessment around airports*” (Simons et al., 2015, p. 1625). The study proposes that variable atmosphere affects the acoustic propagation and variations in the aircraft emitted noise are the two main contributors to this variability. There are many reports from residents (Richard Weiss et al., 2018; Wint, 2018) and airport authorities (Schiphol Airport, 2023) from across the world which acknowledge that the new generation aircraft in particular the Airbus A220-100 generate intermittent loud whistling noises that are highly disturbing. Such intermittent loud noises contribute to the overall noise levels as well as increasing the level of annoyance for residents in the area. In summary, the level of observed variation suggests that there is a significant amount of unpredictability and uncertainty about the nature of the noise impact that an aircraft will generate at a specific ground level site on a given time and day.

6 Limitations

This study has three potential limitations. The first concerns the reliability of the unconventional citizen science method and equipment, the second pertains to the selection of measurement locations, and the third relates to the amount of data collected.

First, this research adopts a citizen science approach and equipment that does not directly align with the data collected by the fixed noise monitors placed near the LCA runway. This study aims to specifically compare the noise generated by new aircraft, like the Embraer E190-E2, with the old aircraft such as the Embraer E190 away from the runway. This study involves taking measurements in locations such as residential gardens that are beyond the reach of existing noise monitoring sites. This study is based on a rigorous study design (section 2), methodology and protocol (section 2.1) and uses a smartphone app that was specifically designed for monitoring aircraft noise (section 2.3). Despite the app’s limitations, it has been used in relation to other airports in Holland where it has contributed to policymaking (SchipholWatch, 2019b) and data from a similar app (WideNoise) has been used by the Royal Borough of Windsor & Maidenhead in their submission to the Airports Commission (2013).

It is the rigorous study design, methodology, analysis, and internal consistency of the data that indicate that this study’s findings are robust. However, like all scientific research, this study should be validated and would benefit from a follow-up study with Class 1 sound level meters that can create data that is directly comparable with the existing noise datasets.

Second, other validation studies like the one conducted by Filippone, Zhang, and Bojdo (2019) utilise measurement microphones positioned only a short flight distance of 8.5 kilometres from the runway. Yet, the rationale of the study presented here is that flight distance does not impact the measurements in this case due to the shelved approach flightpath at LCA which allows the monitoring sites to collect comparable measurements (see section 2). Despite the monitoring sites being situated beyond the LCA noise contour, they are still affected by overflight aircraft noise as evidenced by resident complaints from this area (London City Airport, 2020, p. 15).

Third, it is important to clarify that this study does not aim to definitively determine whether the new planes are universally quieter or louder. Such a study would require a more complex study design and large quantities of data. Instead, the goal of this study is confined to evaluating the noise impact during real-world overflights, specifically away from the runway at LCA. In terms of scope and size, this study is on par with the indicative aircraft noise surveys commissioned by LCA (2022b), which encompass a similar number of flights. The amount of data presented in this study is sufficient to suggest that any difference in noise levels between new and old aircraft during overflight is not very large.

7 Discussion and Conclusions

This study highlights three conclusions: that there is an urgent necessity for a more extensive follow-up study, that there is considerable uncertainty regarding noise impacts at LCA, and that citizen science should be used to support future airport monitoring.

First, this research identifies that the noise level of new and old generation of aircraft at LCA is very similar during overflight. Indeed, at a third of the monitoring sites the new aircraft were louder. This raises doubts whether a shift towards the new aircraft would create any meaningful reduction in aircraft noise for the communities overflown at LCA. It also raises questions about the airport expansion noise models, which are premised on the assumption that the new generation aircraft are significantly quieter (Bickerdike Allen Partners, 2020). The importance of these findings means there is an urgent need to validate the study by setting up a larger formal follow up study using professional noise meters beyond the vicinity of the runway. LCA is aware of the preliminary findings of this study (Walker & Doherty, 2022) and during a LCA Consultative Committee meeting, stated that they "*did not agree with the findings of the report and will provide its own findings"*(London City Airport Consultative Committee, 2022, p. 2). It is a positive step that the airport has engaged with the preliminary findings of this citizen science study, and their commitment to follow up on this issue may be the path towards a study to validate these findings.

Second, this research contends that airport stakeholders bear the obligation of conveying public information with greater precision and nuance, both in terms of what is established and what remains uncertain concerning noise. The level of uncertainty regarding noise grows as one moves farther from the runway and its precise measurement systems. While aircraft may exhibit known characteristics under controlled test conditions, real-world settings include intermittent whale-like noises, unpredictable weather conditions and pilot behaviour introduce a significant level of uncertainty regarding the noise impact experienced at a specific location on a given day. This suggests that airport stakeholders should refrain from employing universalising expressions such as 'cleaner, quieter new generation aircraft', as these phrases can be misleading and fail to adequately convey the real-world impacts experienced by residents.

Finally, this study reconfirms that citizen science can play a significant role in airport monitoring, as was found in previous studies (Berti Suman & van Geenhuizen, 2020; Boussauw & Vanoutrive, 2019; Carton & Ache, 2017; Nold, 2018). Moreover, there are increasing calls to formalise the role of citizen science within environmental decision-making (Berti Suman et al., 2023). The study shows that citizen science methods and tools can address significant policy-relevant research questions that lacked prior datasets, with strong involvement from the affected community. Citizen science can act as a 'canary in the mine' early warning for topics that require urgent investigation by the relevant authorities to assess environmental impacts. At the same time citizen science can complement traditional monitoring methods which lack the granularity of data and local insight that can only be provided by individuals living in the affected areas. Citizen science can make airport operations and noise mitigation more transparent and help to build mutual trust between airport stakeholders and residents and support policy decision making.

CRediT authorship contribution statement

Christian Nold: Conceptualisation, Validation, Formal Analysis, Data Curation, Writing – original draft, Writing – review & editing, Visualisation. **Muki Haklay**: Writing – original draft. **Tim Walker**: Conceptualisation, Methodology, Investigation, Data Curation, Writing – review & editing, Project Administration. **John Doherty**: Conceptualisation, Methodology, Investigation, Data Curation, Writing – review & editing, Project Administration. **Martin Morris**: Investigation. **Gregory Boon**: Investigation.

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This paper extends the preliminary report 'Comparison of maximum noise levels of New Generation and Old Generation aircraft in use at London City Airport – A Citizen Research Study' (Walker & Doherty, 2022).

Open Research

The dataset for this study is available from Open Research Data Online via this link: https://doi.org/10.21954/ou.rd.24453841. The dataset is an Excel file that includes the raw data as well as pivot tables used to generate the diagrams. No registration is required to access the data. The data is under a Creative Commons Attribution 4.0 International licence.

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