On the development of aircraft noise levels from the example of Munich Airport

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The challenge of aircraft noise

The demand for air traffic is unbroken both for passengers and cargo. In many countries, air traffic has already increased above the pre-Covid levels of 2019. However, this growth comes along with aviation's negative impacts on the environment, for instance, aircraft noise.

In the past, while air traffic has strongly grown, aircraft technology has improved, too. A main driver for quieter aircraft were improved aircraft engines. In particular, the increase of the bypass ratio of turbofan engines enabled significantly lower noise emissions.

The question may be posed: How much have noise levels increased along with the increase in air traffic? This paper, from the example of Munich Airport, discusses the long-term development of noise levels from air traffic.

Munich Airport – brief background

In May 1992, Munich Airport opened when it replacing the former Munich-Riem Airport. Munich Airport is located about 28.5 km northeast of Munich. It has two parallel runways in East-West direction.

Over the years, air traffic at Munich Airport has strongly grown. While in 1993, annual passenger numbers were at around 12.0 million, passenger numbers rose to 23.1 Mill. in 2000, 34.7 Mill. in 2010, and 47.9 Mill. in 2019. Annual aircraft movement numbers increased, too, yet at lower rates. While in 1993, aircraft movement numbers were at about 192,000, this number reached about 417,000 in 2019.

Munich Airport – aircraft noise monitoring

Munich Airport operates 16 stationary noise monitoring stations ("noise monitors") in the vicinity of the airport. The positions of the noise monitors as well as flight routes at the airport are shown in Figure 1.

Figure 1: Noise monitoring stations at Munich Airport

Noise measurements follow the DIN 45643 "Measurement and assessment of aircraft sound" [1]. It is to note that DIN 45643 was revised in 2011. Continuous data for the period from 1993 to 2024 is thus restricted to metrics included by the DIN 45643 of 1984 [2].

In the following, two noise metrics are presented. Firstly, the equivalent continuous sound pressure level $L_{eq(4)}$ is used according to DIN 45643 of 1984. Note that for the $L_{eq(4)}$ a doubling of the number of sound events corresponds to an increase of 4 dB. Secondly, a number above threshold (NAT) criterion is presented: the number of noise events above 80.5 dB(A). For this, the AS-weighted maximum sound pressure level $L_{p,AS,max}$ is applied.

Results - equivalent continuous sound levels

The $L_{eq(4)}$ for the noise monitor "Schwaig" and years from 1993 to 2024 is given in Figure 2. The noise monitor is located to the East of the airport close to its Southern runway. Due to its proximity, "Schwaig" typically is the noise monitor with highest noise levels of all 16 noise monitors. Arrivals to and departures from the Southern runway are relevant.

As seen from Figure 2, at "Schwaig" the $L_{eq(4)}$ shows a slightly increasing trend from the exception of the Covid-hit years 2020 and 2021. With the level of 1994 as basis (59 dB(A)), the long-term increase is about 2 dB until 2019 (61 dB(A)). During this period, aircraft movement numbers more than doubled, as depicted in blue, and passenger numbers almost quadrupled, as shown in purple (see Figure 2).

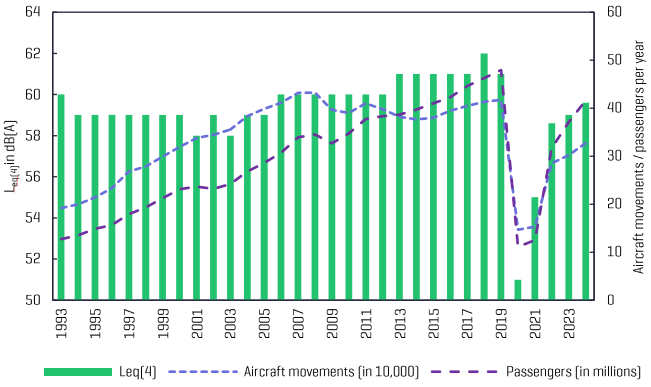

Figure 2: Equivalent continuous sound level $L_{eq(4)}$ at noise monitor "Schwaig" compared to passenger and aircraft movement numbers

Another example is given by the noise monitor "Eitting" in Figure 3. "Eitting" lies farther to the East of the airport. Arrivals and departures from both the Southern and the Northern runway are relevant. Compared to "Schwaig" lower noise levels are monitored. Similarly, the $L_{eq(4)}$ shows a slightly increasing trend. With the level of 1994 as basis

(54 dB(A)), the long-term increase is about 2 dB until 2019 (56 dB(A)).

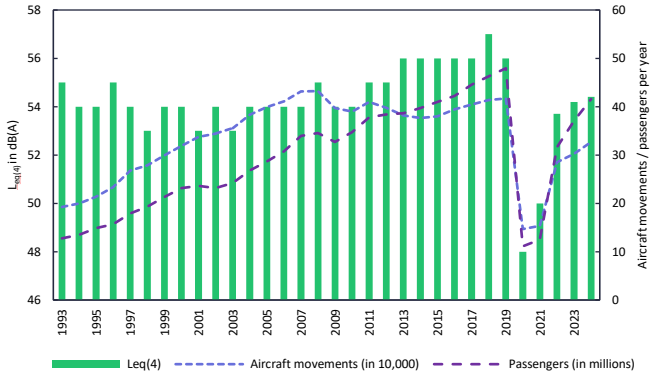

Figure 3: Equivalent continuous sound level $L_{eq(4)}$ at noise monitor "Eitting" compared to passenger and aircraft movement numbers

How did noise levels develop elsewhere? At some noise monitors, the $L_{eq(4)}$ shows an increasing trend. The highest increase is found at noise monitor "Asenkofen" with an increase in $L_{eq(4)}$ of about +6 dB (2019 vs. 1993). At some noise monitors, the $L_{eq(4)}$ remained at a similar level (2019 vs. 1993), for example at "Hallbergmoos". At some noise monitors, the $L_{eq(4)}$ shows a decreasing trend, the strongest found at "Neufahrn" with about -2 dB (2019 vs. 1993). Different trends at different noise monitors result, amongst others, from different flight route distributions and from the influence of the operational direction (West vs. East).

Our first conclusion is: aircraft movement numbers, as mentioned, more than doubled between 1993 and 2019. Rather than increasing by 4 dB or more, the observed increases in $L_{eq(4)}$ are significantly lower. In other words: the equivalent continuous sound level development is decoupled from the air traffic growth.

Results - number of events above 80.5 dB(A)

In the following, the number of noise events above $L_{p,AS,max}$ = 80.5 dB(A) are shown. Figure 4 presents noise events from 80.5 dB(A) to 85.5 dB(A) in light green, from 85.5 dB(A) to 90.5 dB(A) in medium green, noise events above 90.5 dB(A) in dark green. Considered are noise events at the 14 noise monitors that existed during the entire period from 1993 to 2024. Noise monitors "Asenkofen" and "Pallhausen" (see Figure 1) are not considered as they were only installed after 1993.

As seen in Figure 4, in 1993 more than 18,000 maximum noise levels above 80.5 dB(A) were detected. Numbers significantly decreased during the 1990s. For the year 2019 a 55% reduction of maximum noise levels above 80.5 dB(A) is found (vs. 1993). By 2024, the reduction is at 69% (vs. 1993).

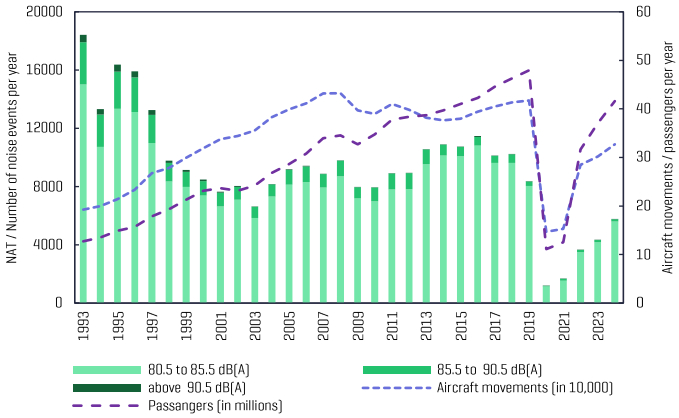

Figure 4: Number of maximum sound levels above 80.5 dB(A) at Munich Airport compared to passenger and aircraft movement numbers

Accordingly, Figure 5 shows the number of noise events above $L_{p,AS,max}$ = 90.5 dB(A). Here, the decreasing trend is even more distinctive: In the early 1990s, almost 500 maximum noise levels per year were monitored. Then, numbers rapidly decreased to less than 100 maximum noise levels by 2001, and 25 or less from 2017. A 98% reduction of maximum noise levels above 90.5 dB(A) is found for the year 2019 (vs. 1993). By 2024, the reduction is at even 99% (vs. 1993).

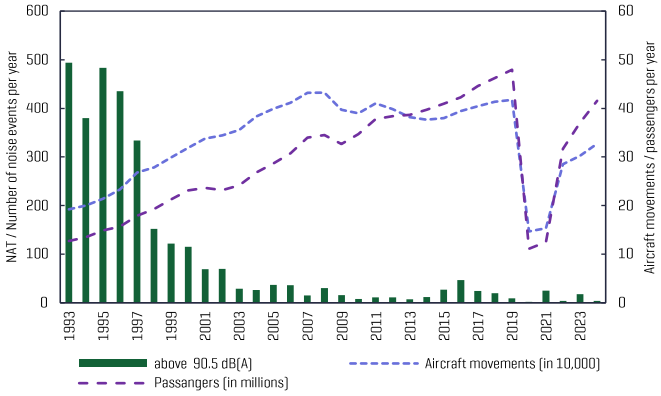

Figure 5: Number of maximum sound levels above 90.5 dB(A) at Munich Airport compared to passenger and aircraft movement numbers

Our second conclusion is: while in the past three decades aircraft movement numbers significantly increased, the number of noise events above 80.5 dB(A) significantly decreased. The number of noise events above 90.5 dB(A) decreased strongly.

The (missing) link between increasing air traffic and the found developments in noise levels is technology: the development of improved aircraft and engines by manufactures and their introduction into aircraft operators' fleets - as detailed in the following.

Aircraft fleet renewal process

Aircraft operators generally do not abruptly change their fleets. Rather, fleet renewal is a slow, continuous process.

As civil aircraft easily operate for 25 years, it may take long until an aircraft type has gained significant shares of the fleet. Two examples are presented in the following.

Firstly, as short-haul aircraft, the model Boeing B737: The Boeing B737-200, introduced by Boeing as soon as 1968, is of the first generation of the B737 series. Three decades later, in 1997, the Boeing B737-800 was introduced as part of the B737 "Next Generation" models. Significant noise reductions were realised with the B737-800. While the B737-200 engines' bypass ratio was at about 1.7:1, bypass ratio is at about 5:1 for the engines of the B737-800.

Figure 6 illustrates the share of the B737-200 (in blue) and of the B737-800 (in green) of all aircraft movements at Munich Airport. While the share of the B737-200 was at 8% in 1993 it rapidly decreased in following years (see Figure 6). On the other hand, the share of the B737-800 continuously increased up to a share of 7% in 2014.

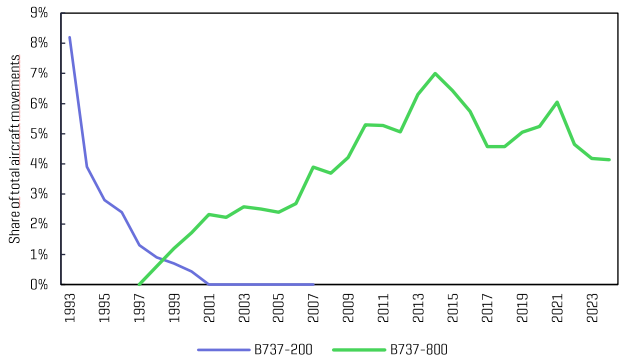

Figure 6: Share of Boeing B737-200 and Boeing B737-800 movements of all aircraft movements at Munich Airport

As second example, the long-haul aircraft models Airbus A340 and A350: The A340, with its characteristic four jet engines (bypass ratio at 6:1 to 7.5:1), was introduced by Airbus in 1993. Its successor, the A350, entered service in 2015. Again, significant noise reductions were realised with the A350 having only two jet engines (bypass ratio about 9:1).

Figure 7 illustrates the share of the A340 (in blue) and of the A350 (in green) of all aircraft movements at Munich Airport. As seen, when the newer A350 gained shares at Munich Airport, according shares of the older A340 fell.

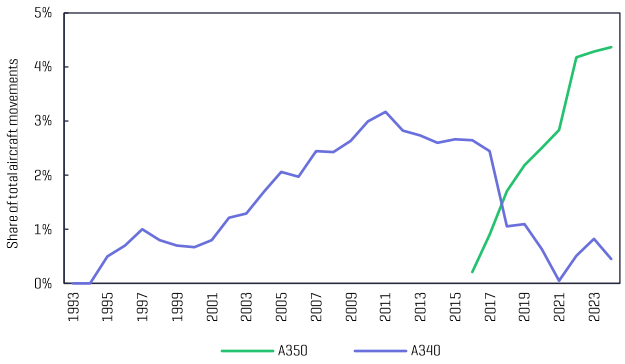

Figure 7: Share of Airbus A340 and Airbus A350 movements of all aircraft movements at Munich Airport

Summary and conclusion

To sum up: At Munich Airport, in the past three decades aircraft movement numbers strongly grew. However, noise did not. From 1993 to 2019, while aircraft movements more than doubled (+117%), the development of the equivalent continuous sound level decoupled from air traffic growth. At some noise monitors, the $L_{eq(4)}$ showed an increasing, at some monitors a decreasing trend, at some monitors it remained at a similar level.

The number of noise events above 80.5 dB(A) developed contrary to the growth in air traffic: while aircraft movements more than doubled from 1993 to 2019 the number of noise events above 80.5 dB(A) decreased by 55%, from 1993 to 2024 by 69%. For noise events above 90.5 dB(A) reductions are even stronger: from 1993 to 2019 a minus of 98% is found, from 1993 to 2024 of 99%.

If we stated a theoretical "noise per passenger" criteria, the development would be even more favourable: From 1993 to 2019 passenger numbers at Munich Airport almost quadrupled (+299%) as more passengers per aircraft were carried.

Main driver for noise reductions are improved aircraft and engine technology and the subsequent aircraft fleet renewal process.

The developments at Munich Airport align with published data from other airports. It is to expect that the observed trends are similarly applicable to other German and European airports as aircraft also operate elsewhere.

Literature

[1] Deutsches Institut für Normung e. V.: DIN 45643. Messung und Beurteilung von Fluggeräuschen (2011), Beuth Verlag GmbH, Berlin, Deutschland

[2] Deutsches Institut für Normung e. V.: DIN 45643. Messung und Beurteilung von Flugzeuggeräuschen (1984), Beuth Verlag GmbH, Berlin, Deutschland