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# Noise points as an instrument to measure (and limit) noise exposure – empirical findings from Europe 2015-2020

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**Abstract**

Aircraft noise is the biggest environmental problem around airports, as it has a negative impact on the health of local residents. Therefore, aircraft noise is an important constraint in airport development. Residents' concerns can lead to restrictions on airport capacity, as in the recent case of Amsterdam Schiphol. At this airport, a reduction/limitation of aircraft movements was chosen as a policy instrument to reduce noise impact. Such an approach can be criticized from the point of views of economic efficiency and noise impact among others, as only the number of aircraft movements is taken into account and neither different noise levels nor departure/approach times are not considered. However, the latter parameters also have a significant noise impact, e.g. the different noise levels caused by different types of aircraft. Furthermore, airlines have no advantage in using modern, quieter aircraft or avoiding evening or night for operations if only the number of movements are considered in a regulatory policy. In the worst case such simple restrictions can even have negative impacts on the health of local residents. In this paper, the authors present an alternative approach in which the noise impact at an airport is quantified by different noise point systems. The idea of such systems is similar to the quota count used for London airports at night. Two different options for calculating noise points are presented. The noise point systems are applied to available data of aircraft movements at European airports for the period 2015-2020. Due to the current relevance for aviation policy, a special focus is placed on Amsterdam Schiphol in the analysis and discussion. Based on empirical data, it can be shown that decoupling noise impact from the number of aircraft movements is possible for major European airports, even in a relatively limited time frame. Furthermore, noise point systems could not only be used for noise monitoring, but also as a regulatory tool that ensures the limitation (or even reduction) of noise impact while allowing for a more sustainable growth of the air transport system. From the point of view of noise impact and economic efficiency, such an approach is preferable to a restriction of aircraft movements.

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*Keywords:* Aircraft noise; airport regulation; noise quota; environmental policy

## 1. Introduction

Aircraft noise is a major concern of residents in the vicinity of airports when it comes to the development of the aviation system. Various instruments to reduce aircraft noise, are summarized by the ICAO in the balanced approach to aircraft noise management (International Civil Aviation Organization, 2010). Aircraft noise emissions are also regulated at source with certification standards of aircraft. In 2014, the ICAO Council adopted noise regulations of Annex 16, Vol I, Chapter 14 for civil transport aircraft certified after 31$^{st}$ December 2017 (International Civil Aviation Organization, 2017). Although aircraft cause noise emissions, for which the respective operators are responsible, airports are the focus of criticism from local residents. Hence, various measures are implemented by airport operators. These also include noise-related airport charges, which are intended to provide aircraft operators incentives to use state-of-the-art technology and to protect residents especially during the most sensitive night time.

Limits on aircraft movements are repeatedly discussed as an instrument to reduce the negative externalities of air transport. Most recently, the Dutch government's plan to limit the number of annual aircraft movements at Amsterdam Schiphol to 460,000 per year from the winter season 2023/2024 caused a substantial turmoil in the aviation industry. The cut represents a reduction of 8 % of movements from pre-Corona pandemic levels. A further reduction to 440,000 movements is planned, which represents a reduction 12 % from pre-Corona levels and 20 % from earlier development plans (Dunn, 2023). The aviation industry is reacting extremely negatively to the Dutch government's plans, citing continuing efforts to reduce aircraft noise and announced legal action against the proposal (IATA, 2023). The restriction of air traffic not only affects the interests of airlines, airports and residents, but also has far-reaching economic effects, as connectivity is affected, as well as employment in the aviation industry and other industry depending on air transport connections.

In this paper, the authors propose an alternative approach to a simple aircraft movement cap, as in the case of Amsterdam Schiphol. The leading research questions to be answered are:

- Which options exist to quantify aircraft noise and to transform them into a noise point scheme?
- What is the historical trend of aircraft noise, when the noise point system is applied to actual flight movements at European airports?
- What are the implications of the findings for regulatory policy?

The paper is structured as follows: The current literature on instruments regulating aircraft noise is summarized in a brief overview. Then, the methods for different noise point systems are presented. Subsequently, the noise point schemes are applied to actual flight movements at European airports. The paper closes with a discussion of the implications of the findings for regulatory policy.

## 2. Literature Review

The reduction of aircraft noise and its impacts is a major element of environmental economic research in air transport. Within ICAO's balanced approach, noise reduction strategies have multiple ramifications, such as reduction at source, operational restrictions, land-use planning and operational procedures (Ehmer et al., 2012).

The literature review under the scope of this paper concentrates on the potential design options and economic effects of noise caps and tradeable noise permits.

The introduction of tradeable noise permits has been proposed as early as 1999, where Fichert (1999) pointed out that a limitation on the noise quantity could be calculated by using the equivalent continuous sound level Leq as outlined in the German airport noise regulations. Then it is possible to calculate to what extent each aircraft movement contributes to the Leq. Hence, the contribution of each individual aircraft movement to the overall sound level can be estimated and transferred into tradeable permits.

Wadud and Gühnemann (2016) compare carbon and noise trading. Local particularities and the non-linear nature of noise pose significant challenges in a design for a noise trading scheme, as compared to carbon trading. Moreover, the authors emphasize that noise is a particular issue at hub airports, characterized by high market shares and corresponding market power of local network carriers, which will influence market conduct in terms of supply and prices. This observation is well founded. It seems reasonable to expect that a noise certificate market at capacity constrained airports could operate in a similar way to secondary slot trading. At Heathrow Airport, as the best example of a hub airport with airport capacity constraints where slot trading is allowed, airlines are only inclined to sell slots when in significant financial distress in many cases.

Bréchet and Picard (2007) criticize traditional command-and-control approaches that impose restrictions on aircraft movements. They also criticize financial instruments (e.g. noise charges) that neither quantify nor take into account real aircraft noise for residents. The authors' alternative approach consists a noise trading scheme, allowing residents to set both the quantity of permits and receive the revenues of selling the permits to airlines.

Noise points proposed in this study are based on a similar idea as the Quota Count (QC) system at the London airports. This Quota Count has been in operation at Heathrow, Gatwick and Stansted since 1993 to limit night-time noise (Civil Aviation Authority, 2020). The presented noise point systems include the latest aircraft types, but do not entail tradeable noise permits.

## 3. Methodology & Data

### *3.1. Noise point calculation*

Depending on the purpose to be pursued with the introduction ofnoise points, there are different ways to define noise points. The individual flights can be differentiated separately or combined into aircraft versions, aircraft types or aircraft groups to calculate noise points. Another definition criterion are the sound parameters on which noise points are to be based, e.g.: maximum sound level, single event level (SEL) or certification level. If necessary, further weightings can be included into the definition. Surcharges for certain times of day, for example, can be included in the definition. Since an aircraft always takes off and lands at an airport, the noise points for take-off and landing can basically be combined into one noise point. Because take-offs and landings can take place at different times, a separation is preferable for time-of-day weightings.

Finally, it must be cleared whether the noise points are to be based on calculations or on measurements. If noise points are to be defined locally for an airport, measured levels at the aircraft noise monitoring stations are more suitable, while calculated contour areas are more suitable for a global definition.

In this study two possible definitions of noise points are examined: The first definition is based on area equivalents (Schmid et al., 2023). An area equivalent $A_n$ is the quotient of the contour area of an aircraft $F_n$ in relation to the contour area of a reference aircraft $F_{ref}$, i.e.

$$A_n = \frac{F_n}{F_{ref}} \tag{1}$$

Instead of an aircraft or reference aircraft, groups of aircraft can also be used. By nature, contour surfaces are determined by calculations.

The second possible definition is based on flight movement equivalents: A movement equivalent $B_n$ corresponds to the number of movements of the reference aircraft type causing the same noise immission as one movement of the respective aircraft type, i.e.

$$B_n = 2^{(L_n - L_{ref})/q} \tag{2}$$

with q as the doubling parameter (bisection parameter). The levels $L_n$ or $L_{ref}$ can be derived from immission points as well as from contour surfaces (Blinstrub et al., 2021). For energy equivalence $q = 3$, two movements of one aircraft type are equivalent to one movement of a type that is 3 dB louder.

The noise calculations of this study were carried out using the DLR software tool AZBPLUS (Blinstrub et al., 2021), which is based on the calculation rules for noise calculations in the "Instructions for the Calculation of Noise

Abatement Areas" (AzB) (The Federal Minister for the Environment, Nature Conservation and Nuclear Safety, 2008). Table 1 summarizes the key characteristics of the noise calculation in this study.

Table 1. Key characteristics of noise point calculation

| Characteristic | Area equivalence | Movement equivalence |
|---|---|---|
| Noise level estimation | calculated | calculated |
| Aircraft grouping | proposed AzB21 aircraft groups (Blinstrub et al., 2021) | proposed AzB21 aircraft groups (Blinstrub et al., 2021) |
| Temporal resolution | unweighted and weighted time slices | unweighted and weighted time slices |
| Parameter | area of SEL 90 dB contours | average of SEL (Immission points in a distance of 10, 15 and 20 km below the flight path) |
| Doubling parameter q | n.a. | 3 |

Table 2 shows the resulting unweighted noise points for the proposed aircraft grouping according to AzB21 (Blinstrub et al., 2021; The Federal Minister for the Environment, Nature Conservation and Nuclear Safety, 2021) used in this study. The reference group is S3_M130_T2_N7 (representative aircraft type e.g. Airbus A320), which is given the value 1.

Between 2015 and 2019, 60 % of all movements at many European airports were carried out with aircraft from the S3_M130_T2_N7 aircraft group. Therefore, this aircraft group is the dominant one for the noise impact (Schmid et al., 2023). For this aircraft category, the number of aircraft movements is of the same order of magnitude as the sum of the noise points. If more aircraft quieter than in group S3_M130_T2_N7 are used, the sum of the noise points will be lower than the number of flight movements. Conversely, if more aircraft louder than in group S3_M130_T2_N7 are used, the sum of the noise points will be higher than the number of flight movements.

Table 2. Unweighted noise points by aircraft class, reference group is the S3_M130_T2_N7

| Aircraft class | Propulsion Type | No. of engines | Bypass ratio | MTOM Class | Noise Certification | Typical aircraft | Noise points $A_n$ Area equivalence | Noise points $B_n$ Movement equivalence |
|---|---|---|---|---|---|---|---|---|
| P3_M015_TU | Propeller | n.a. | n.a. | 5.7t-15t | Chapter 3, 4 or 10 | Dornier Do 228 | 0.1 | 0.2 |
| P3_MXXX_TU | Propeller | n.a. | n.a. | >15t | Chapter 3, 4 or 10 | ATR 72 | 0.3 | 0.4 |
| S3_M020_TU_NU | Jet | n.a. | n.a. | <20t | Chapter 3 or higher | Cessna Citation | 0.3 | 0.2 |
| S3_M050_TU_N7 | Jet | n.a. | 2-7 | 20t-50t | Chapter 3 or higher | Bombardier CRJ | 0.5 | 0.5 |
| S3_M050_TU_NX | Jet | n.a. | >7 | 20t-50t | Chapter 3 or higher | Embraer E175-E2 | 0.3 | 0.3 |
| S3_M070_TU_N7 | Jet | n.a. | 2-7 | 50t-70t | Chapter 3 or higher | Embraer E190 | 0.9 | 0.8 |
| S3_M070_TU_NX | Jet | n.a. | >7 | 50t-70t | Chapter 3 or higher | Embraer E190-E2 | 0.4 | 0.5 |
| S3_M100_TU_N2 | Jet | n.a. | <2 | <100t | Chapter 3 or higher | MD-82/83 | 3.7 | 3.2 |
| S3_M130_T2_N7 | Jet | 2 | 2-7 | 70t-130t | Chapter 3 or higher | Airbus A320ceo | 1.0 | 1.0 |
| S3_M130_T2_NX | Jet | 2 | >7 | 70t-130t | Chapter 3 or higher | Airbus A320neo | 0.6 | 0.6 |
| S3_M220_T2_N7 | Jet | 2 | 2-7 | 130t-220t | Chapter 3 or higher | Boeing 767 | 2.0 | 1.8 |
| S3_M320_T2_N7 | Jet | 2 | 2-7 | 220t-320t | Chapter 3 or higher | Airbus A330 | 2.2 | 2.4 |
| S3_M320_T2_NX | Jet | 2 | >7 | 220t-320t | Chapter 3 or higher | Airbus A350 | 1.0 | 1.2 |
| S3_M500_T2_NX | Jet | 2 | >7 | 320t-500t | Chapter 3 or higher | Boeing 777-300ER | 1.9 | 2.2 |
| S3_M320_T3_N7 | Jet | 3 | 2-7 | 220t-320t | Chapter 3 or higher | MD 11 | 4.1 | 4.9 |
| S3_M320_T4_N7 | Jet | 4 | 2-7 | 220t-320t | Chapter 3 or higher | Airbus A340-300 | 3.1 | 5.2 |
| S3_M500_T4_N7 | Jet | 4 | 2-7 | 320t-500t | Chapter 3 or higher | Boeing 747-400 | 6.0 | 8.4 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| S3_M500_T4_NX | Jet | 4 | >7 | 320t-500t | Chapter 3 or higher | Boeing 747-8 | 4.4 | 6.5 |
| S3_MXXX_T4_NX | Jet | 4 | >7 | >500t | Chapter 3 or higher | Airbus A380 | 2.9 | 4.7 |

In order to achieve a better representation of, firstly, the different perception and, secondly, impacts of noise emitted during different times of day, an additional weighting for both noise point methods can be applied. The calculation follows the methodology published in the Federal Immission Control Act (Federal Government, 2006) for the calculation of the day/evening/night noise index LDEN. Noise emitted during the day (from 6:00 to 18:00 local time) is considered without a weighting factor, while noise emitted during the evening (18:00 to 22:00 local time) is weighted with a factor of 3.16 (corresponds to a level addition of 5 dB) and noise emitted during the night (22:00 to 6:00 local time) is weighted with a factor of 10 (corresponds to a level addition of 10 dB). The weighting factors of 1, 3.16 and 10 have been applied for the noise point system accordingly, so that a Boeing 747-400 taking off during daytime, for example, requires 6 noise points in the system An (area equivalence) or 8.4 noise points in the system Bn (movement equivalence), while in the evening the required noise points increase to 19 in system An and 26.6 in system Bn. For a take-off during nighttime noise points required increase to 60 in system An and 84 in system Bn, respectively.

### *3.2. Aircraft movement data*

The EUROCONTROL R&D Data Set was selected as the data source for aircraft movements at airports in Europe (EUROCONTROL, 2023). The data set contains the IFR aircraft movements by aircraft type (ICAO Aircraft Identifier Code) with actual off-block times at all airports in the EUROCONTROL area for four sample months per year (March, June, September and December) for the period from 2015 to 2020. The data set includes 1382 airports in the EUROCONTROL area with a total of 15.6 million aircraft departures. All aircraft types contained in the data set were allocated to one of the aircraft classes, as shown in Table 2. As the data set only contains actual off-block times, actual take-off times have been estimated using EUROCONTROL's set of taxi-out times.

## 4. Results

The noise point system as described in section 3 was applied to the flight movements contained in the EUROCONTROL R&D dataset. Due to simplicity only take-offs are presented in the study. With this approach it is possible to conduct an analysis of the noise development in Europe over time as well as to compare individual airports.

On European scale, the average noise point requirement remains relatively constant over the period under review (Figure 1).

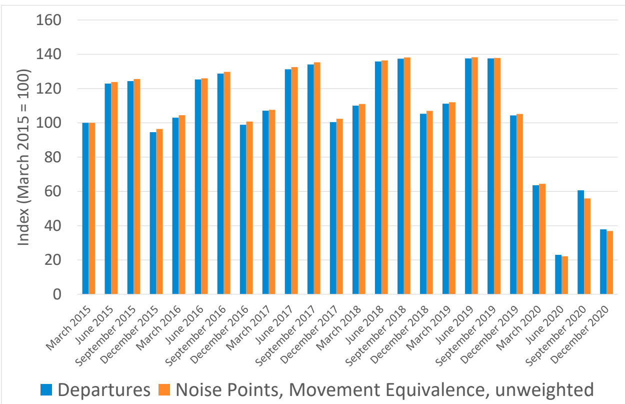


Fig. 1. Temporal development of number of departures and sum of noise points of movement equivalence for departures for all airports in the EUROCONTROL area, indexed to March 2015 = 100

The average sum of noise point of movement equivalence requirement remains relatively constant over time, as shown in Figure 1 (see also Schmid et al., 2023). This can be explained by two developments. More modern engines (with bypass ratio as proxy) lead to lower noise impact whereas larger aircraft (with MTOM as proxy) lead to higher noise impact (see table 2 for the resulting noise points). For a more detailed view the relative proportional development of flight movements is shown in figure 2. While the share of aircraft with engines of a bypass ratio larger than 7 (e.g. Airbus A320neo, Airbus A350, Boeing 737MAX, Boeing 787) has increased from 2.1 % in 2015 to 7.9 % in 2019, the share of large aircraft >20t MTOM has increased from 82.2 % to 85.3 % at the same time. 2020 is excluded to the very specific effects of the COVID19 pandemic.

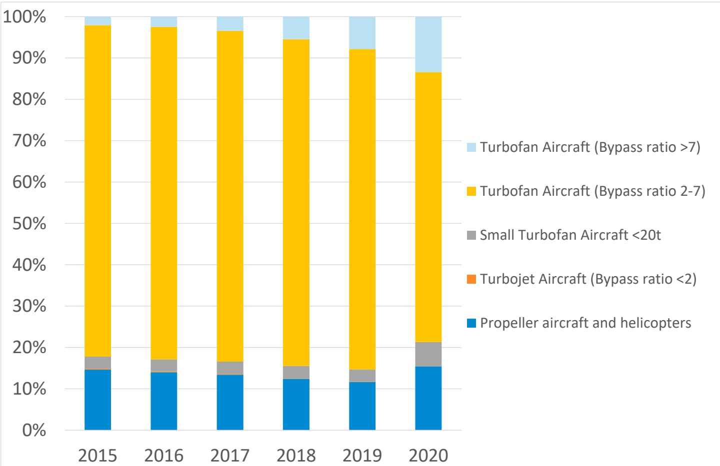


Fig. 2. Proportion of flight movements by aircraft size/engine type (bypass ratio)

For individual airports, the situation is somewhat different. An airport of major interest is Amsterdam Schiphol, as already explained in the introduction. In times before the COVID-19 pandemic, a constant trend for the decoupling between the number of departures and required noise points for departures could be observed (Figure 3). In this case the number of aircraft movements has increased slightly and the sum of noise points has decreased slightly for both definitions of noise points.

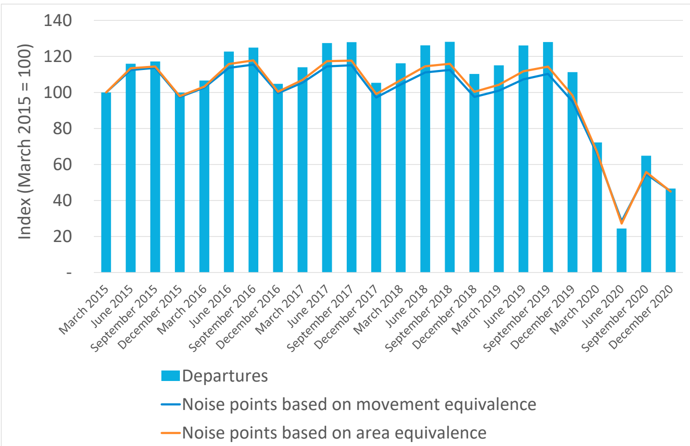


Fig. 3. Temporal development of monthly numbers of departures and sum of noise points for departures at Amsterdam Schiphol, indexed to March 2015 = 100

Figure 4 shows the temporal development of noise points per departure at the airport Amsterdam Schiphol. This graph shows that the number of noise points per departure has decreased slightly over time before the COVID-19 pandemic. As an example the $L_{DEN}$-weighted noise points based on movement equivalence have been reduced from 5.1 noise points per departure in March 2015 to 4.1 in December 2019. During the COVID 19 pandemic, a sharp increase in noise points per departure was observed, due to the decrease in passenger traffic and a short-term, interim increase in cargo traffic with widebody aircraft.

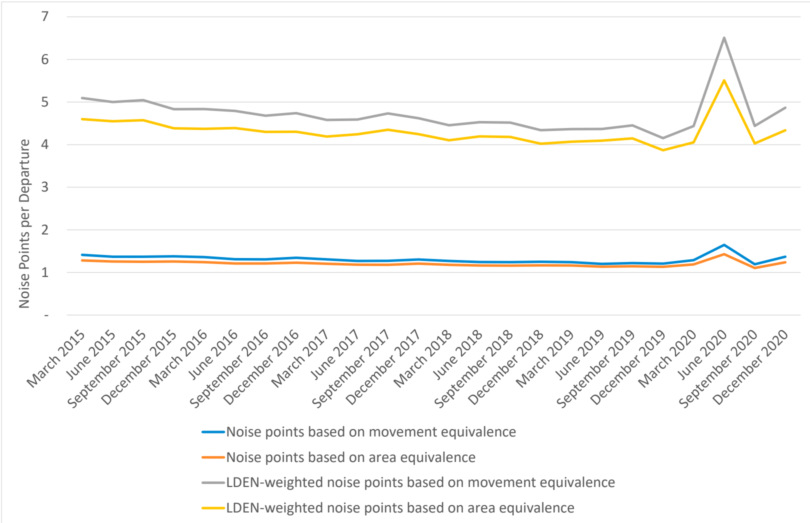


Fig. 4. Temporal development of noise points per departure at Amsterdam-Schiphol

The main reason for the longer-term trend is a change in the fleet composition (table 1). In the four months contained in the dataset for the year 2015, airlines departing from Amsterdam required a total of 379,007 LDEN-weighted noise points based on area equivalence for 75,887 departures. More than a quarter of these points (102,017) were used by 3127 departures of the Boeing 747-400 aircraft. Hence, the Boeing 747-400, albeit only having a 4.1 % share in the number of departures, consumed 26.9 % of the LDEN-weighted noise points based on area equivalence in 2015. Until 2019, home carrier KLM, among other airlines, was in the process of phasing out this particular type. As a consequence, in the respective months in 2019, 1596 departures of the Boeing 747-400 consumed only 53,767 LDEN-weighted noise points based on area equivalence – almost 50,000 fewer noise points than in 2015. In total, LDEN-weighted noise points based on area equivalence for departures in Amsterdam declined to 365,193 (-3.6 % compared to 2015), while departures increased to 84,154 (+10.9 %).

Table 3. Number of departures and sum of noise points at Amsterdam Schiphol.

| Category | 2015 (4 months) | 2019 (4 months) | Relative Change in % |
|---|---|---|---|
| Departures - All Aircraft Types | 75,887 | 84,154 | 10.9% |
| Departures – Boeing 747-400 | 3,127 | 1,596 | -49.0% |
| Noise points based on area equivalence – all aircraft types | 104,922 | 102,416 | -2.4% |
| $L_{DEN}$-weighted noise points based on area equivalence – all aircraft types | 379,007 | 365,193 | -3.6% |
| Noise Points based on movement equivalence – all aircraft types | 95,754 | 96,384 | 0.7% |
| $L_{DEN}$-weighted noise points based on movement equivalence – all aircraft types | 343,663 | 340,787 | -0.8% |
| Noise Points based on area equivalence – Boeing 747-400 | 26,267 | 13,406 | -49.0% |
| $L_{DEN}$-weighted noise points based on area equivalence – Boeing 747-400 | 102,017 | 53,767 | -47.3% |
| Noise Points based on movement equivalence – Boeing 747-400 | 18,762 | 9,576 | -49.0% |
| $L_{DEN}$-weighted noise points based on movement equivalence– Boeing 747-400 | 72,869 | 38,405 | -47.3% |

## 5. Discussion

As no decoupling between the number of departures and the required noise points on a European scale can be observed, the period of time taken into account is probably too short. Fleet turnover, i.e. the introduction of more modern aircraft in meaningful quantities on a European scale, simply takes quite a lot of time.

The development at Amsterdam Schiphol, where a decoupling of the number of aircraft movements and noise points can be observed, shows that only the number of movements is not a valid indicator for noise impact. In addition, efforts by the aviation industry to make air traffic quieter are not supported with such an indicator. The phase-out of the noisiest aircraft can achieve a substantial reduction of noise. This example in particular shows that the consumption of noise points is concentrated on a relatively small number of flights and/or aircraft types, at least at airports with a significant share of long-haul flights. If aircraft types relevant for noise impact are replaced by more modern, quieter aircraft types, this also results in a decrease of the sum of noise points without a reduction of the number of movements. If the sum of noise points at an airport was used as the main indicator, airlines would have the opportunity to free up noise points for further growth in flight movements by replacing the noisiest aircraft without increasing overall noise. If an assessment additionally based on LDEN-weighted noise points, the airlines would also have the option to shift flights from the evening and night into daytime in order to use fewer noise points.

As shown in figure 5, the distribution of noise points from the noisiest to the quietest quartile of flights is rather imbalanced: In 2019, one quarter of all LDEN-weighted noise points based on movement equivalence was consumed by only 4.6 % of the noisiest departures. Another quarter of noise points was consumed by 45.4 % of the quietest departures.

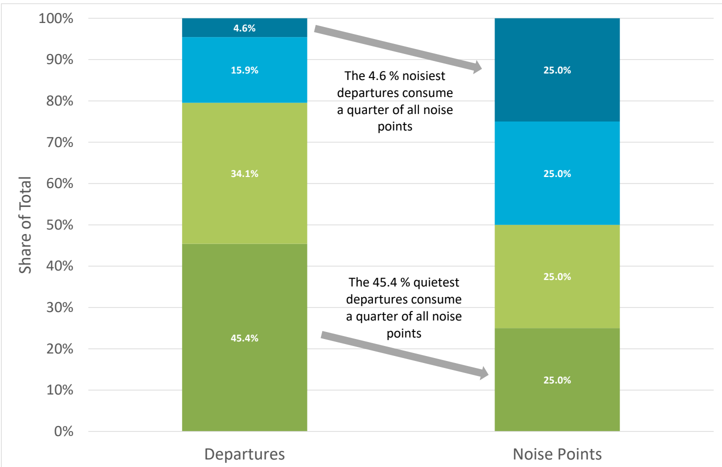


Fig. 5. Distribution of departures and $L_{DEN}$-weighted noise point based on movement equivalent at airport Amsterdam Schiphol in 2019

## 6. Conclusion and Outlook

Noise point systems, as outlined in this paper, can not only be used for noise monitoring, but also as a basis for the regulation of aircraft noise at airports. The way it works could be similar to a classic cap-and-trade scheme, which has been successfully applied to cap carbon dioxide emissions in European industry, energy and air transport sectors. With a reduction of the cap over time, residents in the vicinity of airports could participate in the progress in aircraft technology and the subsequent fleet-rollover of airlines. At the same time, the aviation industry could be allowed to grow the number of flight movements, as long as the operations are quieter (measured in terms of noise points). This could also be achieved by using quieter aircraft or operating less during evenings and nights. Noise can also be mitigated by replacing or combining the movements of smaller aircraft with less movement of more modern, larger aircraft. The Airbus A350, for example, takes nearly the same noise points as the Airbus A320ceo, but offers 2.5 times the seat capacity of the A320ceo. It could be a promising way for aircraft manufacturers to develop widebody aircraft optimized for short-haul operations to achieve greater efficiency in terms of operations, noise impact and emissions on high-demand / high-traffic airport pairs.

With the presented noise point systems and a cap of noise points, a fair distribution of costs and benefits for the aviation industry and local residents could be supported in a much more effective and efficient way thanyearly or hourly movement caps. Systems comparable to the one presented in this article are either being in operation or being proposed at various airports in Europe.

The methods developed is definitively promising and could be advanced further. If daily weightings are to be included in a noise point system separate noise points should be identified for departures and arrivals, because the departure time and arrival time of an operating aircraft can be located within different assessment periods, which was not in the scope of this study. Overall, it would be preferable for an airport if noise points were based on the noise values measured for each individual flight movement. However, such an approach represents a compromise between operationalization and setting the right incentives for noise abatement. Also, on the economic side, benefits and costs could be quantified accurately, providing further arguments on the efficiency of a noise point system with tradeable permits, as compared to a movement cap.

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