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Balanced approach study Schiphol Airport

Final report

Aviation Consultants

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Report

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1 Introduction

1.1 Introduction

The Dutch Ministry of Infrastructure and Water Management (IenW) is currently in the process of implementing a proposal by the Dutch Cabinet to reduce capacity at Schiphol Airport to 440.000 movements per annum[1].

To introduce this capacity restriction, an EU member state needs to follow rules and procedures as prescribed in EU regulation No 598/2014[2], commonly known as the Balanced approach procedure. The Balanced approach procedure should provide an answer to the question whether a capacity reduction is the most cost-efficient measure to meet the noise abatement objectives.

IenW is proposing this capacity reduction for the noise abatement objectives that need to be met in November 2024:

- 20% reduction of the number of highly annoyed people within the 48 dB(A) L_{den} contour
- 20% reduction of the number of houses within the 58 dB(A) L_{den} contour
- 15% reduction of the number of severely sleep disturbed people within the 40 dB(A) L_{night} contour
- 15% reduction of the number of houses within the 48 dB(A) L_{night} contour

These reductions are relative to a baseline scenario. The baseline scenario is the situation with 500,000 movements (including 32,000 night time flights as allowed by the airport' decree) and includes all planned measures and autonomous developments until November 2024. The baseline scenario doesn't include any additional measures.

1.2 Research question

IenW has commissioned To70 to perform a study following the method as mentioned in Annex I of EU regulation No. 598/2014 to assess which (combination of) measure(s) may be taken to meet the noise abatement objective in November 2024. This includes:

- A description of the airport, environmental objectives, development of noise contours over previous years and planned or existing measures to manage aircraft noise;
- Forecast of the noise impact without new measures, including a description of airport developments;
- Assessment of additional measures to reach the noise abatement objective as set by IenW.

A qualitative assessment on the autonomous development and feasibility of additional measures towards 2027 is also part of this study. This perspective to 2027 will be presented separately from the analysis of the noise abatement objective for 2024.

1.3 Scope and assumptions

- This research is performed in accordance with EU regulation No. 598/2014;
- This research is performed in close parallel with a research performed by Decisio and Beelining about the cost-effectiveness of the (combination of) measures to meet the noise abatement objectives;

[1] https://www.rijksoverheid.nl/documenten/kamerstukken/2022/06/24/hoofdlijnenbrief-schiphol

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.173.01.0065.01.ENG&toc=OJ:L:2014:173:FULL

- The (combination of) measures that were identified during this research are aimed to meet the noise abatement objectives, but can have an extensive impact on the operation;
- This research has been conducted without the direct involvement of the stakeholders affected by the (combination of) measures that are part of this research. The study approach and intermediate results were presented during technical cooperation sessions organised by IenW;
- The timeframe for the perspective is, as suggested by IenW, limited to 2027. Any developments and additional measures that would have effect on the noise impact after this year are no part of this research.

1.4 Reading guide

The structure of this report can be linked to the requirements as described in Annex I of EU regulation No. 598/2014. Chapter 2 contains the current situation of airport, including some context on how the airport has evolved over time. Chapter 3 provides a forecast of the noise impact if no additional measures will be taken. Chapter 4 starts with an overview of all available additional measures and ends with a detailed description of additional measures that will be analysed in this research. Chapter 5 provides an overview of the results of the additional measures that were researched. Chapter 6 contains an overview and the results of combinations of measures. In chapter 7, a perspective to 2027 is given regarding the expected autonomous developments and feasibility of additional measures.

2 Current situation at Schiphol Airport

This chapter provides a description of the airport, the environmental objectives for the airport, the historical noise situation and a description of the existing and planned measures to manage aircraft noise already implemented in the framework of the Balanced approach and their impact on and contribution to the noise situation.

2.1 General description of the airport

Schiphol airport is the main international airport in the Netherlands located approximately 10 kilometers southwest of the city centre of Amsterdam in the municipality of Haarlemmermeer.

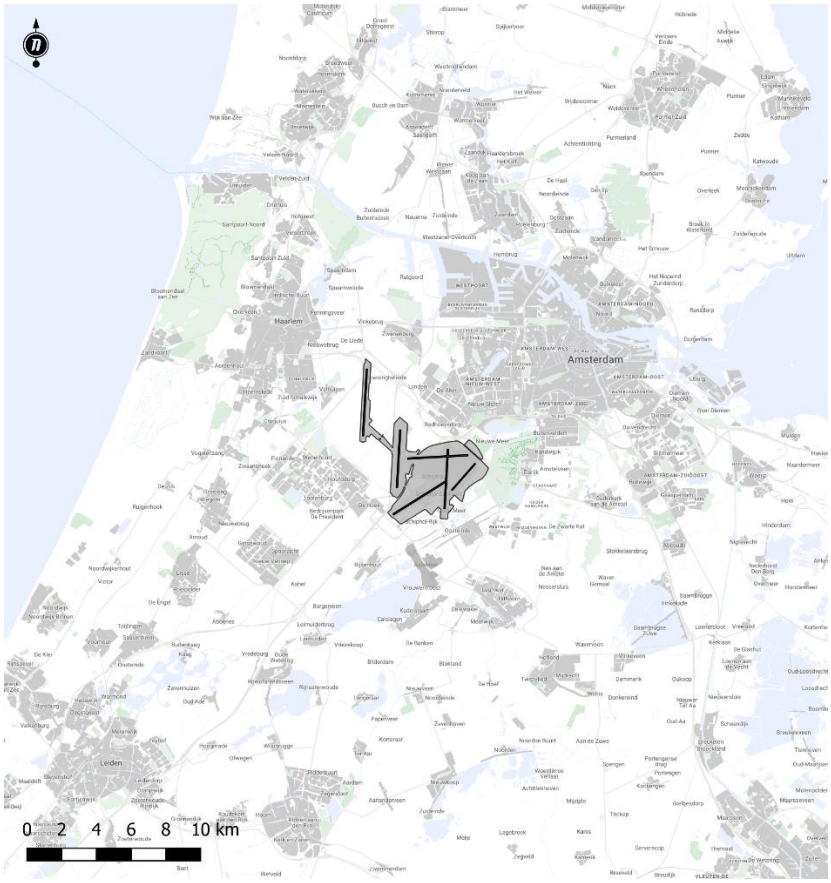

Figure 1 – Schiphol Airport location

The airport is operated 24 hours a day, 365 days a year. From 2009 to 2019 the number of annual flights increased from approximately 400,000 flights to close to 500,000 flights. During that period, the number of passengers increased from 45 million to over 70 million annual passengers. The airport experienced significant declines in air travel in 2020 and 2021 due to the global pandemic, but partially recovered in 2022.

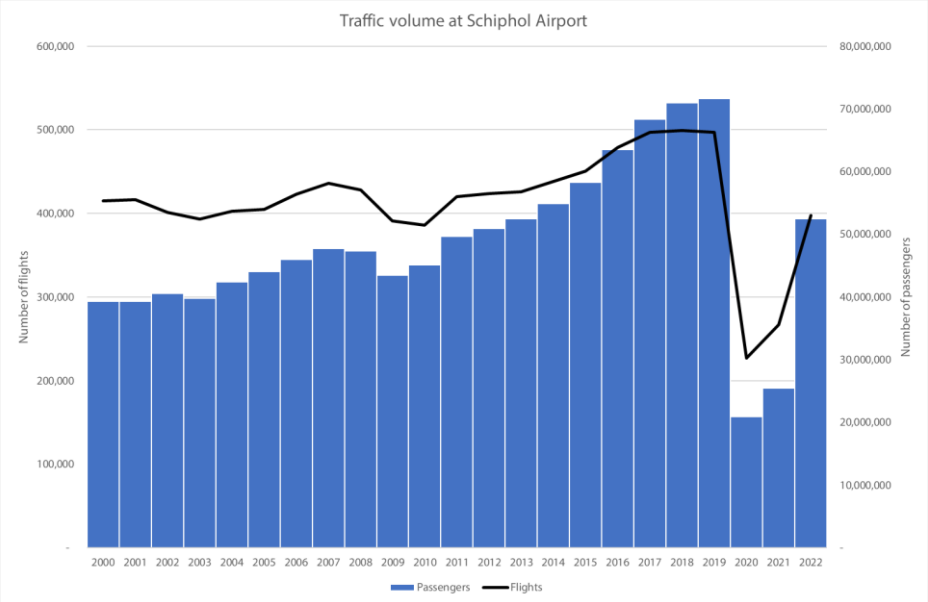

Figure 2 – Number of flights and passengers, source Central Bureau of Statistics

Schiphol Airport is a hub airport accommodating point-to-point and transfer passenger. Peak periods are scheduled to accommodate inbound traffic waves followed by outbound traffic waves. During peak times, more than 100 flights can be scheduled per hour.

2.2 Runways and runway use

The airport has six runways. The runways have been laid out facing a variety of wind directions to maximise the probability that aircraft will be able to take off and land:

- Runway 18L/36R (Aalsmeerbaan) – aircraft take off in a southerly direction and approach from the south;
- Runway 09/27 (Buitenveldertbaan) – aircraft take off in an easterly or westerly direction and approach from the east;
- Runway 06/24 (Kaagbaan) – aircraft take off in a southwesterly direction and approach from the southwest or northeast;
- Runway 18R/36L (Polderbaan) – aircraft take off in a northerly direction and approach from the north (in operation since 2003);
- Runway 18C/36C (Zwanenburgbaan) – aircraft take off in a northerly or southerly direction and approach from the north or the south;
- Runway 04/22 (Schiphol-Oostbaan) – this runway is shorter and used mainly for General Aviation, private jets and helicopters. Air Traffic Control the Netherlands can bring this runway into use for international air traffic, where necessary.

Figure 3 provides an overview of the runways and how they are oriented in relation to the residential areas around the airport.

Figure 3 – Runway system, source Schiphol Airport

Which runways and runway combinations are used is determined firstly by the weather. The environmental rules for the use of Schiphol Airport also play a role in determining the use of the runways. This takes place on the basis of the 'preferred sequence'.

2.2.1 Daytime runway use between 6.00 a.m. and 10.30 p.m.

During peak times, three runways are usually in use at the same time. At certain times, this may even be four. Outside peak hours, two runways are in use. In exceptional circumstances, only one runway may be in use. This is then used for both take-offs and landings. By day, many different runway combinations of two and three runways are possible. The runway combination is changed a number of times during the day. These changes are the result of changes in traffic volumes and changing weather conditions.

2.2.2 Runway use at night between 10.30 p.m. and 6.00 a.m.

At night, one runway is in use for take-offs and one for landings. In principle, only runway 18R/36L (Polderbaan) and runway 06/24 (Kaagbaan) are used.

2.3 Flight paths

Three arrival initial approach fixes are used for arrivals into Schiphol Airport. These initial approach fixes are ARTIP, RIVER and SUGOL. 42% of the traffic approaches Schiphol Airport via ARTIP, 26% via RIVER and 32% via SUGOL[3].

For departures, five departure sectors are defined:

- Sector 1 is departing traffic towards Asia, Scandinavia and Russia;
- Sector 2 is departing traffic towards Eastern Europe, Middle East, Asia and Australia;
- Sector 3 is departing traffic towards Southern Europe, Africa and South-America;
- Sector 4 is departing traffic towards the UK and Latin America;
- Sector 5 is departing traffic towards North America.

Figure 4 gives an overview of actual flight paths (based on 2021 data) of departures from Schiphol Airport to the different departure sectors.

[3] Based on prognosis 2023 data from Schiphol, see figure 2.4 in https://open.overheid.nl/documenten/ronl-ede7418996e363d16ca60af6020c79dd5e4063d6/pdf

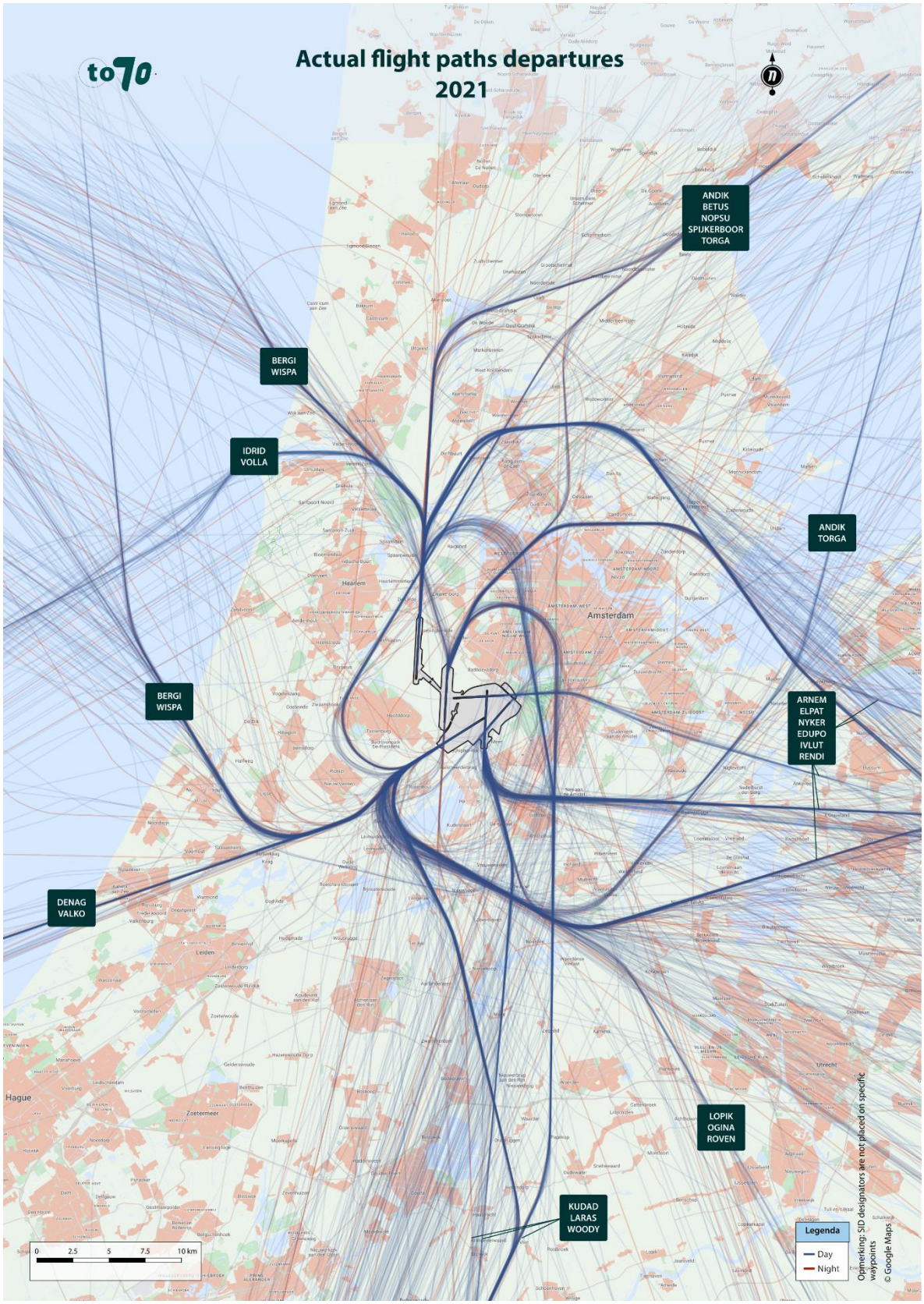

Figure 4 – Flight tracks departures

2.4 Environmental objectives for the airport and the national context

The Dutch Aviation Act has formed the legal framework for Schiphol Airport since 2003. In the Dutch Aviation Act is stated that the airport decree contains rules and limit values that limit the environmental impact around the airport. The Dutch Aviation Act ensures the environmental impact must be equal or better than the protection offered in the first airport decree from 2004. This protection is provided by so called 'criteria of equality', which limit the number of houses, highly annoyed people and severely sleep disturbed people within L_{den} and L_{night} contours. Table 1 shows the criteria of equality based on the residential situation in 2005 and corrected for the use of ECAC Doc 29.

Table 1 - Criteria of equality

Criteria of equality	Limit value
Number of houses within the 58 dB(A) L_{den} contour	13,600
Number of highly annoyed people within the 48 dB(A) L_{den} contour	166,500
Number of houses within the 48 dB(A) L_{night} contour	14,600
Number of severely sleep disturbed people within the 40 dB(A) L_{night} contour	45,000

The criteria of equality are limiting the number of houses, highly annoyed people and severely sleep disturbed people within L_{den} and L_{night} contours, but do not limit the noise exposure at specific areas around the airport. The airport decree contains noise enforcement points and limit values for noise exposure[4] to protect residential areas around the airport by limiting the L_{den} noise exposure at 35 locations and the L_{night} noise exposure at 25 locations.

2.5 Details of noise contours for the relevant previous years

Figure 5 shows the development of the noise exposure (in L_{den}) from 2004 until 2021, calculated using the Dutch Noise Calculation model NRM. The number of highly annoyed people is calculated based on the 2005, 2015 and 2018 residential situation. The NRM model is not compliant with the ECAC Doc 29 standard, but provides an overview of the development of noise contour over a longer period of time. ECAC Doc 29 modelling results for Schiphol Airport are only available since 2019. Schiphol Airport is also publishing a prognosis and evaluates that prognosis based on ECAC Doc 29 noise modelling results every year. The latest publication is of the 2023 traffic forecast[5].

[4] https://wetten.overheid.nl/BWBR0014330/2018-11-01#Bijlage2

[5] https://www.schiphol.nl/nl/download/b2b/1668067136/51JJ0FBmyoSECHh9XkWMt2.pdf

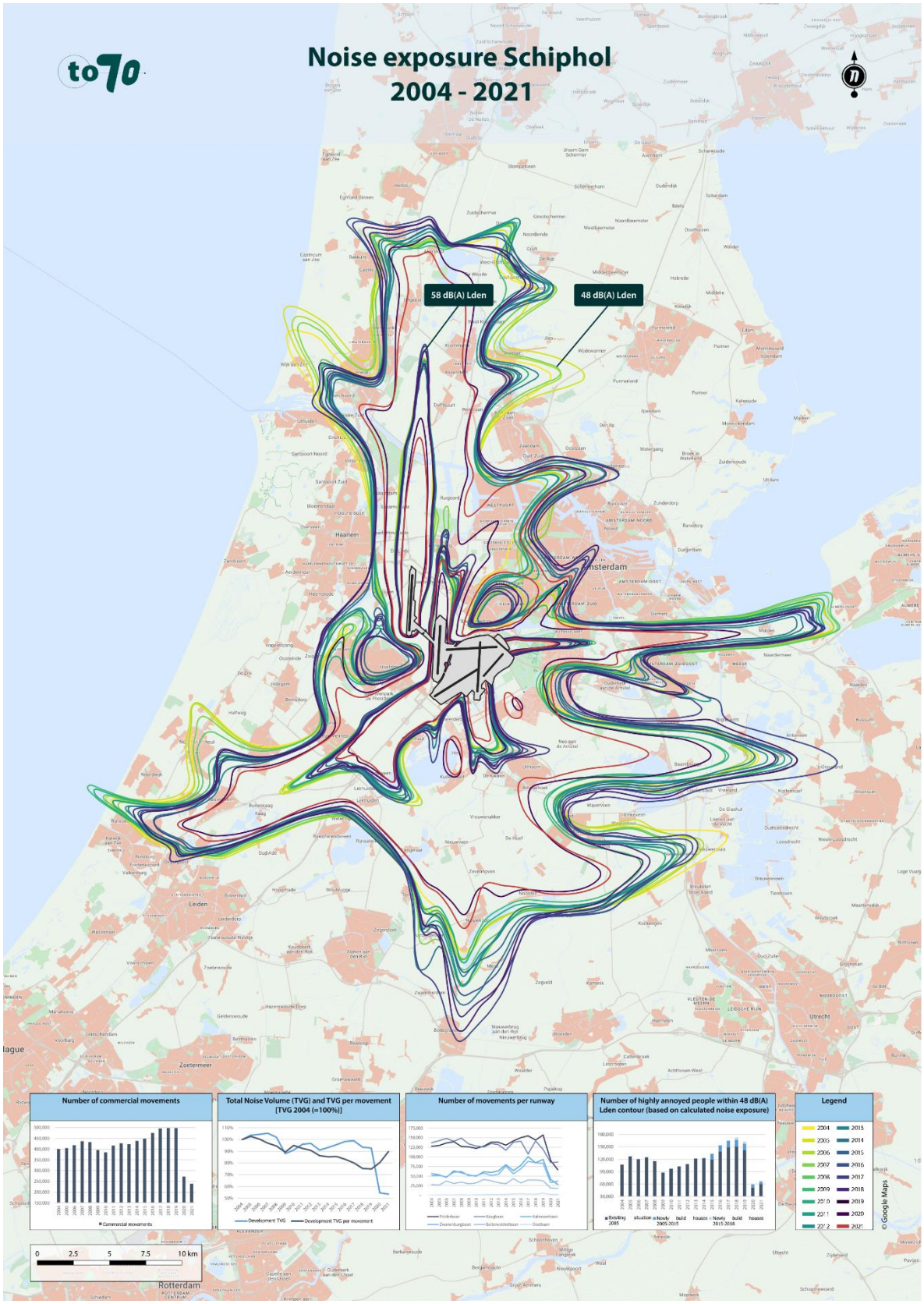

Figure 5 – Development of noise exposure since 2004

Figure 5 shows that the number of highly annoyed people increased from 2010 till 2019 as a result of the increase in number of movements. The figure also illustrates that the noise exposure has increased in some locations, mainly as a result of the increase in the number of movements, but also decreased in other locations as a resulted of fleet renewal and route and procedure optimisations.

The pandemic has resulted in a steep drop in number of movements and number of highly annoyed people in 2020 and 2021.

Figure 5 also shows that the Total Noise Volume (TVG) per movement has been decreasing from 2004 until 2019, an indication that the average noise exposure per aircraft movement is decreasing. The TVG considering all movements has roughly been the same from 2009 till 2019, caused by the combination of a decreasing TVG per movement and an increase in the total number of movements.

2.6 A description of existing and planned measures to manage aircraft noise

This paragraph contains an overview of the existing and planned measures to reduce and manage aircraft noise at Schiphol Airport. The measures are presented per pillar of the Balanced approach.

2.6.1 Reduction of noise at source

Roughly 80% of the flights narrowbody aircraft that weigh less than 160 tonnes. The Boeing 737, Airbus A320 and Embraer 190 are the most predominant aircraft types within this 80%. The other 20% are wide-body aircraft such as the Airbus A330, A350 and A380 and Boeing 777 and 787.

Most of the airlines that operate at Schiphol Airport are investing in the latest generation aircraft types. The top five airlines (in terms of passenger numbers) of 2022, KLM, EasyJet, Transavia, Delta Air Lines and TUI fly, are all renewing their fleet with the latest generation aircraft. KLM is already renewing its fleet with the Embraer E190-E2 and is replacing its Boeing 737 fleet with Airbus A320Neo aircrafts starting in 2023. Transavia is also replacing its Boeing 737 fleet with Airbus A320Neo aircrafts starting in 2024. EasyJet is already operating some of its flights from and to Schiphol Airport with the Airbus A320Neo and will continue to increase the number of Airbus A320Neo and Airbus A321Neo in its fleet. Delta Air Lines is increasingly using its A330Neo instead of the A330-300 for its flights to and from Schiphol Airport. TUI fly is increasingly using the Boeing 737 MAX 8 for the short haul operations and the Boeing 787 for the long haul operations.

Fleet renewal has proven to be one of the most important measures to reduce aircraft noise and associated impact in residential areas around the airport. The significant number of airlines operating from and to Schiphol Airport will keep resulting in an increase in the number of latest generation of aircraft, since these aircrafts have a competitive edge over older generation aircraft. This also results in a continuous reduction of the noise exposure since latest generation aircrafts are often less noisy than older generation aircraft. Schiphol Airport also pushes this with airport charges based on noise certification values of aircrafts, resulting in discounts or additional charges. More information about this can be found in the 2023 Charges and Conditions[6] as published by the Royal Schiphol Group,

[6] https://www.schiphol.nl/en/download/b2b/1667202512/1YFDYlqe3xrkKVaFebMgr4.pdf

2.6.2 Land-use planning and management

In 2002, safety and noise protection zones were established around the airport to prevent the use of the land and buildings at and around Schiphol Airport for safety reasons and limit the number of new and existing residents affected by aircraft noise[7]. Figure 6 shows these safety and noise protection zones that are the main instrument against encroachment.

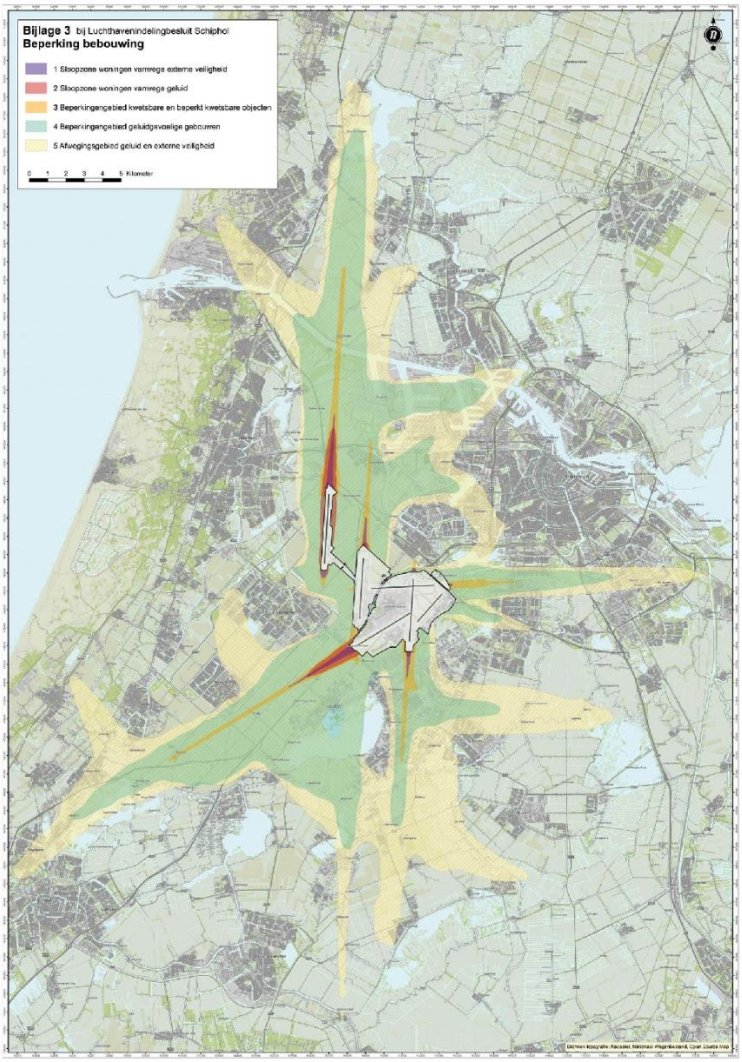

Figure 6 – Noise protection zones[8]

Several projects regarding the insulation of buildings around Schiphol Airport have been carried out in the last decades. This includes the GIS 1, 2 and 3 projects, which were performed in the period between 1984 and 2012. These projects have resulted in approximately 13,000 houses being insulated in order to reduce the noise impact within houses[9]. IenW is currently in the process of another insulation project, this

[7] https://wetten.overheid.nl/BWBR0014329/2021-10-28

[8] https://wetten.overheid.nl/BWBR0014329/2021-10-28#Bijlage3

[9] AT Osborne, 2013, Beleidsevaluatie GIS-3, https://zoek.officielebekendmakingen.nl/blg-256792.pdf

time to insulate houses within the 60 dB(A) L_{den} contour. The process for this insulation project is currently ongoing and the consultation phase has just been completed[10].

2.6.3 Noise abatement operational procedures

There are a number of noise abatement operational procedures in place to minimise the noise impact in residential areas around the airport. The procedure that is the foundation of all other procedures is the preferential runway system. Runways in use at Schiphol Airport will be selected by ATC according to a noise preferential runway system that will ensure that preferred runways (runways with the least amount of houses and people affected by movements on this runway) will be selected if weather allows this. The preferred runways at Schiphol Airport are runway 06/24 (Kaagbaan) and 18R/36L (Polderbaan). These runways are also selected by default during night-time (22:30 – 06:30 local time).

Furthermore, the following noise abatement operational procedures are also in place to further reduce the noise impact in residential areas around the airport:

- Runway 18R is not available for departures and runway 36L is not available for arrivals;
- Runway 36R is not available for departures and runway 18L is not available for arrivals;
- Noise-preferential routes to avoid residential areas are mandated;
- Supplementary standard instrumented departures (SIDS) are effective during night hours (22:30 – 06:30 local time);
- Several (local) changes of routes to improve the noise situation, e.g. radius-to-fix turns;
- The use of the noise abatement take-off and climb procedure, like NADP2 as mentioned in ICAO Doc 8168 Volume I, is recommended for all jet aircraft departures;
- Increased use of continuous decent operations, from 28% in 2015 to 37% in 2020;
- Night transition procedures are in place for arrivals during night hours (22:30 – 06:30 local time);
- Use of reduced flaps landing procedure is recommended;
- After landing, the use of idle reverse thrust is advised during night hours (22:30 – 06:30 local time).

2.6.4 Operating restrictions

Schiphol Airport has a maximum agreed cap of 500,000 movements per annum. The current airport decree specifies a cap in the number of night flights of 32,000.

Furthermore, several operating restrictions regarding the aircraft that operates from and to Schiphol Airport are in place:

- Chapter 2 operations are not allowed at Schiphol Airport, except in case of an emergency;
- New operations are not allowed for Chapter 3 aircraft, for which the margin of the sum of the three certification noise levels, relative to the sum of the three applicable ICAO Annex 16 Chapter 3 certification noise limits, is less than 10 EPNdB;
- For aircraft equipped with engines with bypass ratio equal or lower then 3, take-off and landing is not allowed between 17:00 – 07:00;
- For propeller-driven aircraft, and aircraft equipped with engines with bypass ratio higher then 3, it is not allowed to plan take-off between 22:00 – 06:00.

[10] https://www.internetconsultatie.nl/regeling_gevelisolatie_schiphol_2023/b1

3 Forecast without new measures

This chapter contains the forecasted noise climate if no additional measures will be taken. The forecast is defined for the period up to and including 2024, in line with the noise objective which is set for november 2024, and includes autonomous developments up to and including 2024. A brief description of ongoing developments will be presented as well as the forecasted noise impact for 2024 if no additional measures will be taken.

3.1 Descriptions of airport developments

The Royal Schiphol Group is continuously developing Schiphol Airport to improve safety, to increase capacity and to meet environmental targets. Most noticeable developments on the ground are the expansion of the one terminal concept by building a new terminal (terminal south) and the development of the A-pier. The investment decision to build the new terminal (and associated new piers) is subject of a feasibility study which is expected to be finished in 2023. Furthermore, extension and refurbishment of various stands and taxiways is planned for the coming years to increase capacity, specifically during peak hour operations.

There are also developments already planned and in progress related to the operation in the air. The continuous fleet renewal process by airlines that operate at Schiphol Airport is set to reduce the overall noise exposure by 0.1 dB for landings and 0.2 dB for take-offs per year[11]. Furthermore, the airport and Dutch ANSP Luchtverkeersleiding Nederland (LVNL) are researching and implementing new technology and measures together with the support of airlines to reduce nuisance. They do this in a collaboration called 'minder hinder Schiphol[12].

The use of the Dutch airspace increases and intensifies. Its capacity however is not increasing. The Dutch Airspace Redesign Programme was initiated to increase the efficiency of the Dutch airspace for all airspace users, reduce the impact on local communities and the environment, and improve the military mission effectiveness. The implementation is planned from 2026 onwards.

3.2 A description of the effect on noise climate without further measures

With less than 400,000 movements in 2022, the number of movements was still well below the agreed, and almost realized in 2019, maximum of 500,000 annual traffic movements (of which 32,000 annual night flights). A near to full recovery is expected for the operational year 2024. Furthermore, several other developments are expected to take place during this period:

- A continuation of fleet renewal, as described above,
- Increased arrival runway capacity as a result of the implementation of RECAT-EU,
- Increased use of CDA procedures for specific runway combinations,
- Increased use of reduced flaps operations.

These developments will reduce the noise impact per movements, as well result in less non-preferential runway use.

[11] In line with fleet renewal trend as used in the Environmental impact assessments for Schiphol airport in 2020, see https://www.rijksoverheid.nl/documenten/rapporten/2021/02/16/bijlage-3-mer-nnhs-2020-deel-1-hoofdrapport

[12] https://minderhinderschiphol.nl/

3.3 Forecast noise contours

The most up to date traffic forecast is used to calculate the noise impact of the operational year 2024 without additional measures, which is the annual traffic forecast for the period of November 1st, 2022 until November 1st, 2023. This forecast was developed by the Royal Schiphol Group and made available to To70 for the purpose of this study. Based on this forecast, a baseline scenario is created to determine the forecasted noise impact in November 2024 if no further measures were taken. This forecast contains 500.000 movements (including 32.000 night flights) and includes the autonomous developments that are expected to take place until 2024, as described in paragraph 3.2. This scenario will be used as a baseline scenario to which all additional measures will be compared to.

Figure 7 shows the (calculated) average annual noise contours for the annual average day (L_{den}) for this baseline scenario.

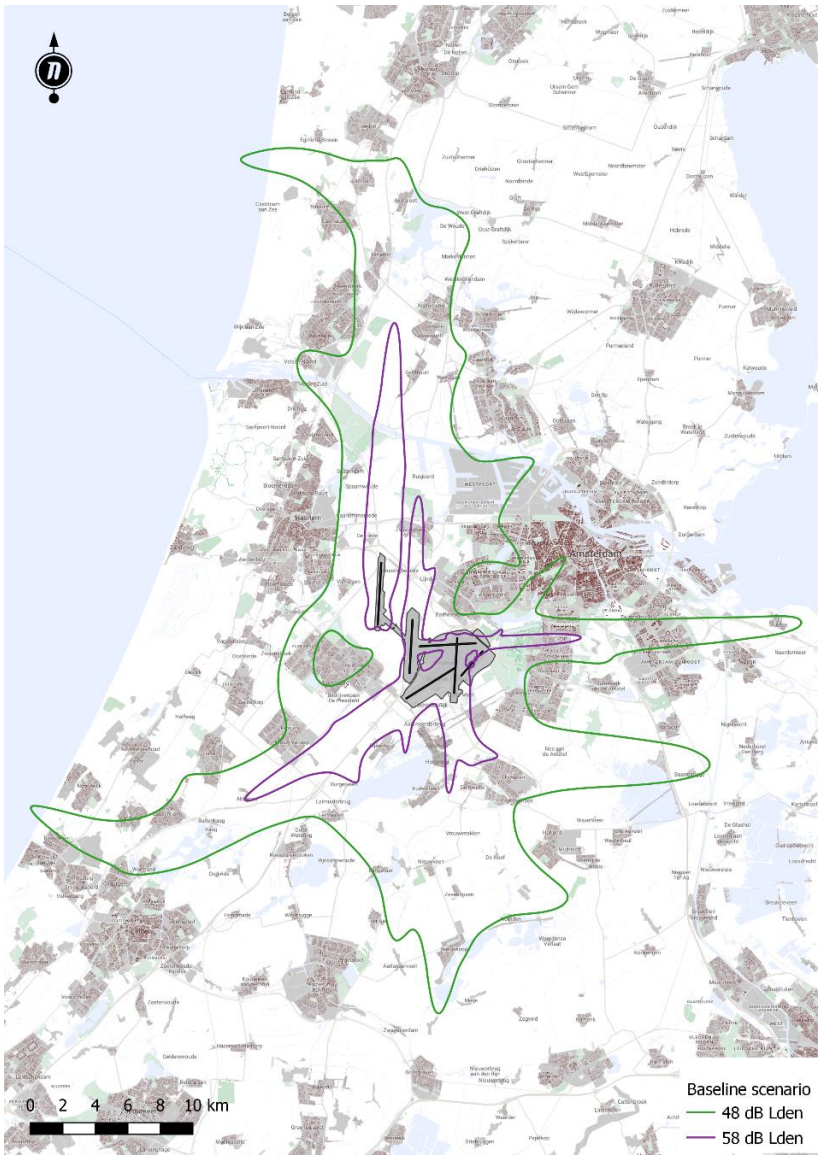

Figure 7 – Lden noise impact for the baseline scenario.

The noise impact of the baseline scenario has been calculated using the Schiphol Airport implementation of the ECAC Doc 29 noise model. Details on the calculation of this baseline scenario can be found in Appendix A .

Figure 7 illustrates that the largest part of the 58 dB(A) L_{den} contour stretches over non-residential areas. The 48 dB(A) L_{den} contour stretches over a larger area; a number of residential areas is impact by noise levels of (more than) 48 dB(A) L_{den}. Figure 7 also shows that the shape of the 48 dB(A) L_{den} contour is determined by the take-off and landing routes that have been optimized over the last decades to minimize the noise impact in residential areas.

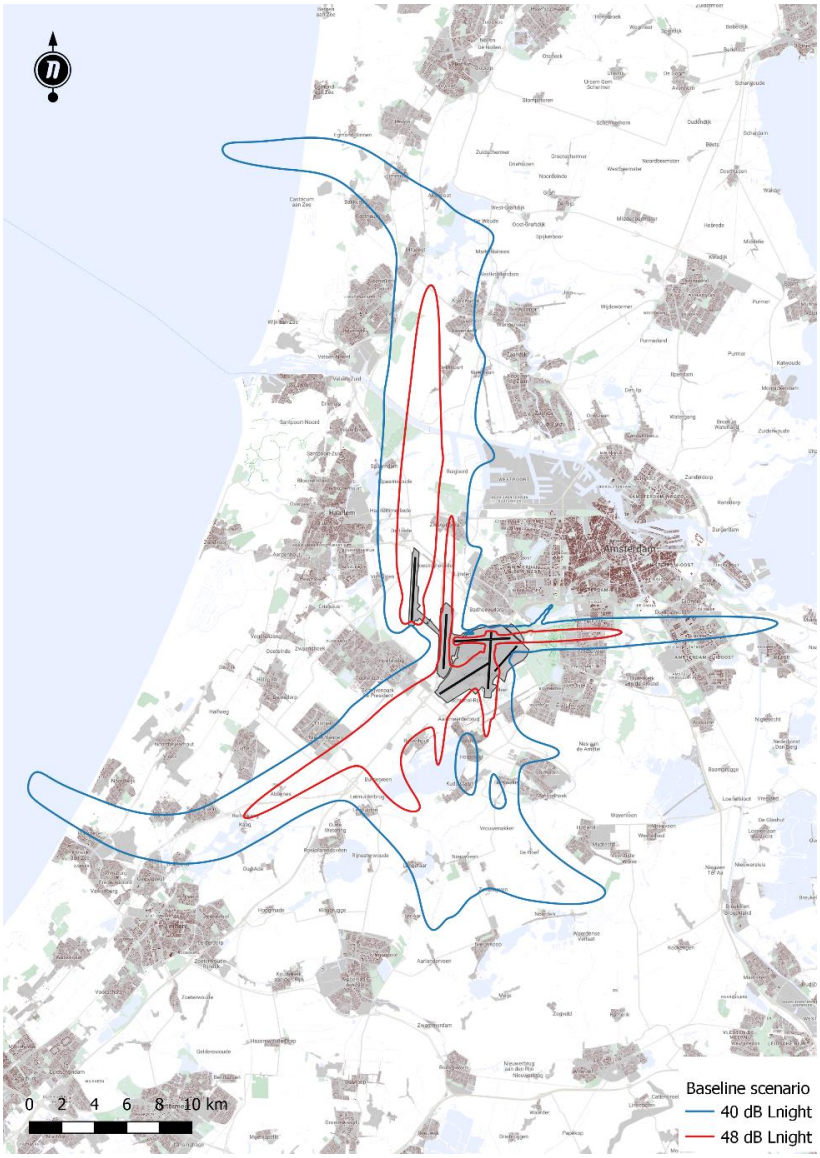

Figure 8 – Lnight noise impact for the baseline scenario.

Figure 8 illustrates that the noise exposure during the night time period (23:00 – 07:00) is dominated by traffic to and from runway 06/24 (Kaagbaan) and runway 18R/36L (Polderbaan). This is a result of the noise

preferential runway use at night. Runway 06/24 and runway 18R/36L are the preferred runways for the night-time operation; the other runways are used in case of specific weather conditions, maintenance or emergencies.

Table 2 shows the noise impact of the baseline scenario for the criteria related to the noise abatement objective[13]. The noise abatement objectives were set by IenW. The noise abatement objective target is related to the baseline situation, and also presented in the table.

Table 2 - Noise impact of baseline scenario on noise abatement objective criteria.

Criteria related to the noise abatement objective	Baseline scenario figure	Noise abatement objective	Target
Number of houses within the 58 dB(A) L_{den} contour	7,081	-20%	5,665
Number of highly annoyed people within the 48 dB(A) L_{den} contour	113,862	-20%	91,090
Number of houses within the 48 dB(A) L_{night} contour	5,685	-15%	4,832
Number of severely sleep disturbed people within the 40 dB(A) L_{night} contour	24,365	-15%	20,710

The criteria as presented above are commonly used in the Dutch aviation policy and regulatory system and relate to the criteria of equality (see section 2.4).

In order to provide a full overview of baseline and impacts, this study also provides, for information purposes, the impact expressed in the criteria as included in the European Noise Directive (END). Table 3 shows the noise impact of the baseline scenario for the END criteria.

Table 3 - Noise impact of baseline scenario on END criteria.

END criteria	Baseline scenario figure
Number of houses within the 55 dB(A) L_{den} contour	19,860
Number of highly annoyed people within the 55 dB(A) L_{den} contour	18,193
Number of houses within the 50 dB(A) L_{night} contour	2,648
Number of severely sleep disturbed people within the 50 dB(A) L_{night} contour	1,393

3.4 Newly constructed and planned residential areas

The number of houses within noise contours, as presented in Table 2 and Table 3, are counted using the registered (existing) houses in residential areas as of 2021. Newly constructed houses and planned residential areas after 2021 might result in different number of houses within contours in the future.

[13] The number of houses and people likely to be affected by aircraft noise are determined using the 2021 residential situation.

Figure 9 shows the newly constructed and planned residential areas until 2050, as was already presented in the 2020 Environmental Impact Assessment as published by Schiphol Airport[14], compared with the L_{den} noise contours from the baseline scenario.

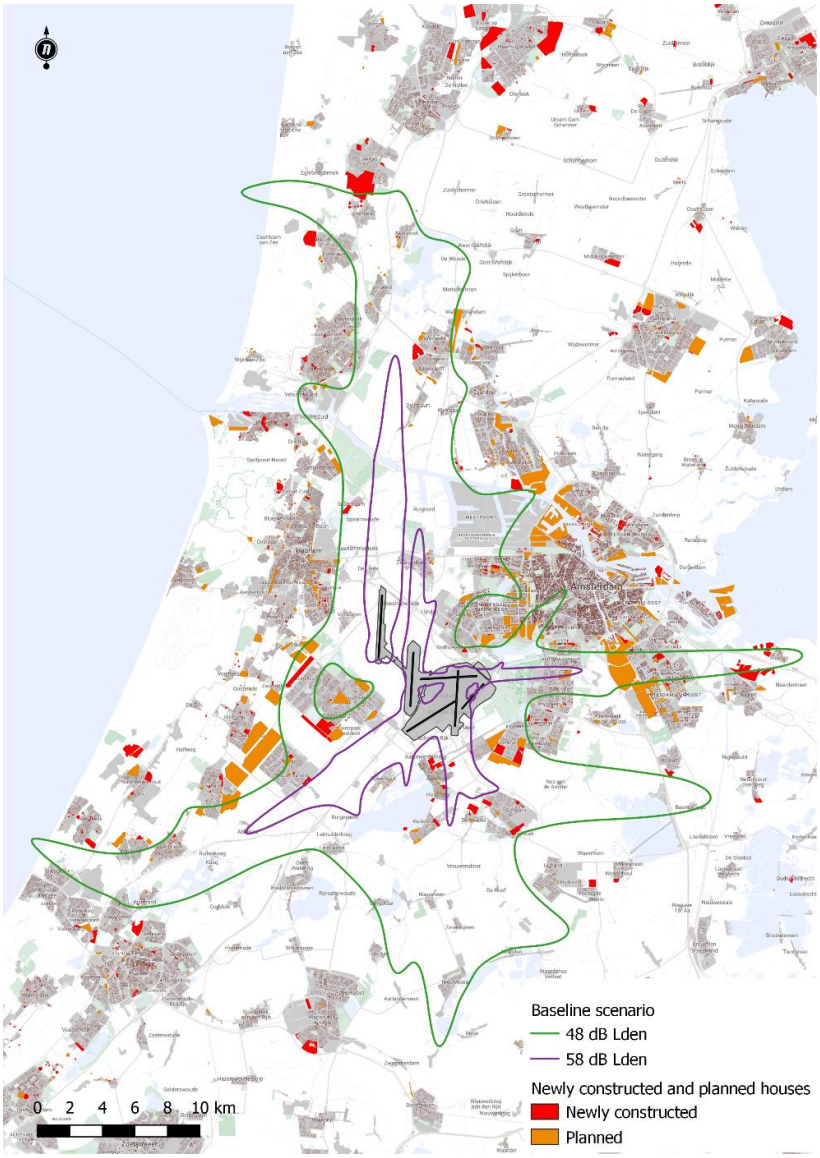

Figure 9 – Newly constructed and planned residential areas

Figure 9 shows that a number of newly constructed residential areas are situated within the 48 dB(A) L_{den} contour. Some of these newly constructed residential areas (in red) are already build and some are constructed this year. Most of the planned residential areas (in orange) are planned from 2030 until 2050 and larger in size.

[14] https://open.overheid.nl/documenten/ronl-901aadcc-e22d-41a6-b09c-b0078ae95d0e/pdf

4 Additional measures

Additional measures are required to achieve the noise abatement objective. This section elaborates on the methodology used to qualitatively assess whether possible noise mitigation measures are selected for a detailed analysis. A selection process was performed in order to both exclude ineffective and/or unrealistic measures as well as to reduce the number of possibilities that are to be analysed in further detail. The measures that were selected are discussed in more detail in section 4.4.

4.1 Longlist of measures

A longlist of possible noise mitigation measures has been made using various sources, including:

- The measures that are part of the collaboration of Schiphol Airport, LVNL and with contribution of airlines in the 'less noise nuisance Schiphol' (in Dutch: 'minder hinder Schiphol') programme;
- Selection of (operational) measures implemented at other major hub airports throughout Europe;
- Land-use planning/isolation measures as initiated by the Dutch government or by the Royal Schiphol Group;
- Potential operational measures identified in finished or on-going research projects specifically for Schiphol Airport;
- Letter from the Dutch Cabinet to the house of representatives from June 2022 to reduce capacity at Schiphol Airport to 440,000[15].

The following measures are identified per pillar of the Balanced Approach and are part of the longlist:

- For reduction of noise at source:
    - Stimulate use of quieter aircraft through financial instrument (including airport charges);
    - Stimulate use of quieter aircraft through noise performance monitoring;
    - Stimulate noise reducing retrofitting aircraft (winglets, engine exhaust modifications, etc.).
- For land-use planning and management:
    - Insulation (conventional insulation, noise cancelling windows, etc.);
    - Expropriation;
    - Building conditions and restrictions (including noise adaptive building programs);
    - Change function of buildings (conversion of offices to homes and vice versa).
- For noise abatement operational procedures:
    - Increase the number of continuous decent approaches (on top of autonomous development);
    - Increase the number of aircraft performing N-1 taxi operations/taxibot taxi operations;
    - Route optimizations to reduce overall number of highly annoyed people;
    - Optimization of current procedures (minimize level segments, optimize climb-out speed, intersection take-offs, reduced thrust take-off etc.);
    - Introduction of new procedures (including RNP-AR approaches during parallel approaches);
    - Increase concentration of flightpaths to minimize overall noise exposure;
    - Extend the night regime using the primary runways (both in the evening and during early morning);
    - Runway closure (full runway closure or during specific circumstances);
    - Increase runway capacity (on top of autonomous development);

[15] https://www.rijksoverheid.nl/documenten/kamerstukken/2022/06/24/hoofdlijnenbrief-schiphol

- Increase crosswind and tailwind limits for runway selection process;
- Minimize the use of the secondary runways through optimization of flight schedule.

- For operating restrictions
  - Introduce a ban on noisy aircraft (overall or during specific times of the day);
  - Cap the number of annual movements (e.g. Dutch cabinet decision to reduce number of movements to 440,000);
  - Cap the number of movements during the night time;
  - Curfew/night-time closure;
  - Additional slot criteria.

4.2 Selection criteria

The longlist of measures has been narrowed down to a shortlist of possible noise mitigation measures using a number of selection criteria. The selection criteria have been defined based on the requirements given in EU regulation No. 598/2014, the properties and challenge of the noise abatement objective and criteria related to ensure a safe and reliable operation:

- Safety → the measure shouldn't introduce a safety risk;
- Achievability → effect of the measure should be achieved by November 2024 (introduction noise reduction target)
- Accordance with legislation → the measure shouldn't conflict with European/national legislation;
- Reliability of the operation → the measure shouldn't significantly decrease the reliability of the airport operation;
- Distribution of nuisance → the measure shouldn't have the sole purpose to shift nuisance to other areas around the airport;
- Quality of the network connectivity → the measure shouldn't result in an irreversible effect on the quality of the network connectivity;
- Emissions → the measure shouldn't result in a significant increase of emissions in favour of noise;
- Modelling → effect of the measure can be determined using ECAC Doc29 noise modelling as implemented for Schiphol airport.

A qualitative assessment using the selection criteria to score all measures results in a shortlist of measures. Appendix B contains an overview of the scores per measure per selection criteria and an explanation on what ground a measure is selected for the shortlist.

4.3 Selection criteria

The following measures are selected for further analysis and are part of the shortlist:

1. Stimulate use of quieter aircraft through revision of airport charges (M1[16]);
2. Two variants to extend the current night regime (M7):
   a) Extend night regime during the evening from 21:40;
   b) Extend night regime during the evening from 21:40 and during the morning until 07:00;
3. Partial closure of runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8);
4. Minimize the use of secondary runways by 'forcing' 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10);

[16] Noise modelling identification tag as they were used during the study

5. Variant to reduce the annual number of movements to 440,000 movements (M14);
   a) Reduce the annual number of movements to 440,000 movements with 32.000 night flights
   b) Reduce the annual number of movements to 440,000 movements with 29.000 night flights
6. Variants to reduce the annual number of night flights (M15):
   a) Reduce the number of night flights from 32,000 to 29,000 movements;
   b) Reduce the number of night flights from 32,000 to 27,000 movements;
   c) Reduce the number of night flights from 32,000 to 25,000 movements;

4.4 Detailed analysis of measures from the shortlist

This paragraph contains a detailed description of the measures that are part of the shortlist. The measures are structured and elaborated in accordance with the four pillars of the Balanced approach. Appendix A provides more detailed description of how the measures are modelled and which assumptions were made.

The costs of the measures for society, passengers and freight and airlines are presented in the research by Decisio and Beelining.

4.4.1 Reduction of noise at source

In the first pillar, reduce noise at source, one additional measure made the shortlist:

1. Stimulate use of quieter aircraft through revision of airport charges

1. Stimulate use of quieter aircraft through revision of airport charges (M1)

A majority of (EU) hub airports have financial incentives in place to stimulate the use of most efficient and environmentally friendly aircraft. However, airport charges are not the sole aspect that airlines take into consideration when selecting an aircraft to service a specific route. From a cost perspective it may not be interesting for airlines to switch aircraft type as a result of other financial and/or operational (dis-)advantages.

An analysis of the traffic in the baseline scenario is performed to quantify the potential noise reduction if additional use of quieter aircraft (on top of the autonomous fleet renewal) will occur if the use of quieter aircraft is further stimulated through (even more) discounts and additional charges on airport charges at Schiphol Airport. An approach has been chosen by changing 65% of the aircraft types within the relatively noisy aircraft (noisiest category is S1) with aircrafts from better performing noise categories (such as S6 and S7)[17].

Aircraft types were assigned to a noise category based on appendix II of Schiphol Airport's airport charges, levies, slots and conditions for the period between April 2023 and April 2024, which can be described as an optimistic scenario since this 'safety net' approach if no noise certification levels are available. Using this method, roughly 87,000 movements were classified as an S1 aircraft. An approach has been selected looking at the airline segment and the ability of the airlines within these segments to replace an aircraft in

[17] Refer to Schiphol Airport's airport charges, levies, slots and conditions for the period between April 2023 and April 2024: https://www.schiphol.nl/nl/route-development/pagina/ams-airport-charges-levies-slots-and-conditions/

the S1 category with a better performing aircraft in the S2 till S7 category. This resulted in the replacement of roughly 56,500 movements into a better performing aircraft in the S2 till S7 category.

4.4.2 Land-use planning and management

In the second pillar, land-use planning and management, no additional measures made the shortlist.

4.4.3 Noise abatement operational procedures

In the third pillar, noise abatement operational procedures, three additional measures made the shortlist:

2. Two variants to extend the current night regime (M7):
   a) Extend night regime during the evening from 21:40;
   b) Extend night regime during the evening from 21:40 and during the morning until 07:00;
3. Partial closure of runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8);
4. Minimize the use of secondary runways by 'forcing' 1+1 runway use (preferred runways) during specific time periods between 07:00 – 08:00 and 13:00 – 15:00 (M10).

2. Extension of night regime (M7)

During peak hours at Schiphol Airport the airport commonly operates in a peak mode, which means that two runways are used for arrivals and/or two runways are used for departures. The use of 3+ runways also introduces a certain dispersion in terms of noise exposure in the surrounding area of the airport. During the night time, Schiphol Airport operates with one preferential runway for arrivals and one preferential runway for departures, night time departure procedures and continuous descent operations. This is commonly known as the night regime.

The night regime was specifically designed to minimize the noise impact in the surrounding areas during the night time. Extending the night regime (into the early morning and/or late evening) will reduce the overall noise impact. Due to limited runway capacity, extension of night regime will result in cost due to delays.

The night regime is currently, in the baseline scenario, in operation between 22:40 and 06:40. This means that during this time, runway 06/24 (Kaagbaan) and runway 18R/36L (Polderbaan) are the main runways in operation. Since extension of the night regime significantly affects the available runway capacity at Schiphol airport, two variants are defined to study the impact on noise and related costs due to delays depending on the flight schedule:

a. Extension of the night regime in the evening from 22:40 to 21:40
   This scenario simulates the effect of extending the night regime with one hour (starting at 21:40 instead of 22:40) during the evening.

b. Extension of the night regime both in the evening from 22:40 to 21:40 and in the morning from 06:40 to 07:00
   This scenario simulates the effect of extending the night regime with one hour (from 21:40 instead of 22:40) during the evening as well as 20 minutes (from 06:40 instead of 07:00) during the morning. This scenario is expected to have more impact on the operation and larger costs, but also a bigger impact on noise in comparison to enforcing the night regime only during the evening.

Extending the night regime by one hour in the evening period is chosen due to two reasons. Primarily, the baseline scenario shows a significant decrease in the number of movements from 21:40 onwards to numbers equal to off-peak situations during the day. Operational data about the runways in use also indicates that the night regime is already extended (if circumstances allow) when there is a surplus in capacity. This measure therefore extends the use of an operational procedure that is already in place from time to time, therefore also contributing to the feasibility of such a measure. It must be noted that more flights might end up in the night period (after 23:00) if increased delays will occur as a result of this measure.

Extending the night regime in the early morning is deemed to have a bigger operational impact given the number of movements that are currently handled in the timeframe of 06:40 – 07:00. Although this would have an impact on the operation, it is deemed feasible to extend the night regime to 07:00 and will have a positive effect on noise exposure in areas impacted by operations from non-preferential runways, specifically runway 18L/36R (Aalsmeerbaan). If more delays will occur as a result of this measure, more flights will end up in the day period (after 07:00), which reduces the noise exposure given the noise penalty factor of 10 for night flights.

3. Partial closure of the runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8)

Closing (or partially closing) a runway at Schiphol Airport will significantly affect the noise impact as well as the operation of the airport. A (partial) closure will shift movements to different runways if weather conditions allow for this. Full or partial closure therefore will redistribute noise to other locations. This means that a runway closure measure wouldn't meet the selection criteria of distribution of nuisance.

However, a partial closure of the Buitenveldertbaan (runway 09/27) is considered a measure that would meet the selection criteria given a number of reasons:

- The location of the runway, which is adjacent to a number of residential areas, indicates that (partial) closure of the Buitenveldertbaan will significantly reduce the overall number of highly annoyed people.
- The introduction of the Polderbaan (runway (18R/36L) resulted in the significant reduction of movements on the Buitenveldertbaan (runway 09/27) and reduction of the number of houses, highly annoyed people and severely sleep disturbed people within the relevant noise contours as result of the introduction;
- The Buitenveldertbaan is (in principle) not a primary runway to facilitate landings and/or arrivals under normal weather conditions. The conditions which require the specific use of the Buitenveldertbaan occur less frequently than the use of the preferential runways. Partial closure of this runway (under specific conditions) is therefore identified as the only feasible runway closure option, to significantly contribute to the noise abatement objectives, with sufficient capacity on other runways/in other runway combinations to ensure the reliability of the operation.

For these reasons, the partial closure of the Buitenveldertbaan is considered as an additional measure worth researching. However, exceptional weather conditions, such as strong winds from specific wind directions and bad visibility conditions, require this runway to be in operation to prevent full or temporary closure of the airport on multiple days of the year. And it must be noted that a partial closure of the

Buitenveldertbaan affects the continued operation in circumstances with strong westerly or easterly winds, significantly reducing the overall capacity at Schiphol Airport in such situations.

The following assumptions were used to simulate the impact of this additional measure:

- The Buitenveldertbaan remains available during weather conditions where operational data shows that the Buitenvelderbaan is the only runway available. This mainly occurs during strong (easterly) winds;
- The Buitenveldertbaan remains available during bad visibility conditions, even if other runways are available and/or more frequently used;
- The Buitenveldertbaan remains available during weather conditions where operational data shows that the Buitenveldertbaan is the prevailing runway. This occurs (in most cases) during specific combinations of (high) windspeed and wind direction conditions;
- The Buitenveldertbaan is not selected during weather conditions where operational data shows another runway (or runways) is (are) more prevailing.

The flight movements that were designated to the Buitenveldertbaan in the baseline scenario and have been moved given the assumptions mentioned above are redistributed over the remaining runways in accordance with the resulting runway selection system.

4. Minimize use of secondary runways (M10)

The runways at Schiphol Airport can be characterized as either a primary or secondary runway. The primary runways are preferred instead of other runways to minimize the overall number of houses and highly annoyed people within the relevant noise contours. Minimizing the use of secondary runways therefore reduces the noise impact in relatively densely populated areas by shifting arrivals and/or departures to the primary runways.

It is most feasible to force 1+1 runway use during periods in between peak periods, since secondary runways are required for capacity reasons during peak periods. Previous research[18] regarding the potential timeframes where secondary runway use can be decreased concludes that secondary runway use can be minimized between 07:00 – 08:00 and 13:00 – 15:00. The 07:00 – 08:00 and 13:00 – 15:00 timeframes are therefore considered the most feasible timeframes to optimize preferred runway use and minimize secondary runway use when considering the departure and arrival peaks through the entire day.

In the period of 07:00 – 08:00, the early morning departure wave hits its peak at 07:00 – 07:20 and transitions to an arrival peak that peaks around 08:20 – 08:40. Forcing 1+1 runway use (only preferred runways) in this period will reduce the number of departures and arrivals on secondary runways. This will also result in an increase in the number of movements on the preferred runways.

In the period of 13:00 – 15:00, the third departure wave is coming to end and the next arrival wave starts at 15:00 (although a sharp peak in number of departures from 14:20 – 14:40 is observed). Forcing 1+1 runway use (only preferred runways) in this period will reduce the number of departures and arrivals on

[18] https://open.overheid.nl/documenten/ronl-19c051ae1b78522e03f4fc15a2a04cdbc973c7f2/pdf

secondary runways. This will also result in an increase in the number of movements on the preferred runways.

Given the outcome of research on this topic, a scenario is defined where the use of primary runways is forced between 07:00 – 08:00 and between 13:00 – 15:00. The increased use of primary runways and no (allowed) use of the secondary runway will result in delays and other operational inefficiencies.

4.4.4 Operating restrictions

In the fourth pillar, operating restrictions, two additional measures made the shortlist,:

5. Reduce the annual number of movements to 440,000 movements (M14)
    a) Reduce the annual number of movements to 440,000 movements (with 32,000 night flights)
    b) Reduce the annual number of movements to 440,000 movements (with 29,000 night flights)
6. Reduce the annual number of night flights (M15):
    a) Reduce the number of night flights from 32,000 to 29,000 movements
    b) Reduce the number of night flights from 32,000 to 27,000 movements
    c) Reduce the number of night flights from 32,000 to 25,000 movements

5. Reduce the annual number of movements to 440,000 movements (M14)

Limiting the overall capacity of Schiphol Airport has significant effects both on the overall noise impact as well as on the future strategies of airlines, specifically regarding their network quality. Complexity also arises from the implementation of such measure, which requires fair treatment for relevant stakeholders. The measure that will be analyzed is the reduction to 440,000 movements annually and is based on the Dutch decree regarding the reduction of flights to 440,000 movements on an annual basis[19]. It is assumed that the reduction will take place on a pro rata basis[20], which means that the airlines with the largest number of movements will need to reduce their number of movements the most (in absolute numbers). The method used to simulate this reduction, from the baseline scenario to a scenario with 440,000 movements, is described in more detail in Appendix A .

[19] Refer to the letter (I E NW/BSK-2022/156292) of the Minister of Infrastructure and Water Management regarding the reduction of flights at Schiphol Airport to 440.000 movements: https://www.rijksoverheid.nl/documenten/kamerstukken/2022/06/24/hoofdlijnenbrief-schiphol

[20] In line with advise report of Airport Coordination Netherlands (ACNL), see https://www.rijksoverheid.nl/documenten/rapporten/2023/02/27/bijlage-3-advies-van-acnl-inzake-reductie-vluchten-schiphol-13-februari-2023

6. Reduce the annual number of night flights (M15)

Previously performed research[21,22] analyzed the cost-effectiveness of reducing the annual number of flights during the night period (23:00 – 07:00) at Schiphol Airport. Reducing the number of night flights is also part of the Aviation Whitepaper 'Verantwoord vliegen naar 2050' as published by the Dutch Cabinet[23] and focuses on three scenarios:

- A reduction of the number of night flights to 29,000 movements
- A reduction of the number of night flights to 27,000 movements
- A reduction of the number of night flights to 25,000 movements

For this measure, we have decided to focus on the same reduction of movements. Previous research did however use a different baseline scenario, which requires an actualization of the cost-effectiveness of this measure in order to compare the results with the other measures under consideration.

[21] Refer to ACNL: https://open.overheid.nl/repository/ronl-0f610578-e0f6-45d2-861b-496c61745237/1/pdf/advies-reductie-nachtvluchten-schiphol.pdf

[22] Refer to Adecs Airinfra Consultants BV: https://www.rijksoverheid.nl/documenten/rapporten/2020/06/26/bijlage-2-adecs-airinfra-ce-delft-2020-onderzoek-nachtvluchtreductie

[23] See paragraph 4.2.4 in https://open.overheid.nl/documenten/ronl-c2ae4e29-a960-4c91-99af-7bca52b8c9f9/pdf

5 Results of individual additional measures

This chapter contains the results of the noise simulations of all measures that are part of the shortlist. First, an overview is presented with the results of the measures compared to the baseline scenario. The results per measure are explained in more detail from paragraph 5.2 onwards. The results of the additional measures using the END criteria are presented in Appendix C .

The costs of the measures for society, passengers and freight and airlines are presented in the research by Decisio and Beelining.

5.1 Overview of results per measure

Table 4 contains an overview of the reduction per measure compared to the baseline scenario. The noise abatement objective per criteria is also displayed in the table.

Table 4 - overview results of shorlist meaures

Measure	Reduction compared to the baseline scenario			
	Number of highly annoyed people within 48 dB(A) L_{den}	Number of houses within 58 dB(A) L_{den}	Number of severely sleep disturbed people within 40 dB(A) L_{night}	Number of houses within 48 dB(A) L_{night}
Noise abatement objective	-20%	-20%	-15%	-15%
Stimulate use of quieter aircraft through revision of airport charges (M1)	-3.6%	-3.6%	-0.5%	-1.5%
Extend night regime during the evening from 21:40 (M7)	-3.0%	-1.4%	-0%	-0%
Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7)	-5.1%	-3.2%	-5.6%	-7.4%
Runway closure (partial closure of the Buitenveldertbaan during specific weather conditions) (M8)	-2.3%	-20.9%	-3.8%	-5.3%
Minimize use of secondary runways (M10)	-2.9%	-2.6%	-0%	-0%
Reduce annual number of movements to 440,000 movements (32,000 night flights) (M14)	-13.9%	-14.0%	-0%	-0%
Reduce annual number of movements to 440,000 movements (29,000 night flights) (M14)	-16.7%	-15.3%	-10.8%	-13.2%
Reduce night flights to 29,000 movements per annum (M15)	-2.8%	-3.4%	-10.8%	-13.2%
Reduce night flights to 27,000 movements per annum (M15)	-4.6%	-4.9%	-18.6%	-22.2%
Reduce night flights to 25,000 movements per annum (M15)	-6.4%	-6.0%	-26.5%	-30.4%

The results lead to the following observations:

- None of the measures result in sufficient noise reduction to meet both the L_{den} and L_{night} noise abatement objectives;

- Partially closing the Buitenveldertbaan (runway 09/27) during specific weather conditions will result in achieving the noise abatement objective for the number of houses within the 58 dB(A) L_{den} contour, but fails to meet the other noise abatement objectives as a standalone measure;
- Reducing the annual number of night flights to 27,000 or 25,000 movements will result in achieving the two L_{night} noise abatement objectives, but fails to meet the L_{den} noise abatement objectives as a standalone measure.
- Extending the night regime during the morning until 07:00 appears to have a significant impact on the L_{night} noise abatement objectives, given this is the result of forcing preferential runway use during 06:40 – 07:00;
- Reducing the annual number of movements to 440,000 movements fails to meet any of the noise abatement objectives on its own;
- It can be noticed that individual measures can have a significant impact on one of the indicators while having a relatively small (or no) impact on other indicators. This is most noticeable for the measure for extending the night regime and minimizing the use of secondary runways through, which only impacts the L_{den} indicators, and the reduction of night flights, which significantly impacts the L_{night} indicators.

It can be concluded that none of the measures result in sufficient noise reduction to meet both the L_{den} and L_{night} noise abatement objectives. Combination of measures are made based on the cost-effectiveness of the individual measures as calculated by Decisio and Beelining in their research. The analysed combinations and the results are presented in chapter 6. Combination of measures

5.2 Reduction of noise at source

Table 5 contains an overview of the impact of the reduction of noise at source measure, being the measure to stimulate the use of quieter aircraft through a revision of the airport charges.

Table 5 - Results for reduction of noise at source measure

Criteria	Baseline scenario	Stimulate use of quieter aircraft through revision of airport charges
Number of highly annoyed people within 48 dB(A) L_{den} contour	113,862	109,774 (-3.6%)
Number of houses within 58 dB(A) L_{den} contour	7,081	6,823 (-3.6%)
Number of severely sleep disturbed people within 40 dB(A) L_{night} contour	24,365	24,240 (-0.5%)
Number of houses within 48 dB(A) L_{night} contour	5,685	5,602 (-1.5%)

The measure to further stimulate use of quieter aircraft through a revision of the airport charges results in an overall reduction of the noise impact. This is the result of roughly 56,500 movements that have been designated a different aircraft type as a result of this measure. A more detailed description of the changes can be found in in Appendix A .

There is only a limited number of movements within the noisiest noise category S1 during the night time. This results in a limited reduction of the number of severely sleep disturbed people within 40 dB(A) L_{night} contour and number of houses within 48 dB(A) L_{night} contour.

5.3 Noise abatement operating procedures

Table 6 contains an overview of the impact of the noise abatement operating procedure measures.

Table 6 - Results for noise abatement operating procedure measures

Criteria	Baseline scenario	Extend night regime during the evening from 21:40	Extend night regime during the evening from 21:40 and during the morning until 07:00	Partial closure of runway 09/27 (Buitenveldert-baan) during specific weather conditions	Minimize use of secondary runways by forcing 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00
Number of highly annoyed people within 48 dB(A) L_{den} contour	113,862	110,484 (-3.0%)	108,050 (-5.1%)	111,211 (-2.3%)	110,606 (-2.9%)
Number of houses within 58 dB(A) L_{den} contour	7,081	6,981 (-1.4%)	6,853 (-3.2%)	5,601 (-20.9%)	6,894 (-2.6%)
Number of severely sleep disturbed people within 40 dB(A) L_{night} contour	24,365	24,365 (-)	22,992 (5.6%)	23,428 (-3.8%)	24,365 (-)
Number of houses within 48 dB(A) L_{night} contour	5,685	5,685 (-)	5,264 (-7.4%)	5,382 (-5.3%)	5,685 (-)

Extending the night regime during the evening from 21:40 will result in a decrease in the number of houses and highly annoyed people that are affected by movements from runway 18C/36C, 18L/36R and 09/27. This measure also results in an increase in movements from and to runway 18R/36L and 06/24, but has little to no effect in the number of houses and highly annoyed people in the areas affected by movements from these runways. This measure has no impact on the number of houses and severely sleep disturbed people within the L_{night} contours.

Extending the night regime during the evening from 21:40 and during the morning until 07:00 will increase the effect on the number of houses and highly annoyed people that is seen for the measure to only extend the night regime during the evening from 21:40. Furthermore, this measure also results in a reduction of the number of severely sleep disturbed people and houses within the L_{night} contours. This is due to the reason that this measure is in effect between 06:40 – 07:00 (L_{night} noise exposure is calculated from 23:00 – 07:00).

Partially closing runway 09/27 will result in a significant decrease in the number of movements from and to this runway (roughly 50% reduction for both landings on runway 27 and take-offs from runway 09). This decrease in traffic will be redistributed to all other runways, with the largest share being redistributed to runway 06/24. A 20.9% reduction of the number of houses within the 58 dB(A) L_{den} contour is achieved since a large part of the total number of houses within the 58(A) dB L_{den} contour is affected by traffic from and to runway 09/27. Less significant impact is expected further away from the airport (within the 48 dB(A) L_{den} contour). The reduction within the L_{night} contours is a direct result from the decrease in the number of movements in combination with the densely populated area that is situated underneath the traffic from and to runway 09/27.

Minimizing the use of secondary runways by forcing 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 will result in a decrease in the number of houses and highly annoyed people that are affected by movements from runway 18C/36C and 18L/36R. This measure also results in an increase in movements from and to runway 18R/36L and 06/24, but has little to no effect in the number of houses and highly annoyed people in the areas affected by movements from these runways. This measure has no impact on the number of houses and severely sleep disturbed people within the L_{night} contours.

5.4 Operating restrictions

Table 7 contains an overview of the impact of the operating restriction measures.

Table 7 - Results for operating restriction measures

Criteria	Baseline scenario	Reduce the number of night flights to 29.000	Reduce the number of night flights to 27.000	Reduce the number of night flights to 25.000	Reduce the annual number of movements to 440.000 (32.000 night flights)	Reduce the annual number of movements to 440.000 (29.000 night flights)
Number of highly annoyed people within 48 dB(A) L_{den} contour	113,862	110,721 (-2.8%)	108,655 (-4.6%)	106,521 (-6.4%)	97,999 (-13.9%)	94,871 (-16.7%)
Number of houses within 58 dB(A) L_{den} contour	7,081	6,842 (-3.4%)	6,736 (-4.9%)	6,655 (-6.0%)	6,090 (-14.0%)	5,995 (-15.3%)
Number of severely sleep disturbed people within 40 dB(A) L_{night} contour	24,365	21,742 (-10.8%)	19,844 (-18.6%)	17,906 (-26.5%)	24,365 (-0%)	21,742 (-10.8%)
Number of houses within 48 dB(A) L_{night} contour	5,685	4,933 (-13.2%)	4,425 (-22.2%)	3,954 (-30.4%)	5,685 (-0%)	4,933 (-13.2%)

Reducing the number of night flights will predominantly reduce the noise exposure in the areas affected by movements from runway 18R/36L and 06/24. This measure has a significant effect on the number of houses and severely sleep disturbed people within the L_{night} contours. The majority of the reduction in number of houses within the 48 dB(A) L_{night} contour is registered in the area affected by runway 18R/36L, specifically in the neighbourhood of Zwanenburg. The reduction to 27,000 night flights will result in a reduction that meets the L_{night} noise abatement objectives, although overshooting the objective with some margin.

The measure to reduce the annual number of movements to 440,000 movements (29,000 night flights) has a significant effect on the L_{den} and L_{night} noise exposure. The number of houses and highly annoyed people within the L_{den} contours is predominantly reduced in the municipalities of Amsterdam, Aalsmeer, Amstelveen and Haarlemmermeer in neighbourhoods mostly affected by the use of non-preferential

runways. Noise exposure in areas affected by traffic from and to the preferred runways is also lower, but less significant in comparison to the areas affected by non-preferential runways.

6 Combination of measures

This chapter contains the results of the noise calculations of combinations of additional measures. First, an overview of the selected combinations is presented. Next, an overview of the results of the noise modelling of the combinations is presented. A more detailed explanation of the results can be found from paragraph 6.3 onwards. The results of the combinations using the END criteria are presented in Appendix D .

The costs of the combination of measures for society, passengers and freight and airlines are presented in the research by Decisio and Beelining.

6.1 Overview of combinations

Several combinations of measures have been made based on the following principles:

1. Combination of measure are made in accordance with the Balanced approach rationale to start with measures from the first pillar (reduction of noise at source) and end with measures from the last pillar (operating restrictions);
2. Combination of measures should be made with the most cost-effective measures;
3. Expert judgement that the estimated impact of combination of measures will meet all noise abatement objectives.

Table 8 contains the combinations that are made using the principles as mentioned above.

Table 8 - combinations of measures

Combination	Measures
Combination A	• Minimize the use of secondary runways by forcing 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10) • Reduce number of night flights from 32,000 to 29,000 movements (M15) • Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7) • Partial closure of the runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8) • Stimulate use of quieter aircraft through revision of airport charges (M1)
Combination B	• Minimize the use of secondary runways by forcing 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10) • Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7) • Partial closure of the runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8) • Stimulate use of quieter aircraft through revision of airport charges (M1) • Reduce annual number of movements to 440,000 movements (29,000 night flights) (M14)
Combination C	• Minimize the use of secondary runways by forcing 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10) • Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7) • Partial closure of the runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8) • Stimulate use of quieter aircraft through revision of airport charges (M1) • Reduce number of night flights from 32,000 to 25,000 movements (M15)

Combination D	• Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7) • Stimulate use of quieter aircraft through revision of airport charges (M1) • Reduce annual number of movements to 440,000 movements (29,000 night flights) (M15)
Combination E	• Extend night regime during the evening from 21:40 (M7) • Reduce number of night flights from 32,000 to 27,000 movements (M15)

The combinations have been calculated separately from the individual additional measures. It should be noted that an assessment whether the combinations of measures still meets the selection criteria has not been performed. Each intermediate step within the combination has also been modelled separately to get a better understanding of the effect that additional measures might have on one another. The results of the intermediate steps are presented in appendix D .

6.2 Result of combinations

Table 9 contains an overview of the reduction per combination of measures compared to the baseline scenario. The noise abatement objective per criteria is also displayed in the table.

Table 9 - overview results of combination of meaures

Measure	Reduction compared to the baseline scenario Number of highly annoyed people within 48 dB(A) L_{den}	Number of houses within 58 dB(A) L_{den}	Number of severely sleep disturbed people within 40 dB(A) L_{night}	Number of houses within 48 dB(A) L_{night}
Noise abatement objective	-20%	-20%	-15%	-15%
Combination A	-17.6%	-35.5%	-18.6%	-25.7%
Combination B	-29.8%	-49.5%	-18.6%	-25.7%
Combination C	-21.1%	-42.5%	-33.8%	-56.8%
Combination D	-24.1%	-20.4%	-14.9%	-22.0%
Combination E	-9.2%	-8.0%	-21.2%	-28.4%

The results lead to the following observations:

- In combination A, three of the four objectives are met. The objective to reduce the number of highly annoyed people within 48 dB(A) L_{den} with 20% is not met. The other objectives are met, but exceed the objective targets;
- In combination B, all objectives are met, but exceed the objective targets, especially the objective to reduce the number of houses within 58 dB(A) L_{den} with 20%. The capacity reduction to 440,000 annual movements (29,000 night flights) has a significant impact on this margin;
- In combination C, all objectives are met, but also exceed the objective targets. The objectives to reduce the number of houses within 48 dB(A) L_{night} contour with 15%, the number of houses within 58 dB(A) L_{den} contour with 20% and the objective of severely sleep disturbed people within the 40 dB(A) L_{night} contour are exceeded by more than 15%. The capacity reduction to 440,000 annual movements (29,000 night flights) has a significant impact on all of these margins;
- In combination D all objectives are met, except the objective of 15% reduction for the number of severely sleep disturbed people within the 40 dB(A) L_{night} contour. This objective is not met by 0.1%;

- In combination E, only the L_{night} objectives are met, and only as a result of the reduction of the number of night flights to 27,000. Additional measures should be added to this combination in order to meet the L_{den} objectives.

6.2.1 Combination A

Combination A contains the most cost effective measures and takes into consideration the order of the Balanced Approach. This combination also contains the most cost-effective capacity reduction measure for the night flights to meet the L_{night} objectives. The last remaining capacity reduction measure, reduce annual number of movements to 440,000 movements (29,000 night flights), has not been selected in this combination to identify the gap between the outcome of this combination and the noise abatement objectives.

The measures have a significant impact on the noise impact within the higher contour values of 58 dB(A) L_{den} and 48 dB(A) L_{night}. Specifically the measure to partially close runway 09/27 (Buitenveldertbaan) during specific weather conditions contributes to this. This measure in combination with the measures to minimize the use of secondary runways by forcing 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 and extending the night regime during the evening from 21:40 and during the morning until 07:00 results in a drop in the number of movements on the non-preferential runways. Other measures or a larger capacity reduction is however required to meet the objective of 20% reduction in the number of highly annoyed people within 48 dB(A) L_{den} contour.

6.2.2 Combination B

Combination B is similar to combination A, but takes into consideration additional capacity reduction (reduction to 440,000 movements per annum (29,000 night flights)) to meet the objective of 20% reduction in the number of highly annoyed people within 48 dB(A) L_{den} contour. Consequence of the addition of the measure to reduce the volume to 440,000 movements per annum (29,000 night flights) is that three of the four noise abatement objectives are significantly higher than the targets. This is in conflict with article 5(6) of EU regulation No. 598/2014[24].

6.2.3 Combination C

Following combination B, combination C shows that the objective of 20% reduction in the number of highly annoyed people within 48 dB(A) L_{den} contour can also be achieved by combining the measure to reduce the number of night flights from 32,000 to 25,000 movements instead of the measure to reduce the volume to 440,000 movements per annum (29,000 night flights). This does however has a significant effect on the L_{night} objectives, which are met by some margin. This is again in conflict with article 5(6) of EU regulation No. 598/2014.

6.2.4 Combination D

Combination D is an attempt to meet all the objectives without overshooting the targets as a result of the combination of measures from the reduction of noise at source and noise abatement operational

[24] Article 5(6) from EU regulation 598/2014 states: *Measures or a combination of measures taken in accordance with this Regulation for a given airport shall not be more restrictive than is necessary in order to achieve the environmental noise abatement objectives set for that airport.*

procedure pillars. This is however in conflict of the way the Balanced Approach methodology works, since that would require member states to first consider all available measures from the first 3 pillars before considering a capacity restriction.

The result of combination D is however a combination of measures that meets the noise abatement objectives with little to no margin for three of the four objectives. This does better suits article 5(6) of EU regulation No. 598/2014.

6.2.5 Combination E

Combination E has been used to simulate the effect of reducing the night flights to 27,000, meeting all the L_{night} objectives, and limiting the number of operational measures to just one. This combination shows that more reduction of noise at source, operational measures or operating restrictions should be taken in order to meet the L_{den} objectives.

7 Perspective to 2027

This research primarily focusses on the measures until November 2024. However, the efforts to reduce the noise impact and associated nuisance by the airport, ANSP, airlines and government is a continuous process and don't stop in November 2024. Therefore, some perspective on which autonomous developments will occur and the potential impact of additional measures until 2027 is desired.

This perspective is provided by rerunning a number of steps that were performed for the situation in November 2024:

1. The autonomous developments and expected impact until November 2027;
2. Check the longlist of measures and see whether additional measures do meet all selection criteria when considering 2027 as the timeframe;
3. Qualitatively determine the noise reduction of additional measures

7.1 Autonomous developments until 2027

The following developments are expected from November 2024 to the end of 2027:

- Fleet renewal and retrofitting;
- Improved navigation performance;
- Local route optimizations (although uncertain whether this will actually occur due to decision making process);
- Improved planning of inbound aircrafts.

These developments will result in a reduction of the noise exposure per movement and an overall reduction of the number of houses, highly annoyed people and severely sleep disturbed people. Fleet renewal and retrofitting is expected to result in an additional 0.3 dB reduction for arrivals and 0.6 dB reduction for take-offs (in line with the long-term trend of 0.1 dB reduction for arrivals and 0.2 dB reduction for take-offs per year).

Improved navigation performance and optimization of current routes and procedures will result in the ability to further minimize the number of houses, highly annoyed people and severely sleep disturbed people on existing routes. Although the impact of this will depend on the decision making process of proposed optimisations. This touches mostly upon the discussion whether dispersion or concentration of noise is desired or not, since the improved navigational performance will allow more concentration.

Several developments will also result in higher predictability of traffic, and more specifically the planning of inbound traffic is expected to be improved. This improvement will result in an optimisation of existing capacity and will reduce non-preferential runway use when possible.

7.2 Longlist of additional measures

For the perspective to 2027, the longlist of measures (see paragraph 4.1) has been used again to identify additional measures which meet all the selection criteria, if the achievability criteria is changed from November 2024 to November 2027. The following measures were identified to meet all the criteria with a focus on November 2027:

- Stimulate use of quieter aircraft through financial instrument (including airport charges);

- Optimization of current procedures (minimize level segments, optimize climb-out speed, intersection take-offs, reduced thrust take-off etc.);
- Introduction of new procedures (including RNP-AR approaches during parallel approaches);
- Increase the number of continuous decent approaches;
- Increase concentration of flightpaths to minimize overall noise exposure.

7.3 Impact of additional measures in 2027

Fleet renewal is an effective way of reducing the noise impact and further stimulating this perfectly aligns with the Balanced Approach philosophy of starting noise reduction at the source. Similar to the measure described for 2024, and additional measure for 2027 could be to further stimulate the use of quieter aircraft by giving a discount on airport charges to less noisy aircrafts and charging noisy aircraft. This measure would provide additional noise reduction (if successful) on top of the autonomous developments already expected regarding fleet renewal.

Insulation

Insulating houses (through conventional insulation, noise cancelling windows or other technology available by 2027) will result in a reduction of the noise exposure inside the houses. The effect of insulating houses will not be visible when performing ECAC Doc29 compliant noise modelling, since the output of the model is noise exposure on the façade of the houses. Although insulation has proven to be effective to reduce nuisance, it has not been considered an additional measure since the impact of the measure isn't visible in the output of the ECAC Doc 29 noise model.

IenW is preparing a new round of insulation for houses within the 60 dB(A) L_{den} contour. The consultation phase is currently ongoing and the investment decision is due to be made in 2023. It is currently unclear how many houses will be insulated.

To provide some context: 3,028 houses are situated within the 60 dB(A) L_{den} contour in the baseline scenario, which includes autonomous developments until November 2024. This number will decrease as a result of the autonomous developments expected until 2027.

A number of additional measures are ready to be implemented in 2027 within the noise abatement operational procedures pillar. Further optimisation of current procedures is expected to reduce the noise impact, but is highly reliant on the decision making process around the optimisation. Recent history has shown that optimizing current procedures often leads to a different distribution of noise and is less likely to be accepted by all parties involved. Some reduction may therefore be expected, e.g. local route optimisations which is beneficial for all stakeholders, but no major reductions can be expected.

The introduction of new procedures is an ongoing process, for which both technological and procedural developments need to be made. The introduction of new procedures (including RNP-AR approaches during parallel approaches) is part of the PBN roadmap[25] as published by IenW. The implementation of

[25] https://www.luchtvaartindetoekomst.nl/binaries/luchtvaartindetoekomst/documenten/publicaties/2021/05/27/performance-based-navigation-pbn-roadmap-for-the-netherlands-2020-2030/PBN+Roadmap+for+the+Netherlands+2020-2030.pdf

these new procedures is expected to take until 2030 and the potential to reduce the noise impact in the area around the airport affected by these changes. Although it can be seen as an autonomous development, an additional measure could be to see whether these new procedures can become operational earlier in time under specific conditions. There is however a strong dependency of technological advancements and procedural implementations that need to be taken into account.

Whether an increase in continuous decent approach and new procedures are feasible, is partly depended on the progress Dutch Airspace Redesign Programme, which is currently expected to be implemented from 2026 onwards. The potential impact of the measures is therefore also depended on the outcomes of this programme.

A Appendix A – Technical input noise modelling

This appendix contains the technical input that was used to perform the noise modelling. This appendix consists of the following paragraphs:

- Model used to quantify noise impacts, model settings and received input
- Baseline scenario
- Additional measures
- Combination of measures
- Post-processing of data

Model, model settings and received input

The Schiphol noise modelling tool (SCM) has been made available to To70 by the Royal Schiphol Group to perform this study. Within the SCM tool, the 2023 traffic forecast, along with all relevant underlying input data, was made available to To70 to use as a starting point for this study. This noise module of the SCM tool is ECAC Doc 29 compliant.

Baseline scenario

Starting point for this research was the 2023 traffic forecast with 495,485 movements (31,300 night flights). A number of modelling steps were taken to model the baseline scenario, which includes the autonomous developments and has 500,000 movements (32,000 night flights):

1. The impact of an increased arrival runway capacity is simulated by changing the 'periods' table in SCM. For the summer period, one period (20:00 – 20:20) has been changed from L to O. For the winter period, one period (15:20 – 15:40) has been changed from L to O.
2. The resulting traffic has been exported to incorporate the additional changes required:
    a. The number of movements in the day and evening period (07:00 – 23:00) is scaled to 468,000 movements using one scale factor on all traffic rows;
    b. The number of movements in the night period (23:00 – 07:00) is scaled to 32,000 movements using one scale factor on all traffic rows;
    c. The number of movements has been scaled to account for the 0.1 dB reduction for landings and 0.2 dB reduction for departures to simulate the impact of fleet renewal;
    d. For arrivals, reduced flaps arrival procedures were selected for all arrivals, where flight profile data was available to simulate this effect;
    e. For arrivals on runway 18C and 06 during 2+1 runway use (period 'L') the default CDA procedure was selected, where flight profile data was available to simulate this effect;
3. The resulting traffic was run through the model to determine the noise impact.
4. The resulting noise output is corrected by upscaling the number of movements to account for:
    a. Missing input data;
    b. Standard general aviation correction of 2.5%.

The noise grid was exported for every meteorological year (1971 to 2018) to make one noise envelope. This noise envelope contains the maximum noise level for all the meteorological years in each grid point, while accounting for exceptional meteorological years.

Additional measures

The noise envelope of the baseline scenario is used as a starting point for all additional measures. This paragraph contains the technical description of the changes that were made to the baseline scenario to model the additional measures and the most relevant differences to the traffic.

Stimulate use of quieter aircraft through revision of airport charges

Aircraft types were assigned to a noise category based on appendix II of Schiphol Airport's airport charges, levies, slots and conditions for the period between April 2023 and April 2024. Assigning aircraft to noise categories in this way can be described as optimistic, since this 'safety net' approach is used when no noise certification levels are available. The following rules have been created (in collaboration with Decisio and Beelining) to determine assumptions of the response by the airlines (operating S1 aircraft) to this measure:

- KLM, with its base at Schiphol Airport, doesn't have the ability to react to this measure. All S1 aircraft from KLM remained in the scenario;
- 75% of the S1 aircraft movements of larger network carriers were changed to aircrafts in the S2 till S7 noise categories, if an alternative aircraft is available in the fleet of the airline;
- 25% of the S1 aircraft movements of smaller airlines and low-cost airlines were changed to aircrafts in the S2 till S7 noise categories, if an alternative aircraft is available in the fleet of the airline;
- 100% of freight carriers is replaced, assuming that another airline replace the S1 movements made by freight operators

These rules result in the following changes:

S1 aircraft type	Total movements in baseline scenario	Number of movements replaced by S2 till S7 aircraft	Number of movements remaining S1 aircraft type	Replacement aircraft
A306	470	398	72	A320 and A20N
A30B	69	69	0	A320 and A20N
A310	22	17	5	A330
A319	109	82	27	A20N
A320	51,370	36,804	14,566	A20N and A21N
A321	21,222	10,261	10,961	A20N and A21N
B733	199	131	68	B38M and A220
B734	180	96	84	B38M and A220
B735	10	8	2	B38M and A220
B763	2,328	1,639	688	B788 and B789
DH8D	10,423	6,515	3,908	E175
Total	**86,836**	**56,344**	**30,492**	**-**

Retrofitting aircraft through certified aerodynamic adjustments of engines and/or wings

Commonly, airlines have a number of options to retrofit their aircraft through the installation of, for example, chevron nozzles or vortex generators. These modifications provide aerodynamic advantages that can improve fuel efficiency and/or reduce noise. Such adjustments to airline fleets are already being implemented by airlines that operate at Schiphol Airport.

With regard to the noise aspect of such measures, a number of assumptions need to be made in order to quantify the effect in terms of L_{den} or L_{night}. The noise modelling data does not provide differentiation between the various retrofit modifications that airlines can choose from. Retrofitting measures are therefore not considered as a separate measure, but it must be acknowledged that this measure does contribute to a reduction of the noise impact.

Extending the night regime

For this measure, the periods tables of the baseline scenario are adjusted to simulate an extension of the night regime. The following changes were made for the two variants:

- Extension of the night regime in the evening from 22:40 to 21:40
    - The period selection is changed in between 21:40 – 22:40 to period 'N', which is used for the night regime
- Extension of the night regime both in the evening from 22:40 to 21:40 and in the morning from 06:40 to 07:00
    - The period selection is changed in between 21:40 – 22:40 to period 'N', which is used for the night regime
    - The period selection is changed in between 06:40 – 07:00 to period 'N', which is used for the night regime

This measure will have an effect on the runway use and therefore on the total number of movements per runway. The following changes are observed:

Direction	Runway	Total movements in baseline scenario	Extend night regime during the evening from 21:40	Extend night regime during the evening from 21:40 and during the morning until 07:00
Landing	04	2	2	2
	06	45,715	45,863	46,067
	09	26	24	21
	18C	39,384	40,286	40,213
	18R	95,837	94,906	94,968
	22	3,278	3,235	3,222
	24	547	541	541
	27	22,234	21,568	21,449
	36C	14,133	14,756	14,810
	36R	28,901	28,877	28,764
Take-off	04	6	5	5

	06	22	26	40
	09	9,940	9,780	9,676
	18C	3,599	3,750	3,856
	18L	63,158	62,070	61,430
	22	19	17	17
	24	84,883	85,492	85,873
	27	948	872	857
	36C	22,781	22,018	21,912
	36L	64,586	65,912	66,276
Total		**500,000**	**500,000**	**500,000**

The hourly capacity of the operational night regime is less compared to the hourly capacity of day time operations. This might cause delays, causing aircraft to land or take-off in a different day-evening-night bracket. The impact of these delays is not taken into account for the noise simulation.

Partial closure of runway 09/27 (Buitenveldertbaan) during specific weather conditions

To simulate the impact of partial closure of runway 09/27, changes are made to the 'runway use' table, which contains (empirical) data about which runway combinations are selected under specific weather conditions. The table contains the following unique columns:

- Day/night (day or night)
- Wind direction (in degrees from 0 to 360)
- Wind speed (in knots)
- Visibility (good, marginal or bad)
- UDP (yes or no)
- Runway combinations + frequencies

A total of 3020 unique weather combinations are part of the table. Each unique row in the table contains frequencies of runway combinations used in the reference period (2019) during those circumstances. E.g. one of the rows describes the following frequencies of runways used under the following conditions:

- Conditions
    - Day
    - Wind direction is 340
    - Wind speed is 26 knots
    - Visibility is good
    - Within UDP (yes)
- Runway combinations (incl. frequencies)
    - 36L+36C/06+36R → 13
    - 36L+36C/06 → 74
    - 36L/36R+36C →18
    - 36L+24/27 → 69

This example shows that three runway combinations without the use of either runway 09 or 27 were used 105 (=13+74+18) times in the reference period and one combinations was used 69 times with runway 27.

The runway use table is used in the SCM tool to forecast the use of runways given the flight schedules, the periods table and meteorological conditions. By removing combinations with runway 09/27 in the runway use table, less use of runway 09/27 can be simulated.

Combinations with runway 09/27 are removed from the runway use table, except for the following unique day/night, wind, UDP and visibility combinations:

- For conditions where runway 09/27 is the only or part of all selected runway combinations;
- For conditions where runway 09/27 has the highest frequency of being used;
- When visibility is classified as bad, even if 09/27 runway is not part of the runway combination with the highest frequency.

This measure will have an effect on the runway use and therefore on the total number of movements per runway. The following changes are observed:

Direction	Runway	Total movements in baseline scenario	Partial closure of runway 09/27 (Buitenveldertbaan) during specific weather conditions
Landing	04	2	2
	06	45,715	48,318
	09	26	26
	18C	39,384	44,328
	18R	95,837	99,784
	22	3,278	3,560
	24	547	244
	27	22,234	9,864
	36C	14,133	11,696
	36R	28,901	32,237
Take-off	04	6	7
	06	22	23
	09	9,940	5,817
	18C	3,599	3,726
	18L	63,158	69,298
	22	19	18
	24	84,883	81,889
	27	948	692
	36C	22,781	26,131
	36L	64,586	62,341
Total		**500,000**	**500,000**

Minimize the use of secondary runways

For this measure, the periods tables are adjusted to simulate less use of secondary runways during 07:00 – 08:00 and 13:00 – 15:00 . The following changes were made to the periods table

- The period selection is changed in between 07:00 – 08:00 to period 'O', which represents an 'off-peak' situation with only one arrival and one departure runway in operation;
- The period selection is changed in between 13:00 – 15:00 to period 'O', which represents an 'off-peak' situation with only one arrival and one departure runway in operation.

This measure will have an effect on the runway use and therefore on the total number of movements per runway. The following changes are observed:

Direction	Runway	Total movements in baseline scenario	Minimize use of secondary runways
Landing	04	2	2
	06	45,715	49,940
	09	26	37
	18C	39,384	33,089
	18R	95,837	101,338
	22	3,278	3,024
	24	547	526
	27	22,234	23,778
	36C	14,133	12,583
	36R	28,901	25,743
Take-off	04	6	7
	06	22	23
	09	9,940	8,773
	18C	3,599	3,336
	18L	63,158	55,271
	22	19	18
	24	84,883	93,843
	27	948	856
	36C	22,781	18,382
	36L	64,586	69,432
Total		**500,000**	**500,000**

Reduce the annual number of night flights

The number of movements in the night period is reduced from 32,000 to 29,000, 27,000 and 25,000 movements through a pro rata reduction per airline. For the reduction to 29,000 movements, flights were removed from the first and last hour of the night period (between 23:00 – 00:00 and between 06:00 – 07:00) as was assumed to be expected. In case this method did not yield the target of flights that were to be removed, flights were removed in

the adjacent hour blocks, that are further away from the edges of the night period. This iterative process of selecting adjacent hour blocks to remove flights was performed until the target was reached. This results in most flights being removed closest to the edge of the night period.

A further reduction of the number of flights from 32,000 to 27,000 and from 32,000 to 25,000 was achieved by downscaling the number of night movements of the scenario with 29,000 night flights to 27,000 and 25,000 respectively.

The number of flights removed from the night were placed back in the day and evening. Flights were added to the adjacent hour blocks of the night period, i.e. between 22:00 – 23:00 and between 07:00 – 08:00, which was assumed to be expected.

This measure will have an effect on the runway use and therefore on the total number of movements per runway. The following changes are observed for the number of movements per runway within the night period (23:00 – 07:00):

Direction	Runway	Total movements in baseline scenario	Reduce the number of night flights to 29,000	Reduce the number of night flights to 27,000	Reduce the number of night flights to 25,000
Landing	04	0	0	0	0
	06	7,204	6,619	6,162	5,706
	09	2	2	2	1
	18C	888	818	762	705
	18R	10,500	9,646	8,980	8,315
	22	28	27	25	23
	24	14	13	12	11
	27	1,337	1,237	1,152	1,066
	36C	977	885	824	763
	36R	189	183	171	158
Take-off	04	0	0	0	0
	06	3	3	3	3
	09	145	125	117	108
	18C	188	169	158	146
	18L	934	799	745	689
	22	0	0	0	0
	24	5,214	4,613	4,296	3,977
	27	7	6	5	5
	36C	252	221	205	190
	36L	4,117	3,633	3,382	3,132
Total		**32,000**	**29,000**	**27,000**	**25,000**

Reduce the annual number of movements to 440.000 movements

The scenarios with 440,000 movements are based on the baseline scenario. At first, the number of movements during the day and evening have been reduced to 408,000 (for variant with 32,000 night flights) and 411,000 (for variant with 29,000 night flights) according to a pro rata reduction per airline or airline segment, taking into consideration the expected reactions from airlines to this reduction. The assumptions associated with this approach have been made in collaboration with Decisio and Beelining. The following reactions by airlines and airline segment have been assumed:

- KLM
    - First, movements on very low-frequency intercontinental routes (less than 3x per week) will be removed;
    - Secondly, the remaining flights (until the reduction target is reached) will be reduced on European routes with 2 or more airlines operating on that route.
- Transavia
    - Flights with less than 10 movements per year will be removed first;
    - Secondly, the number of movements over all remaining destinations will be removed proportionally.
- Delta Air Lines
    - Movements to destinations were the total combined number of movements from KLM and Delta is the least will be removed.
- TUI
    - Flights with less than 10 movements per year will be removed first;
    - Secondly, the number of movements over all remaining destinations will be removed proportionally (excluding movements from and to intercontinental destinations).
- Other legacy carriers
    - The number of movements will be reduced on only one destination, if airline only operates from and to one destination;
    - If airline operates from and to two or more destination:
        - First, identification of hub and non-hub destinations have been performed;
        - Secondly, proportional reducing the number of movements on non-hub destinations;
        - Reduction of movements from an to hub destination if required to meet reduction target.
- Low-cost carriers
    - Movements have been reduced on routes with the least amount of movements, resulting in routes to be removed from schedule or reduction on a route;
- Freight operators
    - If an airline operates from and to two or more destinations, movements will be reduced to destinations where alternative freight operations are available;
    - If the airline operates from and to one destination, the number of movements to and from this destination have been reduced.
- Charter operators
    - Flights with less than 10 movements per year will be removed first;

- Secondly, the number of movements over all remaining destinations were removed proportionally.

- Others
  - If the airline operates from and to one destination, the number of movements to and from this destination will be reduced
  - If an airline operates from and to two or more destinations:
    - Flights with less than 10 movements per year will be removed first;
    - Secondly, the number of movements over all remaining destinations were removed proportionally.

After the simulation of market reactions, the schedule has been adjusted accordingly. This was done by linking as many take-offs and landings as possible that are also connected in the schedule (based on airline, time, aircraft type etc.). Subsequently, these movements were removed as a pair in accordance with the market reactions. If no link could be made, the required number of take-offs and landings per airline was removed at random.

Shift to larger aircraft to compensate for reduction of movements

It is expected that some airlines will use alternative aircraft within their fleet to fly from and to Schiphol Airport if the number of movements of that airline is capped. In this way the airline would be able to mitigate (some) of the loss of movements by flying with larger aircraft, with more seat capacity, and therefore increasing the number of passengers on the remaining movements.

This behaviour of airlines to change aircraft types to compensate for the loss of movements has not been taken into account within this measure. It was deemed not feasible to determine the right assumptions, which airlines will show this behaviour and to what extent. This in contrary to behaviour of airlines which movements are most likely to be kept when the total number of movements will be capped.

Using larger aircraft usually results in an increase in noise exposure, since larger aircraft are often heavier and therefore produce more noise. This trend is however changing since latest generation aircraft are significantly less noisy then older generation aircraft. So if changes occur, e.g. a 737-800 or Embraer 190 is being replaced by an A321Neo, it results in a similar sized noise footprint even though an A321Neo is heavier and can carry more passengers.

The number of movements for the night period were reduced for the variant with 29,000 movements in accordance to the description from the 'Reduce the annual number of night flights' measure.

All operational tables that are part of the noise modelling (routes, procedures, runway selection, etc.) have not been changed, with the exception of the periods table. The period table was changed to match the expected peak period (double peak, start peak, landing peak and off-peak) to the number of movements remaining per 20 min period. This has been done by analysing the remaining number of movements in the scenario with 440,000 movements with the baseline scenario. In this way, the peak periods match the reduction of number of movements. The changes were made separately for the winter period and the summer period.

This measure will have an effect on the runway use and therefore on the total number of movements per runway. The following changes are observed:

Direction	Runway	Total movements in baseline scenario	Reduce annual number of movements to 440,000 movements (32,000 night flights)	Reduce annual number of movements to 440,000 movements (29,000 night flights)
Landing	04	2	2	2
	06	45,715	42,242	41,954
	09	26	30	30
	18C	39,384	31,980	32,113
	18R	95,837	86,551	86,330
	22	3,278	2,769	2,798
	24	547	472	473
	27	22,234	20,306	20,370
	36C	14,133	11,721	11,701
	36R	28,901	23,985	24,121
Take-off	04	6	6	6
	06	22	21	21
	09	9,940	8,146	8,201
	18C	3,599	3,169	3,170
	18L	63,158	51,431	51,736
	22	19	16	16
	24	84,883	79,232	79,080
	27	948	783	788
	36C	22,781	17,956	18,092
	36L	64,586	59,180	59,000
Total		**500,000**	**440,000**	**440,000**

Post-processing data

The resulting noise grids per meteorological year are exported from the SCM tool. The noise envelope is created by taking the maximum noise level per grid point across all meteorological years, while accounting for exceptional meteorological years. These are 1981, 1984, 1993, 1994, 1996, 2000, 2002, 2010 for the L_{den} noise grids and 1973, 1976, 1980, 1987, 1994, 1995, 1996, 2010 for the L_{night} noise grids.

Next, the 2021 residential data is combined with the noise envelope grid files to determine the noise levels at each individual house location. The number of houses within contours is determined by counting the number of houses with noise levels at or above the relevant level of the criteria. The 2021 residential data also contains the number of residents per house. This number is used in combination with the Schiphol Airport dose-response relation (as being used in the latest EIA), to determine the number of highly annoyed people and severely disturbed people within the L_{den} and L_{night} contours respectively.

B Appendix B – Scoring of longlist measures

A score has been given to all measures for all the selection criteria. This has been done qualitatively using a pass or fail scoring system. If the measure meets the selection criteria, it is awarded a '+'. If the measure fails to meet the selection criteria it is awarded a '–'. If it wasn't clear whether the selection criteria is met or not, a neutral score was awarded (o). A measure is selected for the shortlist if all selection criteria received a positive or neutral score. A neutral score at the safety and/or modelling selection criteria also excludes the measure from a pass to the shortlist.

Pillar	Measure	Safety	Achievability in 2024	Accordance with legislation	Quality of the network	Reliability of operation	Distribution of nuisance	Emissions	Modelling
Reduce noise at source	Stimulate use of quieter aircraft through financial instrument (including airport charges)	+	+	+	+	+	+	+	+
	Stimulate use of quieter aircraft through noise performance monitoring	+	O	+	+	+	+	+	-
	Stimulate noise reducing retrofitting aircraft (winglets, engine exhaust modifications, etc.)	+	O	+	+	+	+	+	O
Land-use planning and manage-ment	Insulation (conventional insulation, noise cancelling windows, etc.)	+	-	+	+	+	+	+	-
	Expropriation	+	-	+	+	+	+	+	-
	Building conditions and restrictions (including noise adaptive building programs)	+	+	+	+	+	+	+	-
	Change function of buildings (conversion of offices to homes and vice versa)	+	-	+	+	+	+	+	-
Noise abatement operatio-nal procedures	Increase the number of continuous decent approaches (on top of autonomous development)	+	-	+	+	+	+	+	+
	Increase the number of aircraft performing N-1 taxi operations / taxibot taxi operations	+	-	+	+	+	+	+	-
	Route optimizations to reduce overall number of highly annoyed people	+	-	+	+	O	+	+	O
	Optimization of current procedures (minimize level segments, optimize climb-out speed, intersection take-offs, reduced thrust take-off etc.)	O	O	+	+	O	O	O	O
	Introduction of new procedures (including RNP-AR approaches during parallel approaches)	+	-	+	+	+	+	+	O
	Increase concentration of flightpaths to minimize overall noise exposure	+	-	+	+	O	+	O	O
	Extend the night regime using the primary runways (both in the evening and during early morning)	+	+	+	O	O	+	+	+
	Runway closure (full runway closure or during specific circumstances)	+	+	+	+	O	+	+	+

Pillar	Measure	Safety	Achievability in 2024	Accordance with legislation	Quality of the network	Reliability of operation	Distribution of nuisance	Emissions	Modelling
	Increase runway capacity (on top of autonomous development)	+	-	+	+	+	+	+	+
	Increase crosswind and tailwind limits for runway selection process	O	O	+	+	O	+	+	O
	Minimize the use of the secondary runways	+	O	+	+	O	+	+	+
Operating restrictions	Introduce a ban on noisy aircraft (overall or during specific times of the day)	+	+	-	+	+	+	+	+
	Cap the number of annual movements (e.g. Dutch cabinet decision to reduce number of movements to 440,000)	+	+	O[26]	O	O	+	+	+
	Cap the number of movements during the night time	+	+	+	O	O	+	+	+
	Curfew/night-time closure	+	+	+	-	-	+	+	+
	Additional slot criteria	+	-	-	O	+	+	+	-

[26] This balanced approach procedure is part of the trajectory to determine whether the proposed capacity is most cost-effective, hence the neutral score

C Appendix C – EU Directive 2002/49/EC (END) criteria

This annex contains the results of the noise modelling of the baseline scenario, the additional measures and the combination for the following EU Directive 2002/49/EC (END) criteria:

- Number of highly annoyed people within the 55 dB(A) L_{den} contour
- Number of houses within the 55 dB(A) L_{den} contour
- Number of severely sleep disturbed people within the 50 dB(A) L_{night} contour
- Number of houses within the 50 dB(A) L_{night} contour

Measure or combination	Reduction compared to the baseline scenario			
	Number of highly annoyed people within 55 dB(A) L_{den}	Number of houses within 55 dB(A) L_{den}	Number of severely sleep disturbed people within 50 dB(A) L_{night}	Number of houses within 50 dB(A) L_{night}
Baseline scenario	18,193	19,860	1,393	2,648
Additional measures				
Stimulate use of quieter aircraft through revision of airport charges (M1)	17,264 (-5.1%)	18,782 (-5.4%)	1,224 (-12.1%)	2,337 (-11.7%)
Extend night regime during the evening from 21:40 (M7)	17,623 (-3.1%)	19,200 (-3.3%)	1,393 (-0%)	2,648 (-0%)
Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7)	16,860 (-7.3%)	18,269 (-8.0%)	963 (-30.9%)	1,866 (-29.5%)
Runway closure (partial closure of the Buitenveldertbaan during specific weather conditions) (M8)	17,128 (-5.9%)	18,627 (-6.2%)	698 (-49.9%)	1,326 (-49.9%)
Minimize use of secondary runways (M10)	17,193 (-5.5%)	18,715 (-5.8%)	1,393 (-0%)	2,648 (-0%)
Reduce annual number of movements to 440.000 movements (32.000 night flights) (M14)	14,657 (-19.4%)	15,830 (-20.3%)	1,393 (-0%)	2,648 (-0%)
Reduce annual number of movements to 440.000 movements (29.000 night flights) (M14)	14,137 (-22.3%)	15,227 (-23.3%)	873 (-37.3%)	1,704 (-35.6%)
Reduce night flights to 29.000 movements per annum (M15)	17,713 (-2.6%)	19,334 (-2.6%)	873 (-37.3%)	1,704 (-35.6%)
Reduce night flights to 27.000 movements per annum (M15)	17,365 (-4.6%)	18,938 (-4.6%)	688 (-50.6%)	1,364 (-48.5%)
Reduce night flights to 25.000 movements per annum (M15)	16,967 (-6.7%)	18,470 (-7.0%)	532 (-61.8%)	1,036 (-60.9%)
Combination of measures				
Combination A	13,761 (-24.4%)	14,840 (-25.3%)	399 (-71.4%)	704 (-73.4%)
Combination B	11,208 (-38.4%)	12,045 (-39.4%)	399 (-71.4%)	704 (-73.4%)
Combination C	13,207 (-27.4%)	14,250 (-28.2%)	291 (-79.1%)	510 (-80.7%)
Combination D	12,602 (-30.7%)	13,494 (-32.1%)	667 (-52.1%)	1,294 (-51.1%)
Combination E	16,107 (-11.5%)	17,435 (-12.2%)	571 (-59.0%)	1,099 (-58.5%)

D Appendix D – Intermediate steps combination of measures

This annex contains the results of intermediate steps that are modelled to better understand the effect that measures have on each other within combinations of measures. The following intermediate steps have been modelled for combination A, B, C and D[27]:

- Intermediate step T1
  - Minimize the use of secondary runways by 'forcing' 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10), and
  - Reduce the number of night flights from 32,000 to 29,000 movements (M15).
- Intermediate step T2
  - Minimize the use of secondary runways by 'forcing' 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10),
  - Reduce the number of night flights from 32,000 to 29,000 movements (M15), and
  - Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7).
- Intermediate step T3
  - Minimize the use of secondary runways by 'forcing' 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10),
  - Reduce the number of night flights from 32,000 to 29,000 movements (M15),
  - Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7), and
  - Partial closure of runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8).
- Intermediate step T5
  - Minimize the use of secondary runways by 'forcing' 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10), and
  - Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7).
- Intermediate step T6
  - Minimize the use of secondary runways by 'forcing' 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10),
  - Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7), and
  - Partial closure of runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8).
- Intermediate step T7
  - Minimize the use of secondary runways by 'forcing' 1+1 runway use between 07:00 – 08:00 and 13:00 – 15:00 (M10),
  - Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7),
  - Partial closure of runway 09/27 (Buitenveldertbaan) during specific weather conditions (M8), and

[27] Combination E does not have an intermediate step since it only has two measures.

- Stimulate use of quieter aircraft through revision of airport charges (M1).

- Intermediate step T10
  - Extend night regime during the evening from 21:40 and during the morning until 07:00 (M7), and
  - Stimulate use of quieter aircraft through revision of airport charges (M1).

Intermediate steps T1, T2 and T3 are related to combination A, intermediate steps T5, T6 and T7 are related to combination B and C and intermediate step T10 is related to combination D. The following table provides an overview of the results of the intermediate steps in relation to the result of the combination.

Intermediate step or combination	**Reduction compared to the baseline scenario**			
	Number of highly annoyed people within 48 dB(A) L_{den}	Number of houses within 58 dB(A) L_{den}	Number of severely sleep disturbed people within 40 dB(A) L_{night}	Number of houses within 48 dB(A) L_{night}
T1	-5.5%	-5.7%	-11.3%	-13.9%
T2 (incl. T1)	-10.1%	-8.5%	-14.5%	-20.6%
T3 (incl. T2)	-14.1%	-32.0%	-18.3%	-24.3%
Combinaton A	-17.6%	-35.5%	-18.6%	-25.7%
T5	-7.7%	-5.5%	-5.6%	-7.3%
T6 (incl. T5)	-11.7%	-28.8%	-9.1%	-10.5%
T7 (incl. T6)	-15.2%	-31.9%	-9.5%	-11.4%
Combination B	-29.8%	-49.5%	-18.6%	-25.7%
Combination C	-21.1%	-42.5%	-33.8%	-56.8%
T10	-8.2%	-6.7%	-6.1%	-9.0%
Combination D	-24.1%	-20.4%	-14.9%	-22.0%