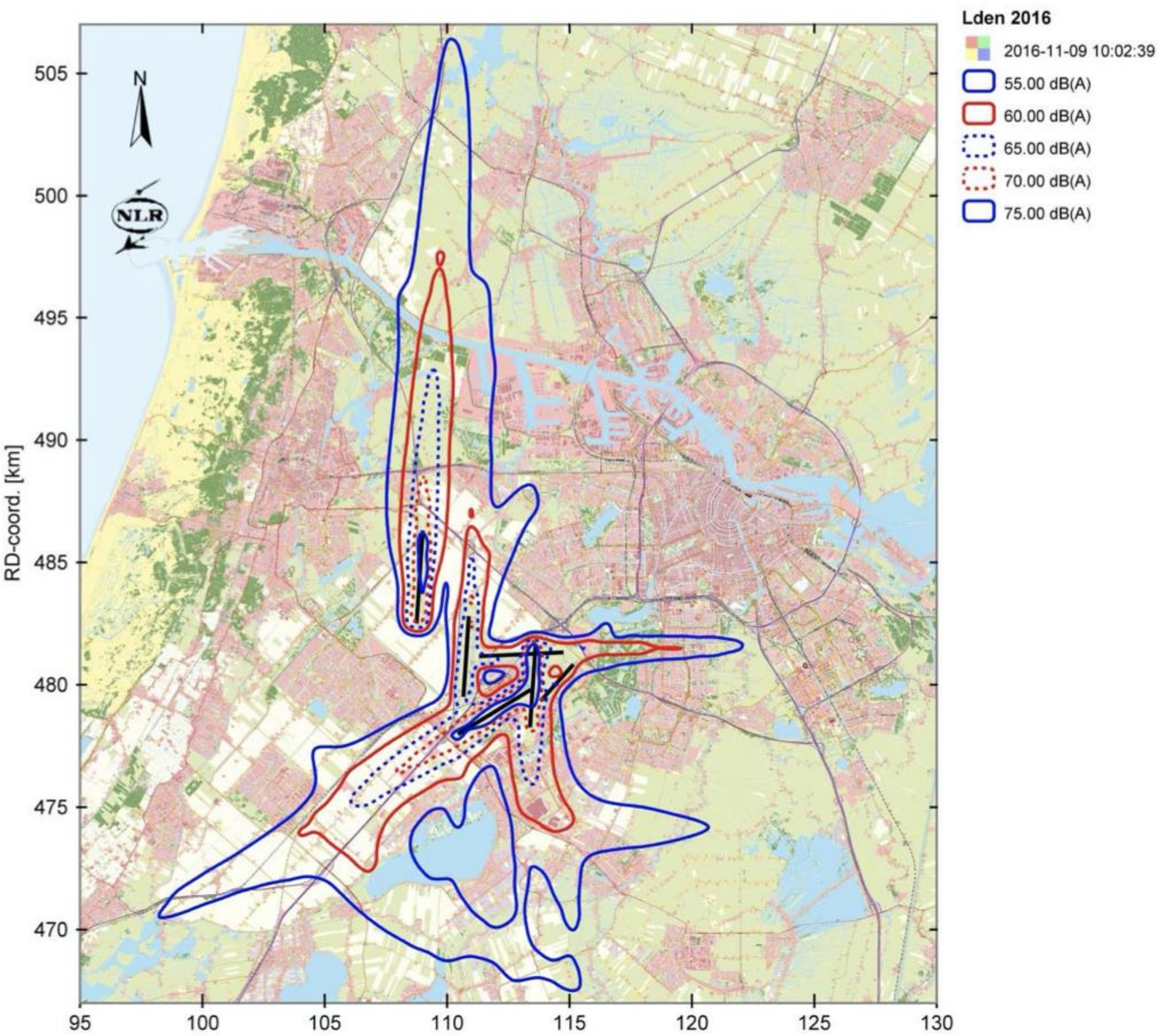
ANIMA
Aviation Noise Impact Management through Novel Approaches

Case Study – Schiphol Airport

Introduction to the airport



Schiphol airport, surrounding communities and L_{den} noise contours

(source: Actieplan Schiphol 2018-2023)

Amsterdam Schiphol Airport is the main international airport of the Netherlands and is located 9 kilometres southwest of Amsterdam. In 2018, 71 million passengers travelled from, to or via Amsterdam Airport Schiphol, thus it is the third busiest airport of Europe in terms of passenger volume. There are 326 direct destinations reachable from Schiphol, resulting in 499.446 air transport movements. Air transport movements consist of 36.9% transferring passengers and 1.7 million tonnes of cargo transported [2]. Schiphol Airport ranks as the world's fifth busiest airport in terms of international passenger traffic and the world's sixteenth busiest for cargo tonnage. The Schiphol Airport passengers increased by 4% in 2018 as a result of an increased number of aircraft movements. The economic impact in 2016 was estimated at $27.3 billion US dollars. The terminal infrastructure consists of one-terminal concept that includes three large departure halls serving local airlines and as a European hub. Schiphol Airport has six runways, covering a total area of

2.79 ha land. The runway use at Schiphol Airport is shown in Figure 1.1. Red coloured flight tracks indicate departures while blue coloured flight tracks indicate take-offs. Schiphol is mainly approached from the North Sea and Flevoland, which is an artificial, low populated island.

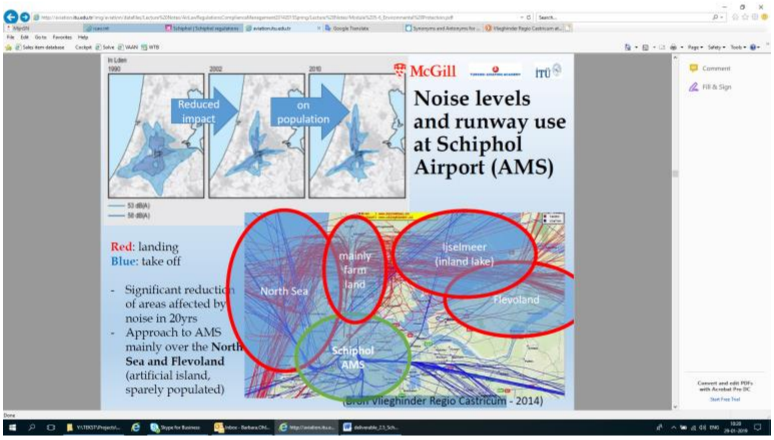


Figure 1.1: Runway use at Schiphol Airport indicating flight tracks for departures (red colour) and landings (blue colour)

The applicable noise regulations include regulations and limitations about handling the air traffic and noise regulations that relate to the "maximum amount of noise". The limitations of the runway system are stated in the Dutch airport traffic order [9]. Another view of all runways is shown Figure 1.2. The current noise regulations at Schiphol work on the basis of enforcement points such as the 24-hour period and the night period. A maximum L_{den} or L_{night} value applies to each of these points.

Approach to the Balanced Approach

In the Aeronautical Information Publication (AIP) Netherlands are details of regulations, procedures and other information pertinent to flying aircraft described [10]. Currently, applied noise and emissions restrictions at Amsterdam Schiphol Airport (AMS) are included in EHAM AD 2.21, under noise abatement procedures. The AIP Netherlands includes departure and arrival procedures that have proved to be highly efficient in respect of noise abatement in the vicinity of Schiphol Airport. Deviations from the procedures are permitted for safety reasons. The noise *abatement procedures* are included in Table 1.2.

Table 1.2: Noise abatement procedures applied in the vicinity of Schiphol

Procedure	Explanation
Take-off and climb procedure	National abatement take-off and climb procedure NADP2 recommended for all jet aircrafts departures. If for operational reasons compliance with the recommended procedure is not possible, NADP1 may be used.
Minimum noise routing	Standard instrument departure routes aiming avoid residential areas as much as possible.
Reduced flaps	Reduced flaps landing procedure is recommended
ILS available	Minimum flaps setting with landing gear retracted

Non precision approach and visual approach	Following descent path using a minimum flap setting with landing gear retracted not lower than 5.2% (3.0 degrees), selecting gear down after passing 2000 ft AMSL and postponing minimum certified landing flap setting until passing 1200 ft AMSL.
Use of runways	a) As landing runway: 06, 18R, 36R, 18C, 36C, 27. b) As departure runway: 36L, 24, 36C, 18L, 18C, 09

Further noise restrictions include engine run-up, controlled APU (ground power units), operating quota in effect and a preferential runway system [10]. The runways at Schiphol Airport are selected by the Air Traffic Control (ATC) according to a preferential runway system. Principles accounted for in the runway system are prevailed traffic safety, departure and landing take place on separate runways, the influence of noise influence and traffic handling, wind and visibility criteria which are in accordance with the guidance material laid down in Annex 16-ICAO (Aircraft noise). The basic rule for the use of a runway combination is that Dutch ATC must handle the most preferred combination of available and usable runways from the runway preference table [10]. During the day basically all runways may be used depending on weather and safety conditions (see Figure 1.2). The primarily preferred runway during daytime is the Polderbaan (36L, 18R). In case of capacity restrictions, the second preferred runway during daytime, the Kaagbaan (06, 24) or the Aalsmeerbaan (36R, 18L) are used. During the nighttime between 23:00 and 06:00 CET the Kaagbaan (06), the Polderbaan (18R) and the Zwanenburgbaan (36C) may be used for landings. For starts the Polderbaan (36L), the Kaagbaan (24) and the Zwaanenburgbaan (18C) are allowed.

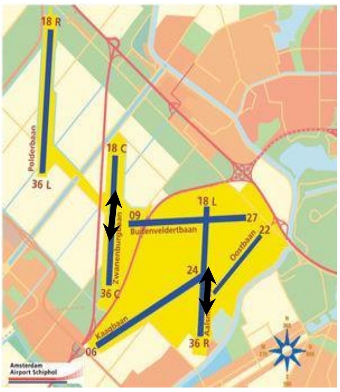


Figure 1.2: Runways at Schiphol Airport

Noise mitigation strategies and land-use planning have been applied in terms of sound insulation of residential and public buildings or by destructing houses and buildings.

1. Introduction to the case study optimisation of start procedures

Noise abatement operational procedures are applied to provide noise relief to communities around airports from both arriving and departing aircraft. Two specific noise abatement departure procedures (NADP's) were developed to mitigate air traffic noise. The NADP1 departure procedure is most effective in confining the noise impact within a small area around the airport [1]. NADP2 has a distant cross-over point to become quieter than NADP-1 and is most effective to reduce fuel consumption.
The difference between NADP1 and NADP2 with respect to the ground and flight speed and the lateral noise exposure is illustrated in Figure 1.3. The noise exposure is shorter due to a higher ground speed when NADP2 is used compared to NADP1 (see point 1 in

Figure 1.3. For the NADP2 departure procedure the flight altitude is lower, which results in a reduction of the lateral noise exposure (see point 2 in Figure 1.3).

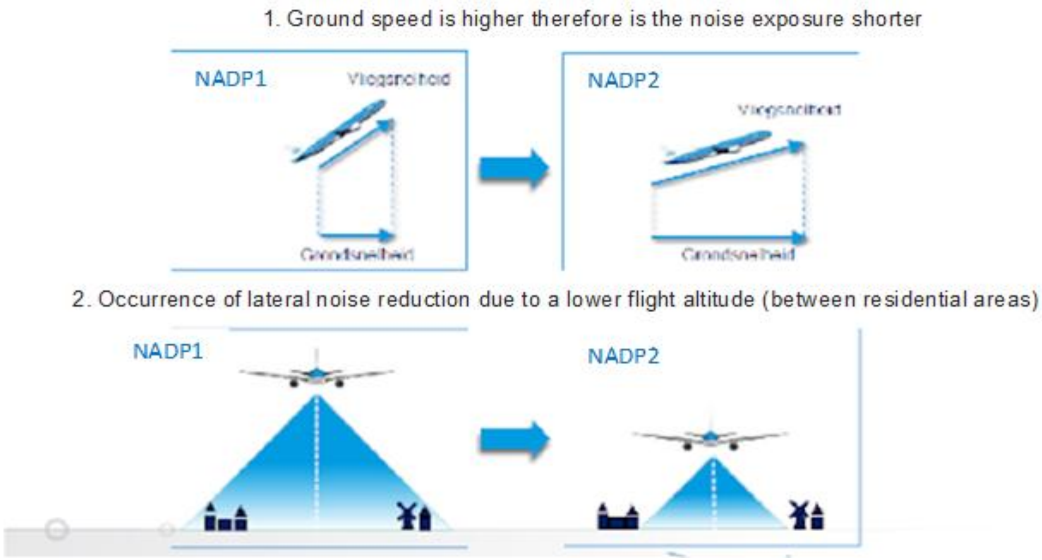


Figure 1.3: Comparison of the ground speed and the lateral noise exposure between NADP1 and NADP2. The NADP2 departure procedure leads to a reduction in noise exposure due to a shorter fly over event and a smaller lateral area of exposure, compared to NADP1.

The NADP describes the procedure in which the aircraft transits from the high take-off power having extended flaps and slats settings towards a climb phase using climb power and all flaps and slats are retracted [5, 6]. Overall, the thrust cutback is performed similarly between NADP1 and NADP2. The main difference is that the altitude at which the aircraft starts accelerating is reduced from 3000 ft (NADP1) to 1500 ft (NADP2) (see Figure 1.4). In other words, the noise abatement departure procedure includes a choice between thrust cutback altitude and acceleration altitude.

For the NADP1, the application of thrust cutback is done before the flaps and slats retraction. The climb thrust is selected at reaching 1500 ft altitude. At 3000 ft, the pitch angle is reduced such that the aircraft will climb and accelerate simultaneously.

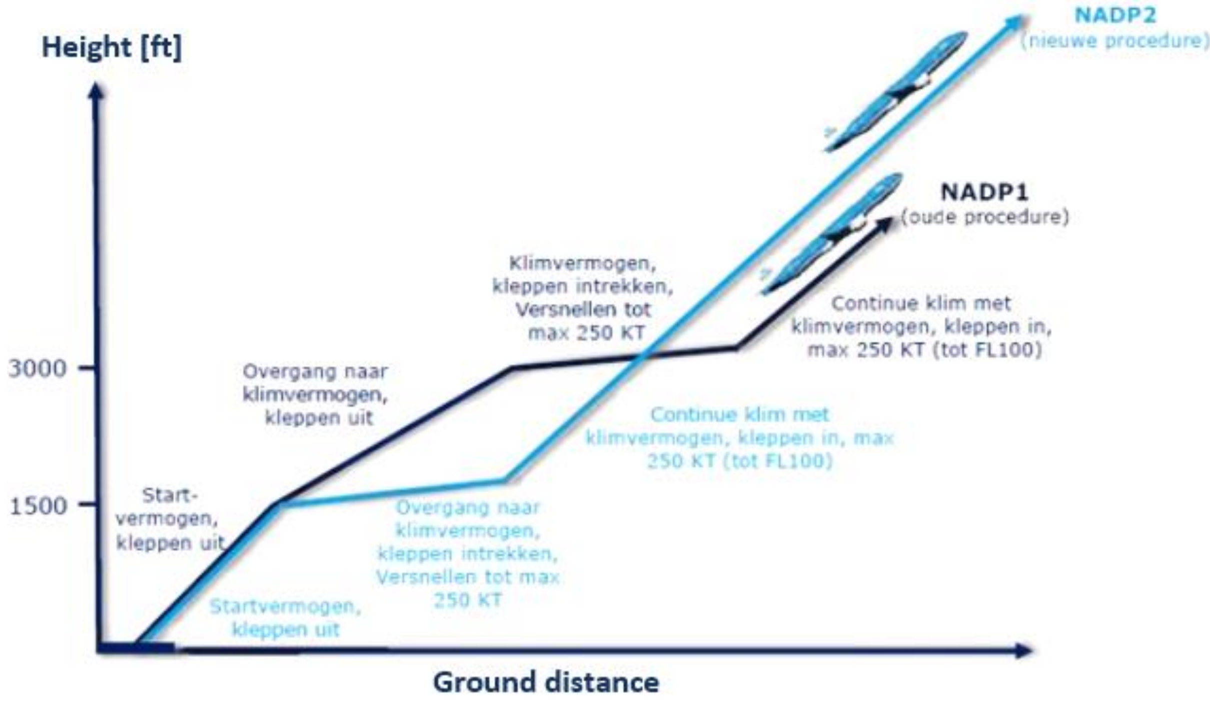


Figure 1.4: Illustration of the climb heights between NADP1 and NADP2. The NADP2 procedure starts with a steeper climb where the acceleration required for flaps and slats retraction starts at 1500 ft.

Delve into the processes behind the case

a. Identification of the 'need'.

Reducing the amount of fuel used during a flight has a direct beneficial impact on the airline. Financial benefits can be achieved related to fuel costs and related to the EU Emission Trading Scheme (ETS). Fuel reduction has additionally a positive impact on the climate. Applying the NADP2 departure procedure was expected to save approximately 20-60 kg of fuel per departure [7]. Along with fuel reduction the number of highly annoyed people was expected to reduce.

b. The design of options.

There was no knowledge of another approach that would result in comparable benefits.

c. The selection of the intervention.

Operations based results, meaning fuel savings, were used for decision making. The effect within the noise contours was beneficial too. Hence, both were overall positive and therefore the decision was to recommend this procedure to all airlines. The noise effect were assessed based on the legal criteria for L_{den} and the locally established dose response relationship. Adopting the departure procedures from NADP1 to NADP2 for Schiphol was more a change in an operational procedure than a decision. That is the reason why the communities were informed ahead of time before the departure procedures were changed, but they were not directly involved in the decision-making process.

d. Implementation

First calculations were carried out to estimate possible fuel saving and noise benefits. The noise-related calculations were based on models using the so called "Grid analysis". This analysis takes the number of houses within noise contours, the number of highly annoyed people and the number of people experiencing sleep disturbance into account. The

calculations were based on different traffic scenarios including only ArceFly flights or the full aircraft fleet at Schiphol Airport.
Flight simulator sessions were carried out to validate the calculated fuel savings and noise benefits. The calculations could be confirmed by the flight simulator sessions. Experiments with actual flight procedures were carried out during a three-month trial using live traffic observations. The data collection included in-flight data, flight information such as flight tracks and flight plans and noise measurements via the NOMOS monitoring stations.
Actual noise and fuel measurements were carried out to test whether the assumption based on calculations and simulations were true. Finally, the usage of the NADP2 departure procedure was expanded and applied for other airlines. Currently, 80% of all departures at Schiphol use the NADP2 procedure.

e. Post-Implementation evaluation.

The essence of the optimisation was defined by improving the overall noise conditions for the area. This means that fuel consumption and noise exposure were used as performance indicators for the overall outcome. Schiphol Airport is also legally bound to look at the overall noise contours. Not applying such an operational procedure could actually be problematic as it stops or limits innovation within the flight sector. Changing the departure procedure from NADP1 to NADP2 is beneficial for the climate, for the airlines and for the overall noise exposure. It comes, however, at the expense of those who live directly underneath the path where the differences are noticeable.

f. The use of metrics, trials, modelling, monitoring, interdependencies etc. will be discussed throughout these sub-sections.

- Experiment with actual flight procedures.

Several factors were analysed to test the calculated fuel consumption and noise levels. Those factors are summed up in Table 1.3.

	Procedure	**Operator**	**Period**
Experimental	NADP2	ArceFly, KLM	3 weeks
Reference	NADP1	Other airlines	Real life

Table 1.3: Overview of test conditions for measuring fuel consumption and noise levels on actual flight procedures

- Actual noise and fuel consumption measurements.

The noise monitoring system (NOMOS) of the Amsterdam Airport Schiphol was used to determine real, measured sound levels of the alternative NADP2 departure procedure. NOMOS consists of a network with more than 25 noise monitoring terminals located in residential areas around Schiphol Airport [8]. Not all 25 measurement terminals were required. The tested runway and route combination together with the relevant NOMOS measurement stations are shown in Figure 1.5.

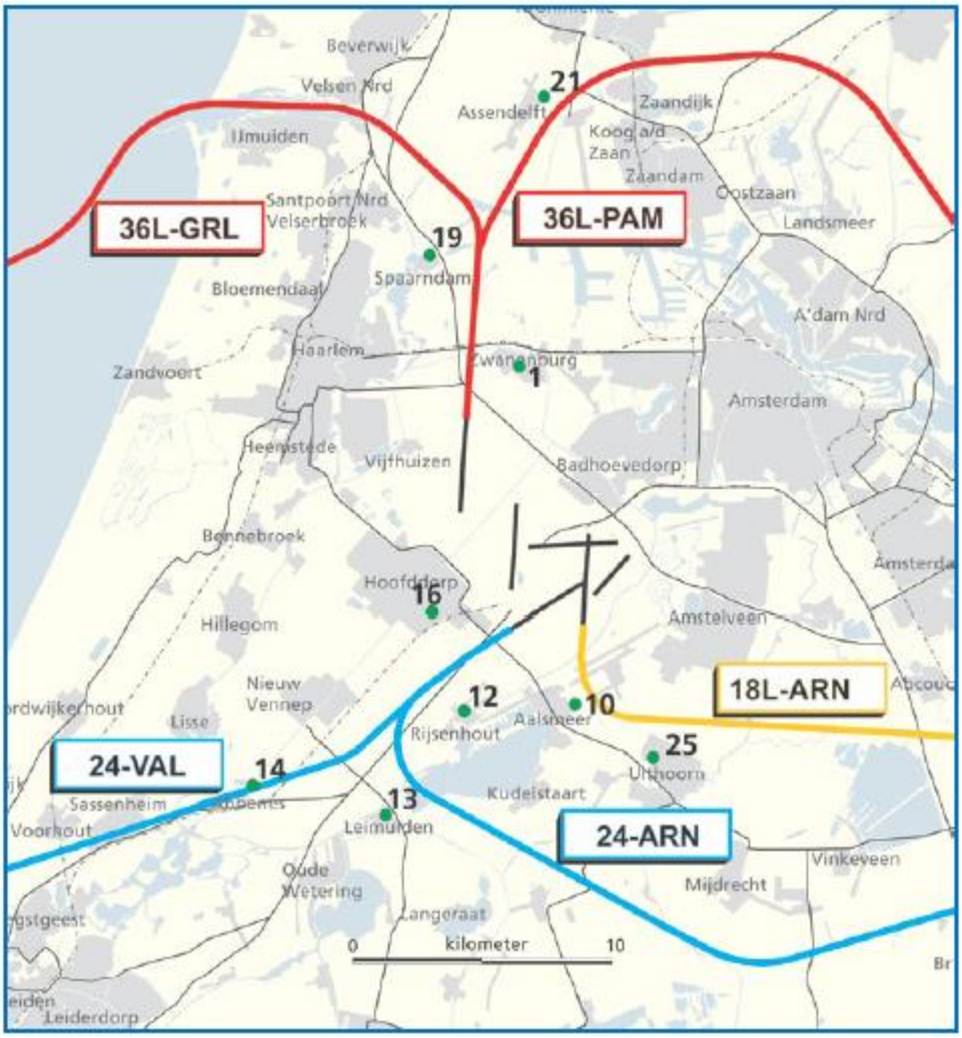


Figure 1.5: Schematic setup of the experimental comparison between reference and control aircraft groups.

In practice, is it very difficult to test two departure procedures under the exact same conditions. An experiment was carried out to determine the isolated effect of the NADP2 departure procedure. A number of pairwise comparisons of acoustic measurements between an experimental group of airplanes and multiple test groups were applied (see Figure 1.5).

- The experimental group of airplanes consisted of flights carried out by the experimental operator (ArceFly or KLM) using the NADP2 procedure. Acoustic and fuel consumption measurements were only carried out during the experimental period.
- The first control group (*Control group 1)* consists of flights carried out by different operators that are usually flying in daily life. This is the only difference between the experimental group and the first control group. All other conditions, including the same aircraft type, the same engine type, the same ICAO type designation and the same runway combination were consistent.
- The second control group (*Control group 2)* included flights that by different operators that are usually flying in daily life. The NADP1 departure procedure was tested during the experimental period of 3 weeks.
- The third control group (*Control group 3)* covered flight conducted by the experimental operator during daily life using NADP1 departures.

The likelihood of any difference in noise levels between the experimental group and the control groups was tested using hypothesis testing. The scheme of the experimental design is shown in Figure 1.6. The relevant comparisons between the experimental and the control group are indicated by green and yellow arrows.

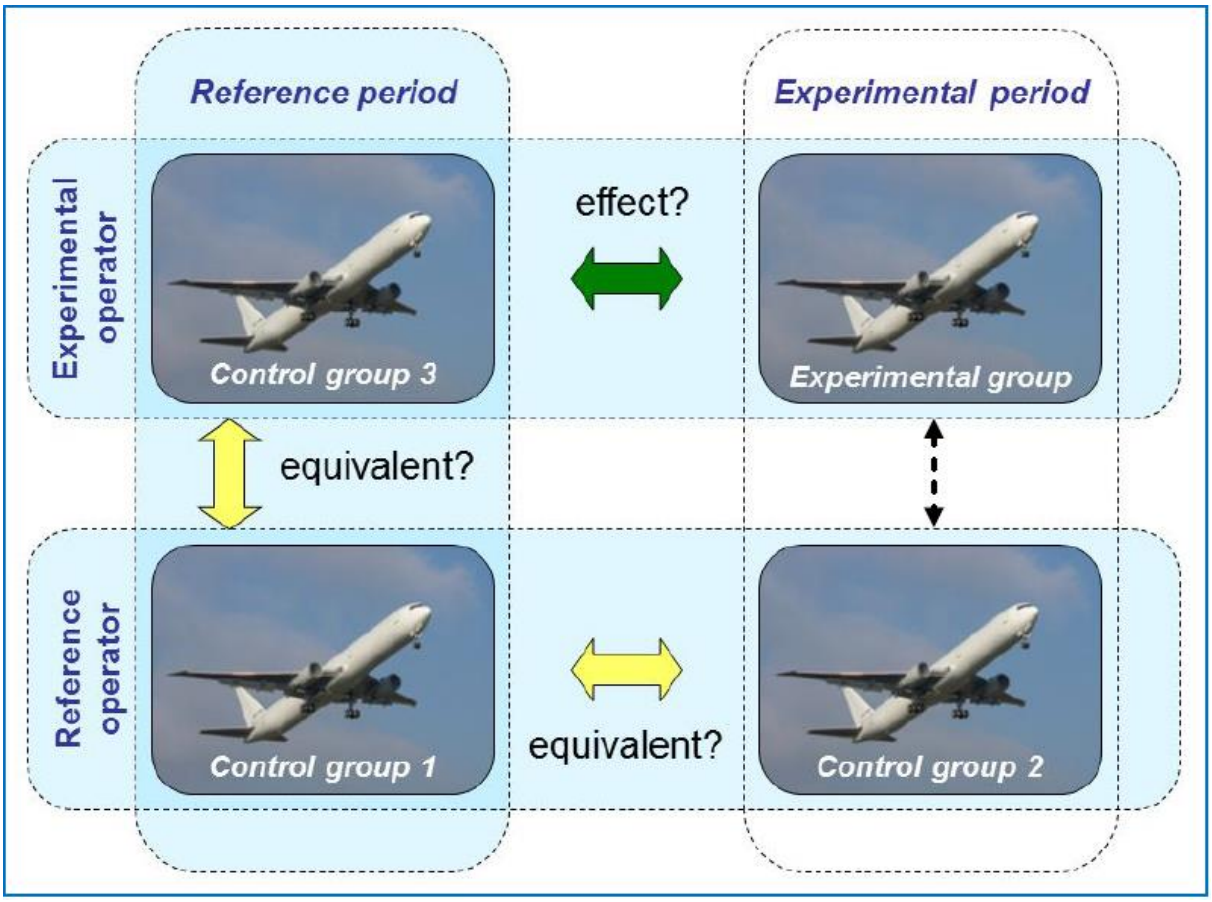


Figure 1.6: Schematic presentation of the experimental design. The measurements from the experimental group were compared with three control groups.

The influence of external and airline dependent disturbances in the acoustic measurements cannot be completely determined. Applied pairwise comparisons can provide a qualitative judgment about the likelihood of the effects of the alternative NADP2 departure procedure. However, the influence from external and airline dependent factors cannot completely be eliminated. To minimise the bias qualification, distinguished levels such as likely impact, probable effect, possible effect and non-significant effect were applied.

- Interdependencies

In terms of operational procedures, the priority was fuel consumption. If changing the departure procedure would have been framed as a noise mitigation measure, the whole project would have been treated differently and we would have been less independent. The question is, at what point is it smart and necessary to involve the local community? Are interdependencies really a matter that the local communities should decide? Because of the high number of critics, it is very important to be careful about how the message is presented and who it is presented to. Schiphol Airport tries to balance everyone’s interests in the best possible way, which also applies to for this project.

Summary of the whole airport case

The benefits assessments for NADP’s procedures are complex and may require detailed modelling in order to be well understood. The results confirmed the expected fuel reduction for the NADP2 procedure. The measured noise levels in residential areas show positive effects. Based on the dose-response relationship, the number of highly annoyed people living in the vicinity of Schiphol Airport decreased. However, drawing an overall conclusion with respect to air traffic noise is complicated. The benefit for the community depends on the location of the residential area.

References:

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