4 Microklimaat Leimuiden – Schiphol Airport

In the Netherlands, the Alderstafel is a consultation roundtable about the development of aviation in its environment. The Alderstafel is named after the chairman, former minister and commissioner of the Queen of Groningen, Mr. Hans Alders. The consultation table was set up in December 2006 to advise the cabinet on the development of Schiphol Airport in conjunction with Eindhoven and Lelystad airports. The Alderstafel aims for a balance between aviation development, nuisance-limiting measures, improving the quality of the living environment and the possibilities for using the space around the airport. With regard to Schiphol airport, the Alderstafel aimed for a reduction of aviation noise annoyance by limiting the number of flight movements in 2008, by promoting continuous descent approaches (CDA) and by optimizing departure and arrival routes. At the same time, Schiphol airport was aiming for growth, introduction of a new air traffic management (ATM) concept and new noise legislation. Together with the idea of growth, new traffic distribution rules were discussed related to the opening of Lelystad airport. The basis for the development of Lelystad Airport is Schiphol's market forecast. Until 2020, the market demand for traffic at Schiphol was expected to be 580,000 aircraft movements per year. The Alders Agreement stipulates that of these 580,000 aircraft movements, 510,000 movements will be able to take place at Schiphol. Capacity will be created at Eindhoven Airport and Lelystad Airport for 70,000 non-Mainport-bound aircraft movements. Both airports are part of Schiphol Group.

With the aim to reduce the noise exposure around Schiphol airport, the Mikroklimaat study in the areas of Rijsenhout and Leimuiden was carried out. In 2009, the departure route from the Kaagbaan to the east was, after a period of experimentation, definitively changed due to the reduction of noise exposure on Rijsenhout. However, the introduction of this change of route had a negative effect on the number of people exposed to aircraft noise in Leimuiden. The runway system at Schiphol airport is shown in Figure 3.

Figure 3: Schiphol runway system (www.vlieghinder.nl).

As a result, the municipality of Kaag en Braassem visited the Alderstafel in November 2011 and made a request for a Microklimaat study. On June 14, 2012, the Alderstafel decided on a Mikroklimaat project for Leimuiden. The flight tracks (see purple lines in Figure 4) for departures from the Kaagbaan are illustrated in Figure 4. The departure route passes both areas around Rijsenhout and Leimuiden (see red circles in Figure 4).

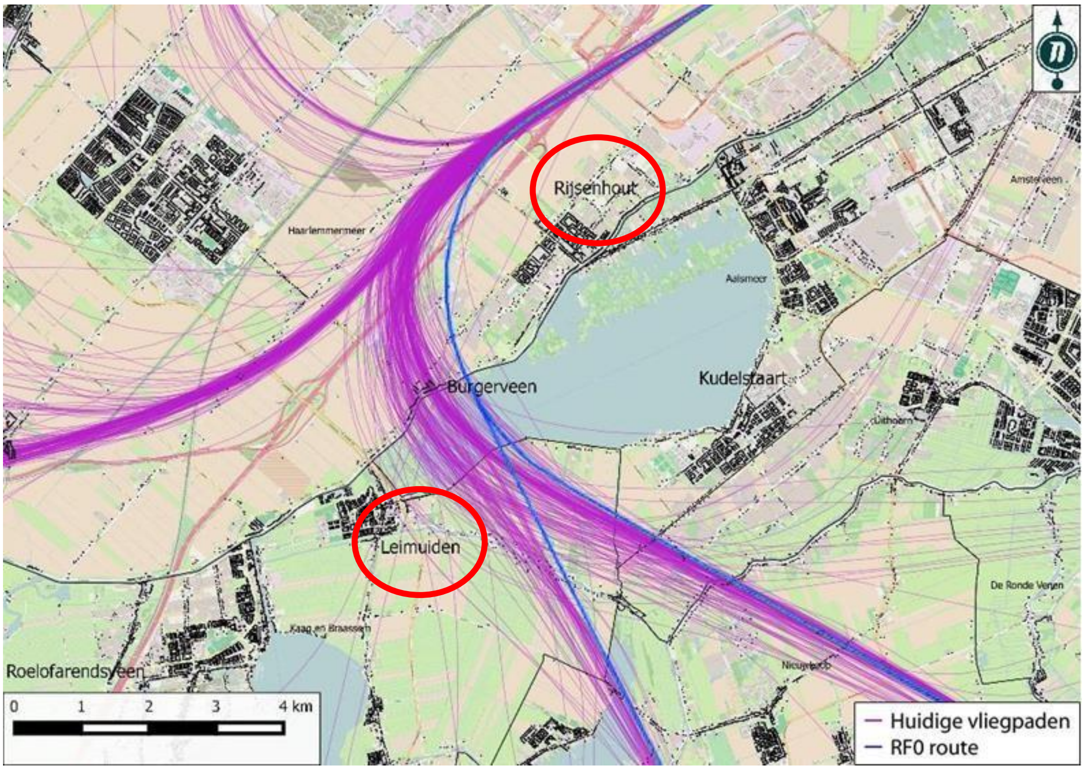

Figure 4: Flight tracks for the departure route from the Kaagbaan (www.rijsenhout.info.nl).

On December 11, 2014, the Alderstafel took a decision on the basis of a quick scan reprioritization of ongoing Mikroklimaat studies. For the Mikroklimaat Leimuiden, a recommendation was made to conduct further research into a combination of a new (optimal) design to fly a fixed curve radius. The original design of the departure procedure implemented during the Mikroklimaat Leimuiden study started in 2015 when a Mikroklimaat study on the area Rijsenhout, together with the implementation of the Noise Abatement Departure Procedure (NADP2) began.

The aim of the Microklimaat Leimuiden study was an optimization of the departure procedure. A radius-to-fix flight procedure was introduced. The purpose of the radius-to-fix was to concentrate flights while making a turn, preventing aircraft from flying spread out over a large inhabited area. In that way, the noise exposure is concentrated and fewer households are exposed to aircraft noise. It was hypothesized that a smaller number of noise exposed households would result in a smaller number of annoyed residents. The flight path was closer to Rijsenhout and further away from Leimuiden (see Figure 4 and Figure 5 for illustrations of the locations).

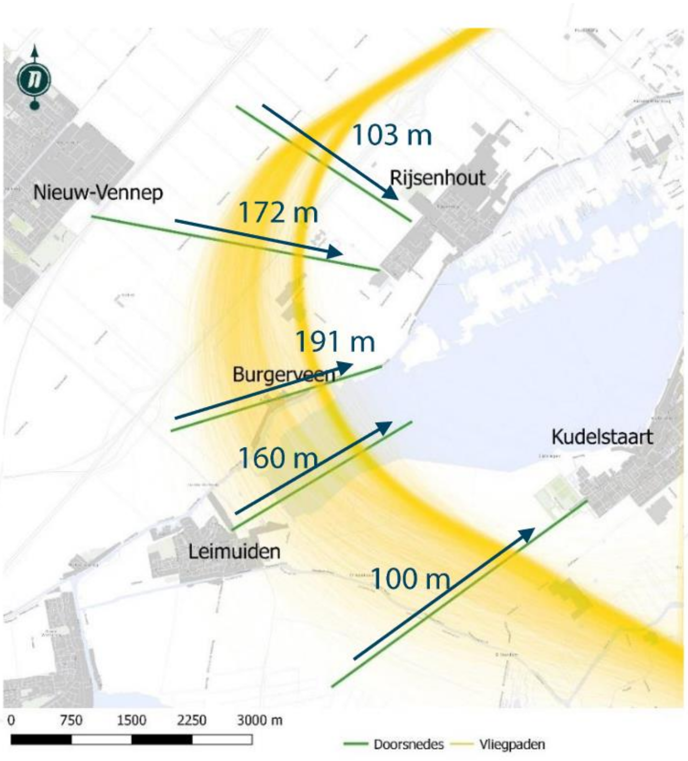

Figure 5: Departure flight paths including an illustration of the radius-to-fix turn (www.omgevingsraadschiphol.nl).

The flight path for the flight turn procedure is shown in yellow in Figure 5. By applying the radius-to-fix procedure, flight paths are less spread towards Leimuiden and more concentrated towards the north, in the direction of

Burgerveen, Kudelstaart and Rijsenhout. The implementation of the Leimuiden Mikroklimaat started in September 2015.

The success criteria for the implementation of the radius-to-fix departure procedure were defined as follows:

- Reduction in the estimated number of highly annoyed residents in surrounding 4 municipalities
- Reduction of the estimated number of highly annoyed residents within the 48 L_{den} contour
- For Rijsenhout, the noise exposure must not exceed the noise levels from before 2007
- For the municipality, Burgerveen, the number of annoyed residents must not increase
- An overall reduction of noise annoyance in Leimuiden

The radius-to-fix departure procedure was proposed, based on the above mentioned preconditions. The effects of this procedure were calculated by the consultant company To70 and assessed by a mixed group of stakeholders, including representatives from local municipalities, the local government, Community Council Schiphol (Omgevingsrad Schiphol – ORS) chairs, residents that were representatives within and outside the ORS and representatives from the Air Navigation Service Provider (ANSP), a hub-airline and the airport. The group of stakeholders was called the "working group".

In December 2015, the working group concluded that the collected research data on the alternative departure procedure provided sufficient information for the execution of an experiment. On January 27, 2016, after consultation of the respective constituencies, the radius-to-fix turn procedure was proposed for implementation.

Monitoring factors for the tested flight procedure were:

- Shift in lateral movements / ground paths of air traffic
- Concentration of flight bundles ("Poortjes Methode")
- Local pivot point ("locale draaipunt")
- Fixed curve radius ("vaste bochtstraal")

Within the current study, the radius-to-fix departure procedure was experimentally tested for approximately 40% of the air traffic during that time in 2017. The expected noise levels were calculated before and after the implementation of the procedure. Noise measurements were additionally carried out during the experimental period.

Within the working group, technical aspects of the departure procedure and the results from the calculations and measurements were presented and explained by external consultants from the consultant company To70. The measured peak noise levels (L_{Amax}) were averaged for the flight movements in 2017 (orange colour, Figure 6) and compared to the averaged peak levels for the flight movements in 2016 (blue colour, Figure 6). In Figure 6 the normalized flight movements are on the y-axis and the peak noise levels L_{Amax} in dB(A) on the x-axis. The data suggest that the normalized number of flights was higher for peak levels between 65 and 69 dB(A) in 2016 compared to 2017.

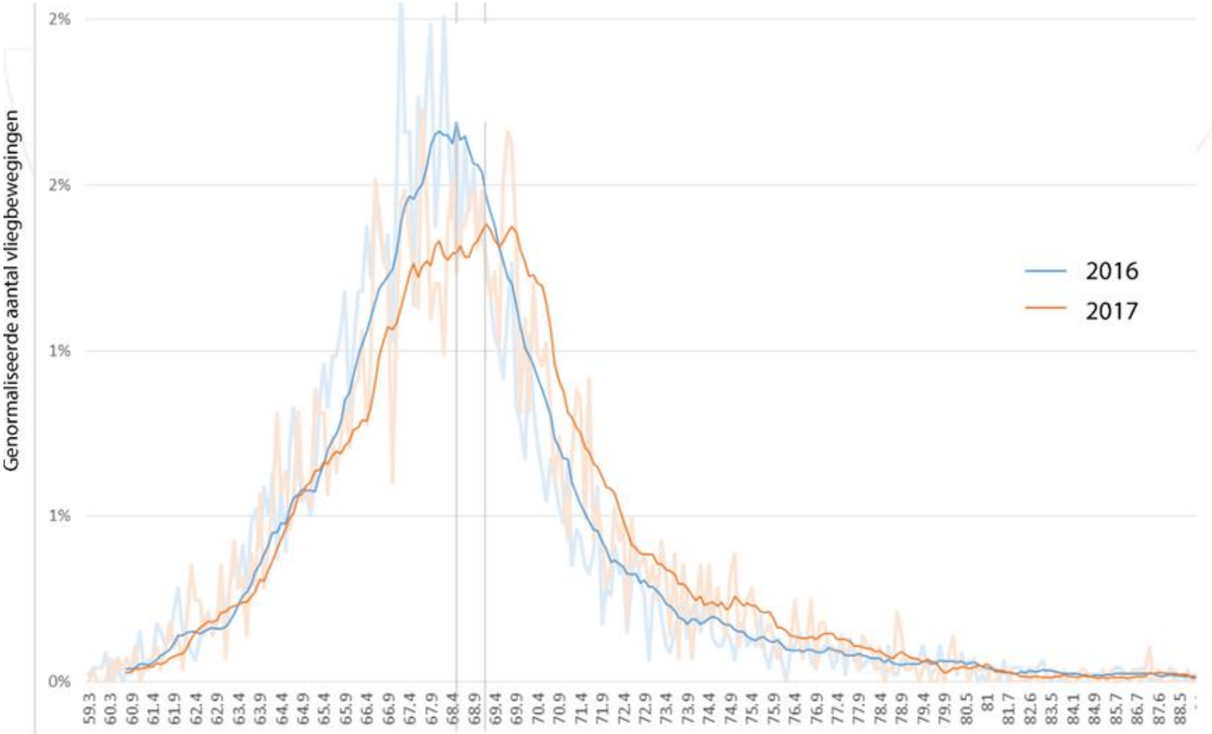

Figure 6: Normalized number of flights over peak noise levels (L_{Amax}) (www.omgevingsraadschiphol.nl).

Additionally, L_{den} levels were calculated for the departures from different runways at Schiphol airport (see Figure 7). The number of take-offs from and landings on the Aalsmeerbaan are higher in the second half of 2017 than in 2016. The second runway was used more intensively due to the increase in the number of movements at Schiphol. Overall, the average noise levels for 2017 seem to be lower compared to the average noise levels in 2016.

Within the ORS Regioforum, the decision for starting and monitoring the experiment was made. The information about the ongoing experiment was shared via local and social media.

In December 2017, the technical status was presented to the stakeholders within the working group. The technical results such as the calculations of noise levels promised a reduction of noise exposure. Most residents were supportive of the new departure procedure. However, there were also signs of doubts amongst the residents of Aalsmeer and Kudelstaart (for information on the location see Figure 4 and Figure 5).

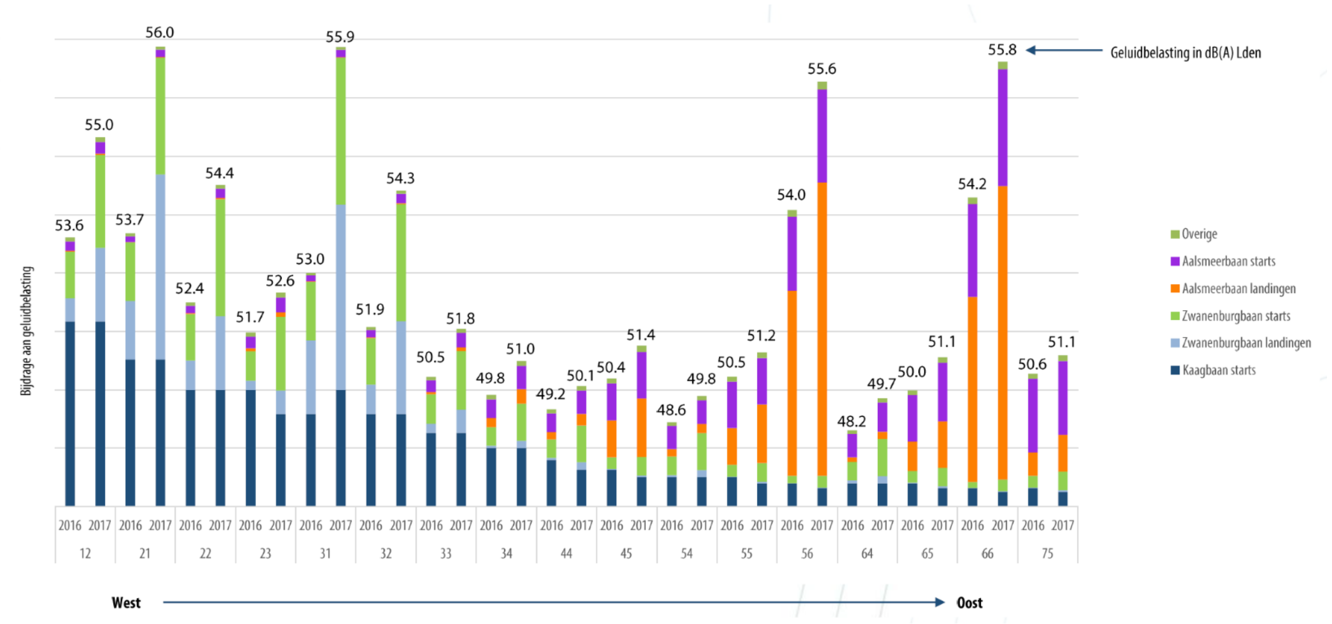

Figure 7: L_{den} noise levels for departures from different runways at Schiphol for 2016 and 2017 (www.omgevingsraadschiphol.nl).

Figure 8 shows the difference of noise exposure in dB for the percentage of residents for Kudelstaart and Leimuiden for 2016 and 2017. The exposure of higher noise levels, caused by air traffic, was higher in 2016 in Leimuiden compared to Kudelstaart. In 2017, the calculated noise exposure in Kudelstaart was higher than in 2016. In Leimuiden, the noise exposure was actually lower in 2016 than in 2017, but still higher than in Kudelstaart.

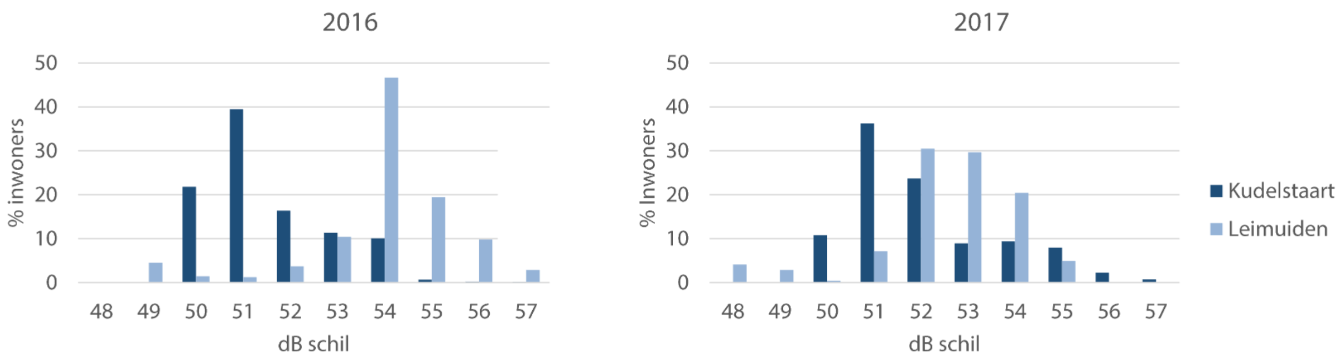

Figure 8: The percentage residents for Kudelstaart and Leimuiden across the difference in aircraft noise exposure between 2016 and 2017 (www.omgevingsraadschiphol.nl).

It was decided that the experiment should be continued to gather more detailed data. In 2018, a decision was made to carry out an annoyance perception study. During this study, input from the residents around Kudelstaart was provided. Reports and complaints around the area Kudelstaart were collected for the time between 2016 and 2018. The data was collected by the Residents Contact Point Schiphol (Bewoners Aanspreekpunt Schiphol - BAS). Notifications are automatically linked to a runway by BAS. Specific and periodic complaints were examined. Specific complaints are, for example, per flight, related to aircraft taking off from the Kaagbaan at a specific time. Periodic complaints are reports over a period. The specific complaints were analysed in 2018. The effect of the experiment was investigated by examining complaints and reports related to flights that flew the radius-to-fix turn departure procedure and a "control group" for flights that flew the original departure procedure (see Figure 9). The grey curve in Figure 9 indicates the total number of complaints, the light blue curve refers to the number of complaints related to the radius-to-fix turn procedure and the black curve refers to complaints related to the original departure procedure. The willingness to report complaints increased for the test groups exposed to the alternative departure procedure (radius-to-fix turn) and in the control group to a similar extent. There was no direct interaction between the increase in complaints and the Microklimaat study indicated.

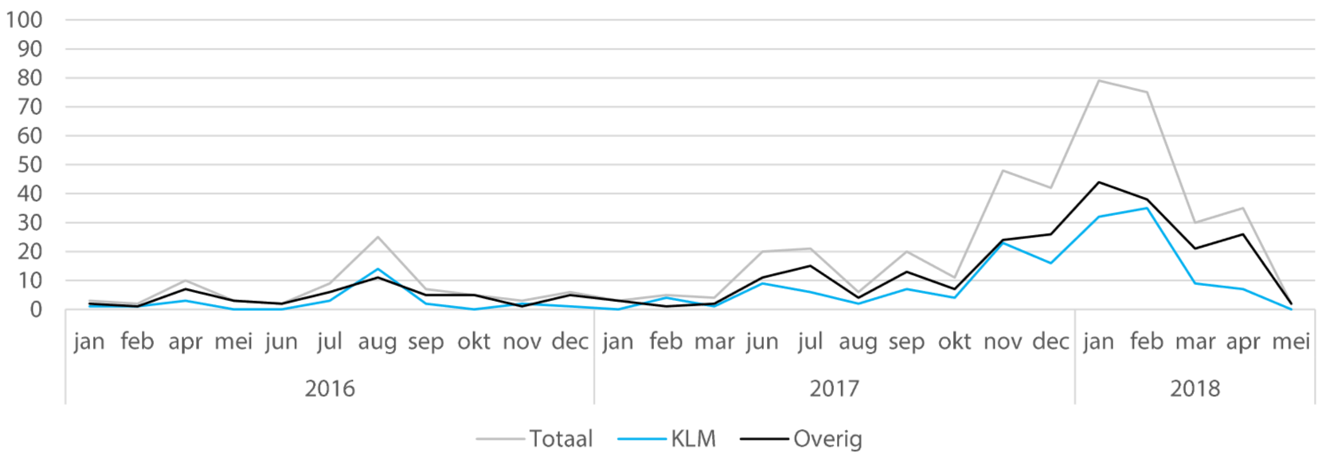

Figure 9: Number of complaints and reports between 2016 and 2018 (www.omgevingsraadschiphol.nl).

The overall number of complaints and the number of reporting persons has increased, which corresponds to the general trend for the Schiphol area (www.bas.nl).

A survey about the living environment, aircraft noise annoyance and residential satisfaction was conducted from November 2018 until October 2019. This survey was commissioned by the Community Council Schiphol. In total, a sample of 1,212 resident responses was collected. During the survey period, approximately 100 telephone interviews were conducted each month for the period of one year. The results of the survey are described further in section 4.2.

4.1 Distilling previous learnings

4.1.1 Methodology

In order to distil previous learnings, we applied the following key words for the literature search:

- Aviation AND noise annoyance AND quality of life AND intervention OR satisfaction OR living environment OR operational procedure

The literature search was applied using Google scholar. The above mentioned combination of keywords provided mainly results on wind turbines, urban development, traffic noise and health related aspects of quality of life. It was especially difficult to identify research related to quality of life and aviation.

4.1.2 Results

It was not possible to identify a large body of literature describing the implementation of comparable operational procedures in aviation. However, the annoyance response to aircraft noise exposure in general has been investigated. The annoyance response to stable and changing aircraft noise exposure has been assessed for changes in flight operations that have been carried out between 2001 and 2003 (Brink et al., 2008). A considerable number of early morning and late evening flight operations have been relocated around Zürich Airport to use another runway. In that way, the effects of a recent step decrease and recent step increase on the exposure-annoyance relationship were investigated. The results from the applied survey showed that residents experiencing a step increase elicited a quite pronounced 'over-reaction' of annoyance which correlated with the magnitude of the change (Brink et al., 2008). The residents' pronounced annoyance reaction was surprising for the authors as the upcoming changes in the flight regime were announced in the media for more than a year in advance. Brink et al. (2008) conclude that residents actually rate their annoyance based on real experienced exposure and not on any imaginary future noise scenario.

Another recent study investigated aircraft noise annoyance and health related quality of life (HQoL) before and after the opening of the 4th runway at Frankfurt Airport (Schreckenberg et al., 2016). The aim of opening the new runway was to increase the capacity of the number of operations from 83 to 120 flight movements per hour. Telephone surveys on the effects of transportation noise on annoyance, disturbances and HQoL, in addition to reported diagnosed health diseases and sleep quality, were carried out. The results suggested an association between HQoL and aircraft noise annoyance, noise sensitivity and aircraft noise exposure. The percentage of highly annoyed people was found to be higher than predicted from general exposure-response curves. It was found that the more residents were annoyed by aircraft noise, the poorer was their HQoL. All in all, the study showed that the impact of aircraft noise on residents living in the vicinity of an airport affects noise-specific stress reactions (annoyance, disturbances) as well as QoL in general (Schreckenberg et al., 2016, 2017).

Aircraft noise annoyance, disturbances, environmental (EQoL) and health-related quality of life (HQoL) were assessed within another survey in which data from 2,312 residents living near Frankfurt Airport was assessed (Schreckenberg et al., 2010). The survey data was compared with data on exposure due to aircraft, road traffic, and railway noise. Results indicate a link between HQoL and aircraft noise annoyance and noise sensitivity. The higher the aircraft noise annoyance, the lower the reported HQoL; especially for higher noise-sensitive participants. There was also a small effect of aircraft noise exposure on reported EQoL (Schreckenberg et al., 2010). A study by Wirth, Brink, and Schierz (2004) found that a high satisfaction with the acoustical characteristics of one's living environment is related to a decrease in noise annoyance. There was no effect with respect to non-acoustical characteristics and noise annoyance.

An effect of noise annoyance on residential satisfaction has also been identified for other noise sources (road and rail traffic; Urban & Máca, 2013); although, there was no influence of noise annoyance on overall life satisfaction.

The relationship between airports and multiple subjective wellbeing measures has been investigated for seventeen English airports (Lawton et al., 2016). The relationship was assessed by merging national household-level data (APS) with geographical location data on airport proximity (within 5 km) and objective measures of aviation noise contours (dB). The results suggest that the presence of daytime aviation noise has a consistent negative impact on five subjective wellbeing measures. A marginal negative association with every additional decibel of aircraft noise was found. The authors suggest a negatively associated effect of living within a daytime aircraft noise contour (at or above 55 dB) and lower life satisfaction, lower sense of being worthwhile, lower happiness, increased anxiety and lower positive affect balance. Overall, it was concluded that living under air traffic flight paths has a negative effect on peoples' overall and momentary wellbeing, equivalent to around half the effect of being a smoker for some wellbeing measures (Lawton et al., 2016). However, as the study took Leq day contours into account to assess noise exposure, it might be tricky to draw conclusions for noise exposure under air traffic flight paths.

4.1.3 Discussion

Currently decisions about operational changes of flight procedures around airports are typically based on calculations of average noise levels, technical aspects of flight procedures or the calculated number of households within a noise contour. Based on this kind of technical data, assumptions are made about the perception and annoyance of aircraft noise. Aircraft noise might affect the environmental quality of life more than road or railway noise and furthermore people of poor HQoL might suffer most from annoyance. Future research should seek to capture the effects of aviation on effective measures of well-being like happiness and anxiety and quality of life, through use of real-time surveys and real-time scenarios.

4.1.4 Conclusion

When residents around airports were able to listen to actual changes in operational flight procedures, the percentage of highly annoyed people was found to be higher than predicted from general exposure-response curves. The consideration and the decision-making process related to changes in operational flight procedures should not only be based on technical calculations of noise exposure and extrapolating from that to predicting annoyance. Rather airports need to adopt a more holistic approach complementing calculations with nuanced understanding of people's reactions regarding noise exposure. The residents' actual perception of aircraft noise and aspects of annoyance should also be taken into account in the decision-making process.

4.2 Survey data

A study was conducted with residents living in the vicinity of Schiphol Airport from November 2018 until October 2019. The study was commissioned by the Community Council Schiphol and conducted by the Dutch company Team Vier. The survey started one year after the implementation of the radius-to-fix approach. Leimuiden is located within the study area; however, the change in aircraft noise annoyance due to the radius-to-fix approach was not specifically addressed in the survey. The aim of the survey was to assess residents' experiences and perceptions of living in an airport's vicinity and identify relevant topics for residents and potential concerns regarding their living environment as the general number of complaints increased for the Schiphol area. The ANIMA research team received permission to use this data for further analyses. This survey data provides a general overview of residential satisfaction, noise annoyance due to different sources, certain days or times of day when specifically aircraft noise is annoying and disturbing, as well as aspects residents are mainly concerned about. In the following sections, the analyses are described and the results discussed.

4.2.1 Methodology

The study area was divided into three areas according to different levels of aircraft noise exposure:

4. Inner area (Binnengebied, close to the airport; 58dB L_{den}),
5. Outer area (Buitengebied; 48dB – 57dB L_{den}),
6. Area outside noise contour (Buiten contour; less than 48dB L_{den}),

with Leimuiden being located in the outer area with L_{den} ranging from 48dB to 57dB. Figure 10 depicts the three study areas on a map.

Figure 10: Map of region around Schiphol Airport indicating the three study areas. The red dot indicates the location of Leimuiden.

As less people live in the inner area than in the other two areas, a disproportionate stratified sample was used allowing for statistical comparison between the groups. The sample consists of 1.212 residents, aged 18 and older, which translates into a response rate of ca. 14%.

The following topics were covered in the survey: residential satisfaction (assessed using a 5-point scale ranging from 1= very satisfied to 5= very unsatisfied), duration of residence, noise annoyance and sleep disturbance due to various noise sources (according to ISO norm ISO/TS 15666, 2003; 11-point scale ranging from 0= not at all to 10= extremely), perception of the previous development of aircraft noise annoyance (answered using a 3-point scale where 1= increased, 2= stayed the same, and 3= decreased) as well as future expectations of aircraft noise annoyance (answered using a 3-point scale with 1= have increased, 2= have remained the same, and 3= have decreased), and frequency about being disturbed by aircraft noise in the past month (4-point scale with 1= often to 4= seldom or never). Item 10 was an open question asking whether participants can indicate days or times of day where they experience most aircraft noise annoyance. Participants, who then indicated certain days or times of day, were presented with questions specifically assessing when they experienced aircraft noise annoyance (n = 779). Moreover, worries about different topics such as the environment (answered on a 3-point scale ranging from 1= a lot of worries to 3= no worries) were assessed.

The data were analysed using SPSS 27.

4.2.2 Results

In the following section, the sample descriptions as well as the different analyses are presented. A description of the sample can be found in Table 2.

Table 2: Sample description.

		inner area	outer area	outside noise contour	Total
N		251	722	239	1212
Age	*m(SD)*	58.7 (13.2)	58.5 (13.9)	56.7 (13.2)	58.2 (13.6)
	min	18	18	19	18
	max	83	87	81	87
Sex	female	140	393	131	664
	male	111	329	108	548
Home office	always	18	20	13	51
	often	12	10	7	29
	regularly	19	49	24	92
	sometimes	32	89	32	153
	seldom/never	59	219	67	345
	missing & n/a	111	335	96	542
Duration of residence	0 - 5 years	20	92	36	148
	5 - 10 years	28	89	21	138

	10 – 20 years	62	206	78	346
	20 – 30 years	57	147	48	252
	> 30 years	84	188	56	328
Highest level of education	no education / basic education / civic integration course / Dutch language course	7	17	2	26
	LBO / VBO / VMBO (framework or profession-oriented learning pathway) / MBO 1 (assistant training)	15	42	8	65
	MAVO / HAVO or VWO (first three years) / ULO / MULO / VMBO (theoretical or mixed course) / secondary special education	37	94	32	163
	MBO 2, 3, 4 (basic vocational, professional, middle management or specialist training) or MBO old (before 1998)	58	178	66	302
	HAVO or VWO (transferred to 4th grade) / HBS / MMS	20	48	17	85
	HBO or WO propaedeutic year/HBO (except HBO master's programme) / WO candidate or WO	70	219	69	358

	bachelor's programme				
	WO-doctoral or WO-master or HBO-master / postdoctoral education	40	115	39	194
	n/a	4	9	6	19
Employment	fulltime	83	205	88	376
	part-time	58	183	55	296
	no	109	333	95	537
	n/a	1	1	1	3
Employment Schiphol	yes	11	23	7	41
	no	130	365	136	631
	missing & n/a	110	334	96	540
Ownership	owner	206	489	168	863
	rent	44	233	70	347
	missing	1	0	1	2
Residential satisfaction	very unsatisfied (5)	8	14	2	24
	unsatisfied (4)	18	23	6	47
	neither satisfied nor unsatisfied (3)	24	45	14	83
	satisfied (2)	125	377	121	623
	very satisfied (1)	75	262	96	433
	missing	1	1	0	2

	m(SD)	2.05 (1.02)	1.83 (.85)	1.73 (.75)	1.85 (.86)

m = means; SD = standard deviation

On a scale from 1 to 5 (1=very satisfied, 5=very unsatisfied), average residential satisfaction is 1.85 (*SD*=.87), showing an overall high residential satisfaction. Only 12.9% of participants were not satisfied with their living environment. Participants stating that they were very unsatisfied mentioned aircraft noise annoyance as the main reason (See Figure 11).

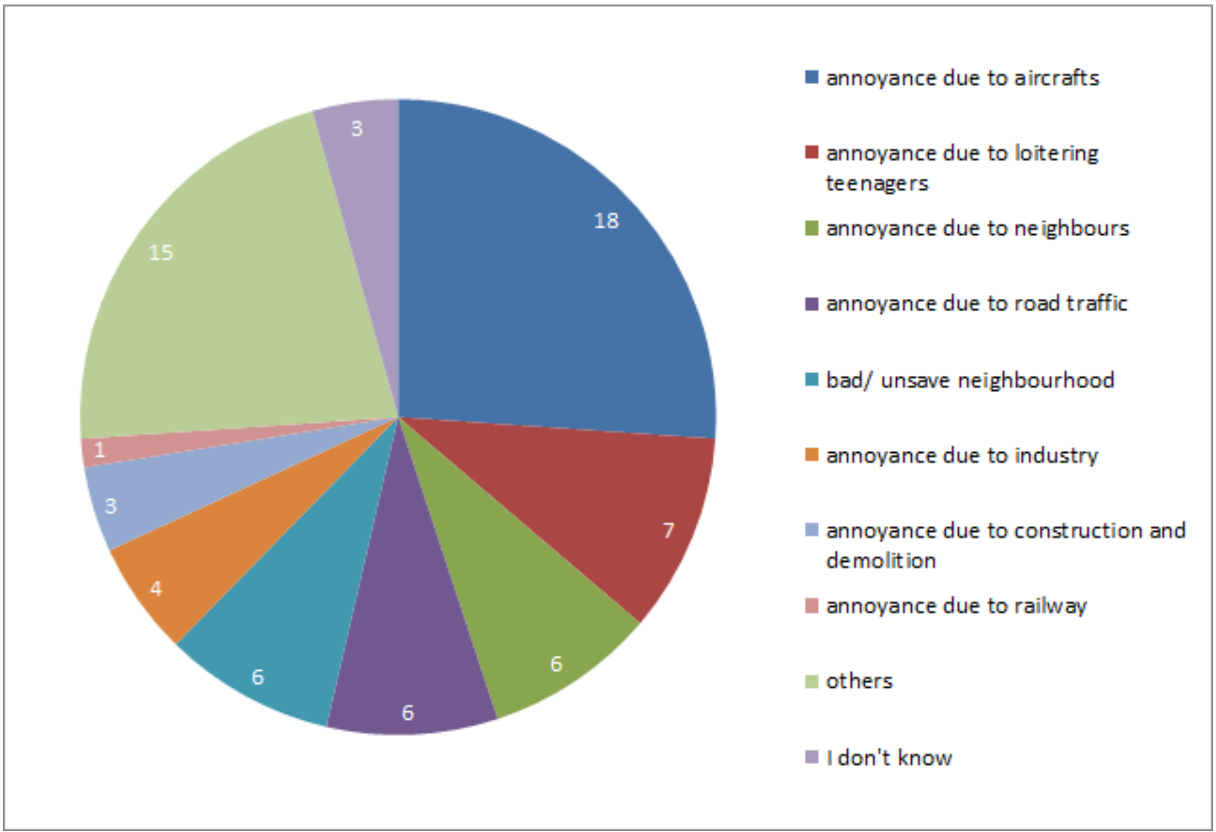

Figure 11: Number of reasons mentioned for dissatisfaction with living environment.

Noise annoyance, sleep disturbance and worries concerning different topics served as predictor variables for residential satisfaction. Table 3 displays an overview of the descriptions of these variables categorized for each study area.

Table 3: Comparison of means (standard deviations) of noise annoyance, sleep disturbances, and worries between groups.

		inner area	**outer area**	**outside noise contour**	**Total**
N		251	722	239	1212
	road traffic	2.93 (2.83)	2.51 (2.72)	2.64 (2.95)	2.63 (2.79)

Noise annoyance 11-point response scale from 0 (not at all) to 10 (extremely)	neighbours	1.71 (2.48)	1.97 (2.57)	1.90 (2.50)	1.90 (2.54)
	railway	.17 (.86)	.50 (1.44)	.71 (1.76)	.47 (1.42)
	aircraft	6.61 (3.11)	4.30 (3.20)	2.97 (2.99)	4.52 (3.35)
	industrial	.88 (1.82)	.67 (1.74)	.76 (1.98)	.73 (1.81)
	construction and demolition	1.46 (2.46)	1.74 (2.46)	2.01 (2.78)	1.73 (2.53)
	loitering teenagers	1.15 (2.17)	1.28 (2.27)	1.29 (2.42)	1.25 (2.28)
Sleep disturbance 11-point response scale from 0 (not at all) to 10 (extremely)	road traffic	1.18 (2.10)	1.04 (2.08)	1.06 (1.93)	1.08 (2.05)
	neighbours	.55 (1.56)	1.02 (2.08)	1.09 (2.00)	.94 (1.97)
	railway	.05 (.37)	.23 (1.04)	.26 (1.12)	.20 (.96)
	aircraft	4.35 (3.64)	2.28 (3.07)	1.26 (2.42)	2.51 (3.25)
	industrial	.35 (1.23)	.29 (1.19)	.32 (1.22)	.31 (1.21)
	construction and demolition	.51 (1.64)	.61 (1.56)	.59 (1.56)	.58 (1.58)
	loitering teenagers	.66 (1.74)	.76 (1.82)	.80 (2.01)	.75 (1.85)
Worries 3-point response scale from 1 (a lot) to 3 (no worries)	safety	2.39 (.73)	2.35 (.71)	2.41 (.70)	2.37 (.71)
	climate change	1.97 (.77)	1.94 (.76)	1.90 (.78)	1.94 (.77)
	CO2-emission	1.96 (.81)	2.02 (.78)	2.08 (.76)	2.02 (.78)

particulate matter, incl. ultra-fine dust	1.81 (.81)	2.01 (.80)	2.03 (.81)	1.98 (.81)
air pollution	1.70 (.77)	1.91 (.77)	1.97 (.75)	1.88 (.77)
noise annoyance	1.89 (.82)	2.32 (.74)	2.47 (.66)	2.26 (.77)
crowded supply routes	2.29 (.76)	2.24 (.79)	2.28 (.77)	2.26 (.78)
parking facilities	2.58 (.71)	2.40 (.79)	2.37 (.77)	2.43 (.77)
public transport connections	2.54 (.72)	2.52 (.74)	2.60 (.65)	2.54 (.72)

It is apparent that participants living in the inner area are most annoyed by aircraft noise rather than any other noise source. Further, noise annoyance due to aircraft noise is rather high compared to other noise sources. A similar result can be found with respect to sleep disturbances. In general, reported worries are highest for air pollution, climate change and particulate matter. The variable that people are least concerned about is public transport connections. A graphical overview of the average worry regarding the different topics can be found in Figure 12.

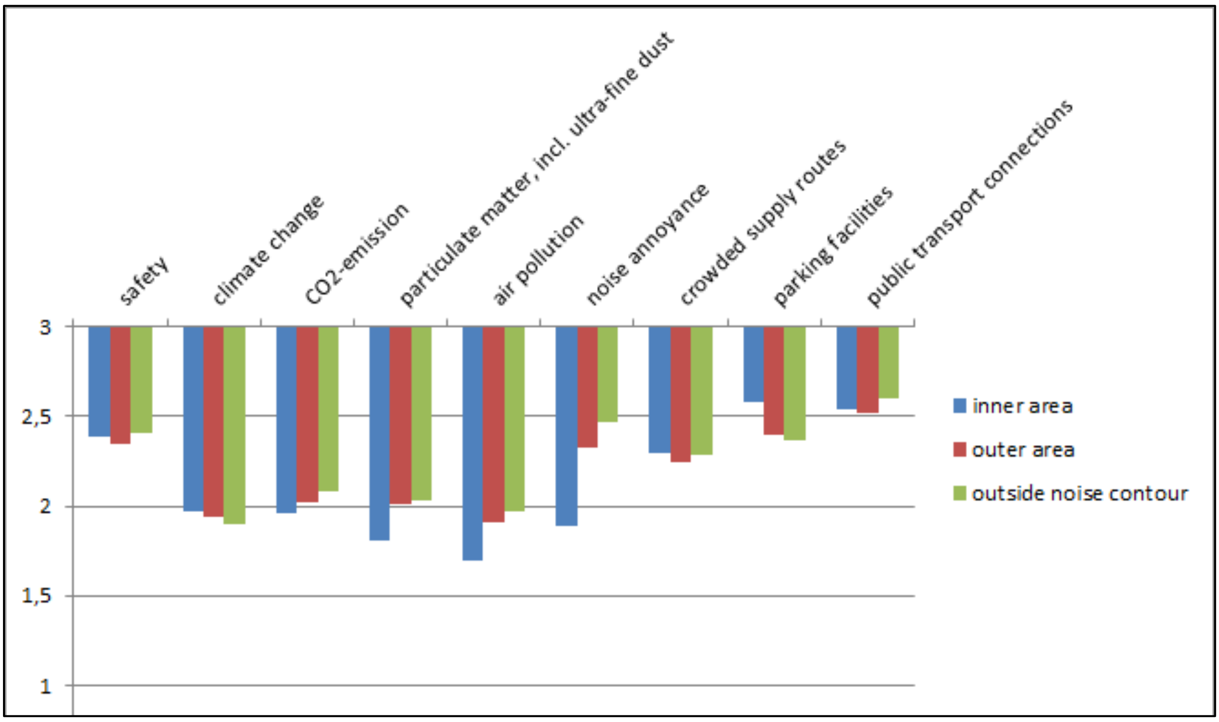

Figure 12: Overview of worry ratings regarding different topics. Rating scale: 1 (a lot) to 3 (no worries).

Participants who indicated certain days or times of a day when they experienced the most aircraft noise annoyance were presented with three follow-up questions for specification. The results are depicted in Figure 13 to Figure 15.

Participants experience more aircraft noise annoyance on weekends than on weekdays. For 20% of participants, lunch-time is the time of a day when they experience the most noise annoyance; followed by the morning hours (14%) and the evening hours (13%). Additionally, the majority of participants experience aircraft noise annoyance at certain times of the year more than at other times.

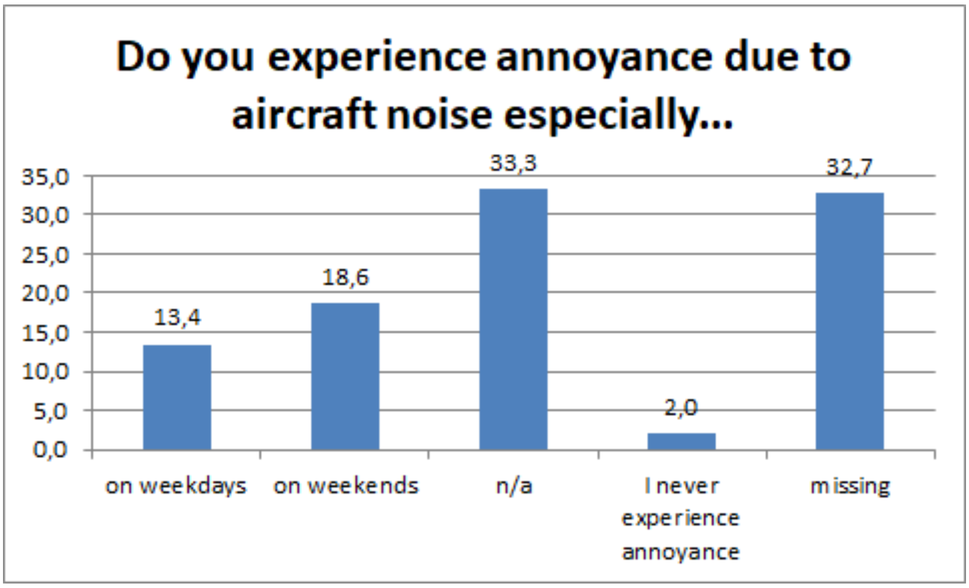

Figure 13: Percentage of participants experiencing aircraft noise annoyance on different days throughout the week. Note: n/a= no answer.

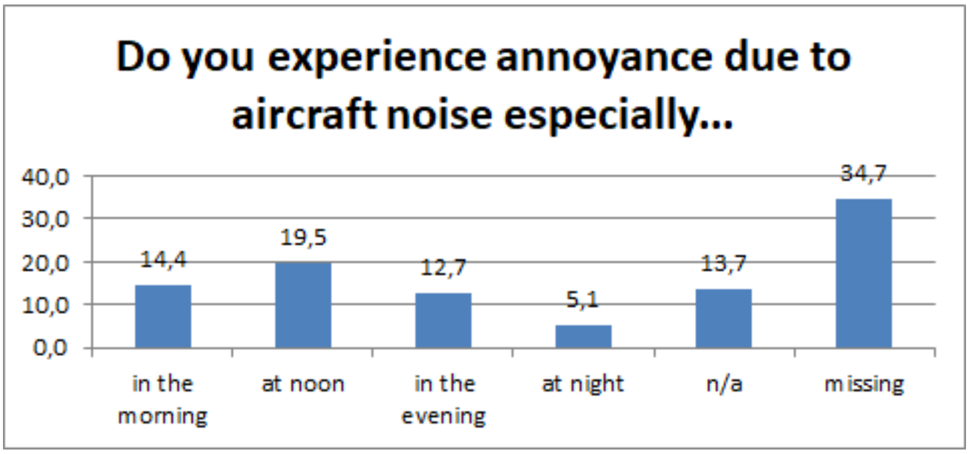

Figure 14: Percentage of participants experiencing aircraft noise annoyance at different times throughout the day. Note: n/a= no answer.

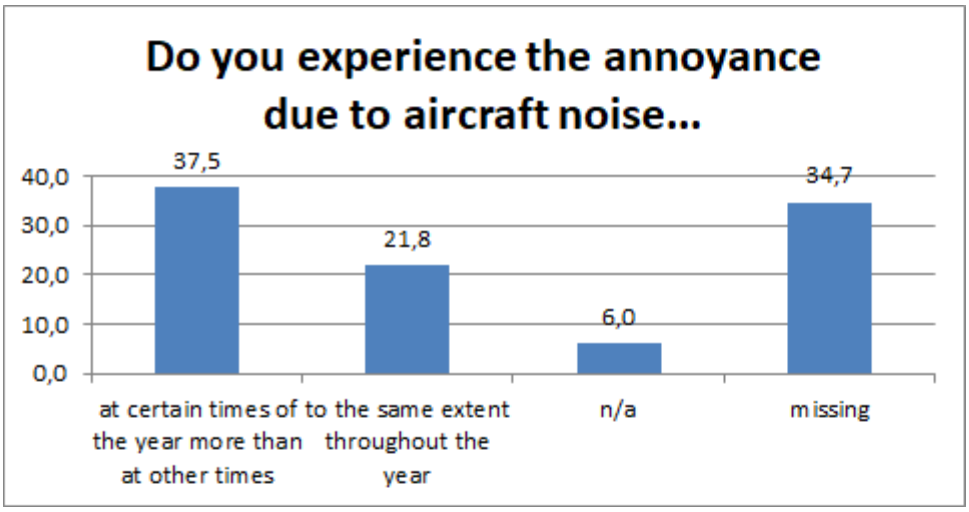

Figure 15: Percentage of participants experiencing aircraft noise annoyance during the year. Note: n/a= no answer.

Figure 16 graphically depicts the strength of the correlations between the different variables. The red colour indicates a negative relationship while the blue colour indicates a positive relationship between the variables. The darker the colour, the higher is the correlation and the stronger is the relationship between the two variables.

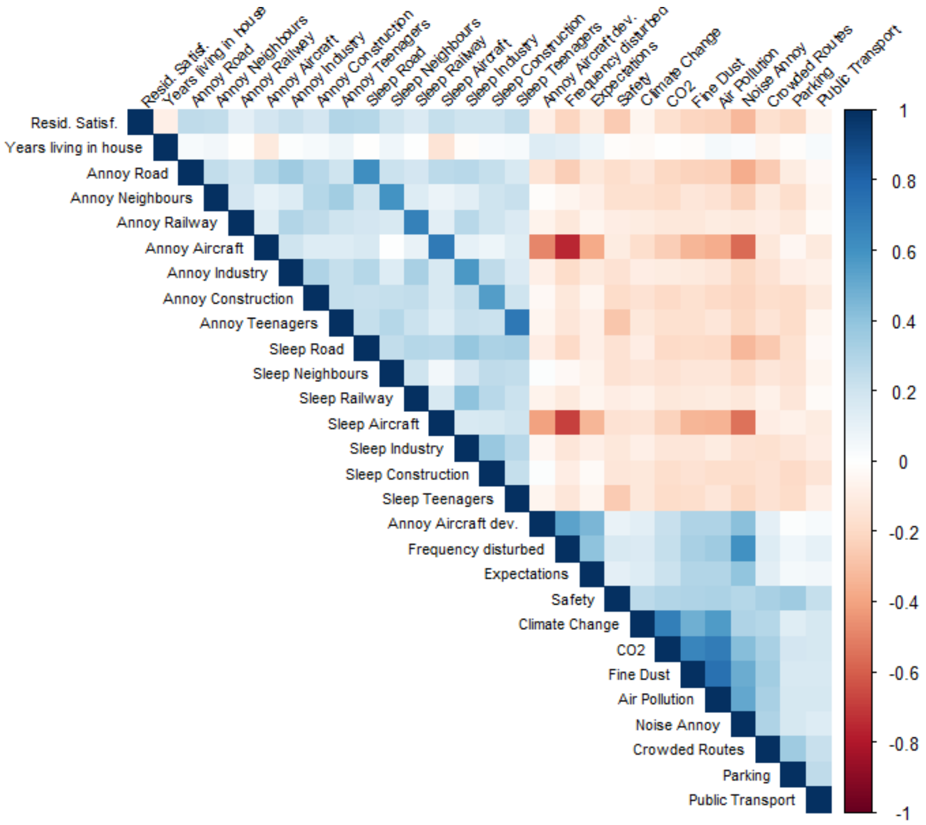

Figure 16: Correlation plot displaying the relationship between the different variables.

The correlation values are depicted in annex 10.1. Residential satisfaction is significantly correlated with all variables of noise annoyance from different sources as well as sleep disturbances due to different sources, showing that higher annoyance and more sleep disturbances are related to a lower level of residential satisfaction. Except for worry concerning climate change and public transport connections, all these variables are significantly correlated with residential satisfaction as well (See Table 10). For example, more worry regarding noise annoyance is associated with less residential satisfaction (r=-.29, p < .01). In addition, the correlations indicate that less residential satisfaction goes along with a higher frequency of aircraft noise disturbance in the past month (r=-.20, p < .01), an increase of aircraft noise annoyance in general (r=-.08, p < .05), and with the expectation of an increase of aircraft noise annoyance in the upcoming 12 months (r=-.10, p < .01).

Aircraft noise annoyance, aircraft noise annoyance development, frequency disturbed by aircraft noise in the past month, as well as expectations for future noise annoyance all correlate significantly with each other. Expectations and the development of aircraft noise annoyance so far are significantly related to each other (*r*=.45, $p < .01$). Participants who indicated that they had been less frequently bothered by aircraft noise in the past month expect their future noise annoyance not to increase (*r*=.41, $p < .01$). Further, the more people are annoyed by aircraft noise, the less they expect a decrease of their noise annoyance in the future (*r*=-.38, $p < .01$). The more people are annoyed by aircraft noise, the more frequently they have been disturbed by aircraft noise in the past month and the more they do not expect a decrease in noise annoyance (See annex 10.1).

Regression analyses were performed to examine the influence of, e.g., aircraft noise annoyance and sleep disturbances due to aircraft noise on residential satisfaction. Age and sex did not have a significant effect on residential satisfaction. Adding the variable aircraft noise annoyance to the model improves the explained variance of residential satisfaction from 14.1% to 18.6%.The R^2 for the overall model was .186 (adjusted R^2 = .179; $F(11,1198)=24.95$, $p < 0.01$), indicating a moderate goodness-of-fit (Cohen, 1988). This means that the predictors altogether explain 18.6% (17.9%) of the variance of residential satisfaction. Given that several aspects that are known to be relevant for residential satisfaction such as the social environment (neighbours) and the infrastructure of the residential area (public transport, shopping possibilities) are not included, the variance explained by the predictors is regarded as high.

The regression coefficients for annoyance due to neighbours, industrial noise, loitering teenagers, sleep disturbance due to road traffic and air traffic are significant (See Table 4). This indicates, for example, that a 1-point increase on the scale for sleep disturbances due to aircraft noise is linked to an increase of 0.02-points for residential satisfaction. Due to the scale used (ranging from 1=very satisfied to 5=very unsatisfied), this increase of sleep disturbance is associated with less residential satisfaction. There is no significant effect of aircraft noise annoyance on residential satisfaction. On the other hand, the regression analysis reveals that worries regarding safety and noise annoyance in general have the largest impact on residential satisfaction.

Table 4: Results of the regression analysis.

				95% CI	
Predictor	**B**	**SE**	**p**	**Lower**	**Upper**
Intercept	2.324**	.140	.000	2.049	2.599
Road traffic noise annoyance	-.006	.011	.608	-.027	.016
Neighbour noise annoyance	.034**	.010	.001	.014	.053
Aircraft noise annoyance	-.015	.010	.133	-.036	.005
Industrial noise annoyance	.047**	.014	.001	.020	.075

Construction and demolition	.002	.010	.809	-.017	.022
Loitering teenagers	.052**	.015	.001	.022	.081
Sleep disturbance road	.049**	.015	.001	.020	.078
Sleep disturbance aircraft noise	.022*	.010	.034	.002	.042
Sleep disturbance teenagers	.000	.018	.999	-.036	.036
Worry safety	-.128**	.034	.000	-.194	-.061
Worry noise annoyance	-.161**	.040	.000	-.239	-.084

B = unstandardized regression coefficient, SE= standard error, p = probability of error, *. significant at .05.; **. significant at .01.

To compare the means of the variables between the different study areas, an Analysis of Variance (ANOVA) was calculated. The ANOVA reveals a significant difference between the three study areas regarding residential satisfaction, annoyance by railway and aircraft noise, sleep disturbance due to neighbours, railway and aircraft noise (see Table 5). Further, how participants' aircraft noise annoyance developed in general, the frequency with which participants were bothered by aircraft noise in the past month, as well as expectations regarding one's future noise annoyance differ significantly between groups.

Table 5: Results of the ANOVA analysis.

Measure	Inner area		Outer area		Outside noise contour		F(2,1207)	p
	m	SD	m	SD	m	SD		
Residential Satisfaction	2.04	.99	1.82	.83	1.73	.75	8.62	.000
Noise annoyance due to								
Road traffic	2.93	2.83	2.51	2.72	2.64	2.95	2.06	.128
Neighbours	1.71	2.48	1.97	2.57	1.90	2.50	.92	.399
Railway	.17	.86	.50	1.44	.71	1.76	9.28	.000
Aircraft	6.61	3.11	4.30	3.20	2.97	2.99	86.61	.000
Industry	.88	1.82	.67	1.74	.76	1.98	1.32	.268
Construction and demolition	1.46	2.46	1.74	2.46	2.01	2.78	2.95	.053
Loitering teenagers	1.15	2.17	1.28	2.27	1.29	2.42	.35	.708
Sleep disturbance due to noise from								
Road traffic	1.18	2.10	1.04	2.08	1.06	1.93	.44	.644

Neighbours	.55	1.56	1.02	2.08	1.09	2.00	6.09	.002
Railway	.05	.37	.23	1.04	.26	1.12	3.80	.023
Aircraft	4.35	3.64	2.28	3.07	1.26	2.42	66.75	.000
Industry	.35	1.23	.29	1.19	.32	1.22	.26	.770
Construction and demolition	.51	1.64	.61	1.56	.59	1.56	.38	.684
Loitering teenagers	.66	1.74	.76	1.82	.80	2.01	.42	.658
General development of aircraft noise annoyance	1.32	.52	1.59	.59	1.65	.57	24.02	.000
Frequency bothered by aircraft noise past month	2.21	1.12	2.96	1.08	3.35	.89	75.81	.000
Expectations aircraft noise annoyance	1.43	.54	1.65	.54	1.67	.50	16.52	.000

m = means; SD = standard deviation, p = probability of error

To assess which groups differ from each other, a post-hoc test was conducted. The results can be found in Table 6. Tukey post-hoc analysis reveals a significant difference regarding residential satisfaction ($p < .01$) between the inner area group and the outside area (.21, 95%-CI[.07, .36]) as well as the outside the noise contour group (.30, 95%-CI[.12, .49]). As the rating scale ranges from 1 (very satisfied) to 5 (very unsatisfied), this means that participants living in the inner area report significantly less residential satisfaction compared to participants living in the outer area and outside the noise contour.

A significant difference for aircraft noise annoyance can be found between all three groups. As can be expected, more aircraft noise annoyance is experienced close to the airport, i.e. the inner area, than in the outer area (2.31, 95%-CI[1.77, 2.85]), and more aircraft noise annoyance is reported in the outer area compared to outside the noise contour (1.33, 95%-CI[.78, 1.88]). Similar results can be found for reported sleep disturbance due to aircraft noise (See Table X). For sleep disturbances due to neighbours and railway noise, the opposite is true: people living in the inner area report less sleep disturbances due to those sources compared to the outer area and the area outside the noise contour.

Within the inner area, more people state that their aircraft noise annoyance has increased in general than people from both other areas (-.27, 95%-CI[-.37, -.17]; -.32, 95%-CI[-.45, -.20]). Similarly, participants' expectations regarding their future aircraft noise annoyance significantly differs between the inner area and the outer area as well as the area outside the noise contour: more people who live in the inner area expect an increase of noise annoyance compared to the outside area (-.22, 95%-CI[-.32, -.12]) and the area outside the noise contour (-.24, 95%-CI[-.36, -.12]).

Not surprisingly, the group from the inner area also reported being more frequently disturbed by aircraft noise in the past month than the outer area group (-.75, 95%-CI[-.93, -.57]) and the group outside the noise contour (-1.15, 95%-CI[-1.38, -.92]).

Table 6: Results of the Tukey post-hoc analysis.

Dependent variable	(I) Area	(J) Area	Mean difference (I-J)	SE	p	95% confidence interval Lower	Upper
Residential satisfaction	inner area (58dB Lden)	outer area (48-57dB Lden)	,21*	,06	,002	,07	,36
		outside noise contour (>48dB Lden)	,30*	,08	,000	,12	,49
	outer area (48-57dB Lden)	inner area (58dB Lden)	-,21*	,06	,002	-,36	-,07
		outside noise contour (>48dB Lden)	,09	,06	,34	-,06	,24
Railway noise annoyance	inner area (58dB Lden)	outer area (48-57dB Lden)	-,33*	,10	,004	-,57	-,09
		outside noise contour (>48dB Lden)	-,54*	,13	,000	-,84	-,24
	outer area (48-57dB Lden)	inner area (58dB Lden)	,33*	,10	,004	,09	,57
		outside noise contour (>48dB Lden)	-,21	,11	,115	-,4572	,04
Aircraft noise annoyance	inner area (58dB Lden)	outer area (48-57dB Lden)	2,31*	,23	,000	1,77	2,85
		outside noise contour (>48dB Lden)	3,64*	,28	,000	2,97	4,30
	outer area (48-57dB Lden)	inner area (58dB Lden)	-2,31*	,23	,000	-2,85	-1,77
		outside noise contour (>48dB Lden)	1,33*	,23	,000	,78	1,88
Sleep disturbance due to neighbours	inner area (58dB Lden)	outer area (48-57dB Lden)	-,46*	,14	,004	-,80	-,13
		outside noise contour (>48dB Lden)	-,53*	,18	,008	-,95	-,12
	outer area (48-57dB Lden)	inner area (58dB Lden)	,46*	,14	,004	,13	,80
		outside noise contour (>48dB Lden)	-,07	,15	,882	-,41	,27

Sleep disturbance due to railway noise	inner area (58dB Lden)	outer area (48-57dB Lden)	-,18*	,07	,028	-,34	-,02
		outside noise contour (>48dB Lden)	-,20*	,09	,049	-,41	-,00
	outer area (48-57dB Lden)	inner area (58dB Lden)	,18*	,07	,028	,02	,34
		outside noise contour (>48dB Lden)	-,02	,07	,940	-,19	,14
Sleep disturbance due to aircraft noise	inner area (58dB Lden)	outer area (48-57dB Lden)	2,08*	,23	,000	1,55	2,61
		outside noise contour (>48dB Lden)	3,10*	,28	,000	2,45	3,75
	outer area (48-57dB Lden)	inner area (58dB Lden)	-2,08*	,23	,000	-2,61	-1,55
		outside noise contour (>48dB Lden)	1,02*	,23	,000	,48	1,56
Has the annoyance from aircraft noise experienced by you (in general)…	inner area (58dB Lden)	outer area (48-57dB Lden)	-,27*	,04	,000	-,37	-,17
		outside noise contour (>48dB Lden)	-,32*	,05	,000	-,45	-,20
	outer area (48-57dB Lden)	inner area (58dB Lden)	,27*	,04	,000	,17	,37
		outside noise contour (>48dB Lden)	-,05	,04	,464	-,16	,05
How often were you bothered by aircraft noise in the past month? Is that…	inner area (58dB Lden)	outer area (48-57dB Lden)	-,75*	,08	,000	-,93	-,57
		outside noise contour (>48dB Lden)	-1,15*	,10	,000	-1,38	-,93
	outer area (48-57dB Lden)	inner area (58dB Lden)	,75*	,08	,000	,57	,93
		outside noise contour (>48dB Lden)	-,40*	,08	,000	-,59	-,21
Future expectations regarding noise annoyance	inner area (58dB Lden)	outer area (48-57dB Lden)	-,22*	,04	,000	-,31	-,12
		outside noise contour (>48dB Lden)	-,24*	,05	,000	-,36	-,12
	outer area (48-57dB Lden)	inner area (58dB Lden)	,22*	,04	,000	,12	,31

	outside noise contour (>48dB Lden)	-,02	,04	,869	-,12	,08

SE = standard error, p = probability of error

4.2.3 Discussion

Overall, the residential satisfaction across the three study areas is quite high. Simultaneously, residents' self-reported aircraft noise annoyance is higher compared to the annoyance due to other noise sources, but is within a moderate range (M=4.51, SD= 3.35). Although, indicated by the large standard deviation, there seems to be a lot of variance in the sample. Participants who have been more annoyed by aircraft noise in the past 12 months express a general increase in aircraft noise annoyance, more frequent disturbances due to aircraft noise as well as a more negative view when it comes to their expected future aircraft noise annoyance.

Factors such as worries regarding safety and noise annoyance in general seem to be more relevant for residential satisfaction than aircraft noise annoyance, expected aircraft noise annoyance, and frequency of disturbance.

Comparing the three study areas, some significant differences become apparent. In the inner area, the reported aircraft noise annoyance is significantly higher than in the other two study areas. Moreover, more disturbances due to aircraft noise, a general increase in aircraft noise annoyance and an expected increase in future noise annoyance are significantly more often reported by participants living in the inner area. Participants from the inner area report significantly less sleep disturbance due to noise from neighbours and railway traffic, but significantly more aircraft noise-related sleep disturbances. This indicates not necessarily an absence of noise from neighbours, but could reflect the prominent role aircraft noise takes in areas within the airport's proximity.

The results indicate that perceived and expected aircraft noise annoyance is highest for people living in close proximity to an airport, but that overall, there are other aspects more prominent for residents in airport regions.

From a methodological perspective, the use of the standardized questions for noise annoyance and sleep disturbance is positive as it enables comparing these results with other studies. Using a 3-point scale assessing the degree of worries regarding different topics with values ranging from 1= a lot of worry, 2= a little worry to 3= no worries, however, might lead to a lack of variance in the results (Lehmann & Hulbert, 1972).

4.2.4 Conclusion

Overall, there seem to be more prominent factors influencing participants' quality of life than aircraft noise annoyance or sleep disturbances, such as worries regarding safety and noise annoyance in general. However, these variables still have an influence and, if addressed, could positively influence quality of life in regions surrounding airports. An important aspect to keep in mind is that the study areas significantly differ with respect to aircraft noise annoyance. Reducing aircraft noise annoyance might therefore have a positive impact on the residential satisfaction of people living close to an airport. Further, aspects such as worries concerning safety and noise annoyance in general (also regarding other noise sources) may be targeted with certain interventions, thereby further improving quality of life.

Future studies should specifically examine quality of life by addressing all indicators (See Figure 1) and evaluate various interventions based on these indicators. This could be achieved, for example, by conducting a survey before and after the implementation of an intervention specifically assessing the different quality of life indicators. It is important that all communities potentially affected by this intervention are included in the study to get a thorough picture of the intervention's impacts. The results could serve as a basis for improving existing interventions and developing new interventions. In this way, not only could residents' noise annoyance be reduced, but, at the same time, their quality of life could be increased. If the decision for one particular intervention is not clear-cut and there are different interventions being considered, it could be beneficial to engage the communities in the decision-making process of selecting one intervention to be implemented as well.

4.3 The impact of the radius-fix-turn on quality of life

There is still a need for further research examining the impact of such an operational procedure on the surrounding communities and to allow for drawing specific conclusions. It becomes apparent that - at least in those regions further away from the airport - aircraft noise does not seem to be the most negative factor and not the main source for noise annoyance and sleep disturbance. However, despite there being more negative environmental influences, aircraft noise still represents an environmental stressor for residents potentially affecting their QoL.

What effect the radius-to-fix approach may have on QoL, can be seen by a different intervention, namely the consultation procedure that addressed a potential flight path change (See the following chapter 5).