

Vienna International Airport Noise Abatement

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Abstract

Purpose: On the topic of sustainable aviation a study was carried out to measure the difference between the actual change in air traffic noise and the airport's residents' perception of the noise change at Vienna International Airport. Therefore, a questionnaire was developed in cooperation with the airport and an online survey was conducted.

Design/methodology: For the survey of the opinion of the affected population of the surrounding communities, a web based online questionnaire is created and distributed via various channels including e-mail, and online forums. After the basic structure of the questionnaire had been defined, the questions were developed in cooperation with employees from the environmental department of VIE, who had a sustainable influence on the questions' order and formulation. As the survey was supposed to be answered by residents around VIE.

Findings: Results of the online study show that only parts of the participants are affected by air traffic noise at VIE. Even less experienced a significant change over the last five years. About one third of the participants stated that they are affected by air traffic noise in one way or another. The majority of these people live in Lower Austria, the federal state in which the airport is located. The participants obviously judge air traffic noise during day time more importantly than air traffic noise at night.

Research limitations/implications: Due to the low number of returns, no statistically relevant conclusions can be drawn, the results of the survey can be used to make some general statements.

Originality/value: Economic growth and deregulation lead to growing aircraft operations. Vienna International Airport with its approximately 260,000 flight movements per year is the biggest airport in Austria and a major hub in Europe. The combination of constantly growing air transport and the resulting noise exposure, as well as the steadily increasing sensitization of the population, bring the issue of aircraft noise emission into the increased interest of the stakeholder of an airport. The study compares the extent of the subjective perceived and the actual noise emissions' change over the last years.

Keywords: Airport management; aircraft noise; air traffic noise abatement; sustainable aviation

1. Introduction

Aircraft noise can be described as a by-product of the pollution produced by any aircraft or its components during various phases of a flight: on the ground while parked caused e.g. by auxiliary power units, while taxiing, on run-up from propeller and jet exhaust, during take-off, underneath and lateral to departure and arrival paths, over-flying while en route and during landing in terms of the noise exerted.

Zaporozhet, Tokarev and Attenborough (2011) state that the aircraft noise associated with the operation and growth of the airports has an impact on local communities and nature. It is the single most significant contemporary environmentally constraint which is likely to have a severe impact in near future. Aircraft noise is generally influenced by some factors such as the number of flights, their timing, the type of aircraft, and the flight path. Aircraft noise is a disturbance produced by any aircraft or its components, during flight, taxiing, landing and take-off. Different aircraft types cause different levels and frequencies of noise. The origins of this noise are caused by three main sources: the aerodynamic noise, the aircraft engine and other mechanical sources.

Aircrafts are complex noise sources and the scientific basis for abating noise from an aircraft relies on advances that have been made in aero acoustics.

The main noise sources in an aircraft in flight are the power unit and the aerodynamic noise, which is particularly noticeable during the landing approach of a jet engine, even with a comparatively low power setting. Unlike acoustics, which mainly concern the sound caused by oscillating surfaces, investigation of an aerodynamic noise can be conditioned by turbulent non-stationary flow. A jet aircraft noise sources mainly includes jet noise, core noise, inlet and aft fan noise, turbine noise and airframe noise. The noise created by any aircraft can be individually classified with respect to its noise sources and the category it belongs to as seen in Figure 1 (Zaporozhets et al. 2011, pp. 6).

<i>Aircraft class</i>	<i>Main sources of noise</i>		
		<i>Power-unit</i>	<i>Airframe</i>
Aircraft – ordinary takeoff and landing	Turbojet	Jet, fan, core noise	Flap and wing trailing edges, flap side edges, slats, gear sources, fuselage and wing turbulent boundary layers
	Turboprop	Propeller, propfan, engine exhaust	
Aircraft – short takeoff and landing	Turbojet	Fan, engine exhaust	Interaction jet with flap
	Turboprop	Propeller	
Supersonic aircraft		Jet	Interaction of flow with frame
Helicopters		Blades of main rotor, engine exhaust	Not important
Aircraft of general aviation	Turbojet	Jet, fan	Not important
	Turboprop	Propeller, engine exhaust	

Figure 1. Classification of aircraft noise sources

One of the major airframe noise sources are landing gears. The noise generated by a landing gear is normally broadband in nature. Several noise sources have been identified on a typical landing gear configuration. The wheels and main struts are responsible for low frequency noise, while smaller details such as the hoses and dressings are responsible for the high frequency noise. This wide frequency spectrum makes the testing of detailed scale models important as high frequencies are an important factor to the overall noise level. Some studies have shown tonal noise due to cavity resonances from tube-type pins in various joints linking gear components, tire treads and hinge-leg door configuration. It seems that this tonal noise depends on inflow velocity, turbulence and flow direction; thus it is impossible to predict whether these noises will manifest themselves during the approach of an aircraft. It should be noted, however, that there is little experimental evidence that vortex shedding-related tone noise is a major problem for current landing gear architectures.

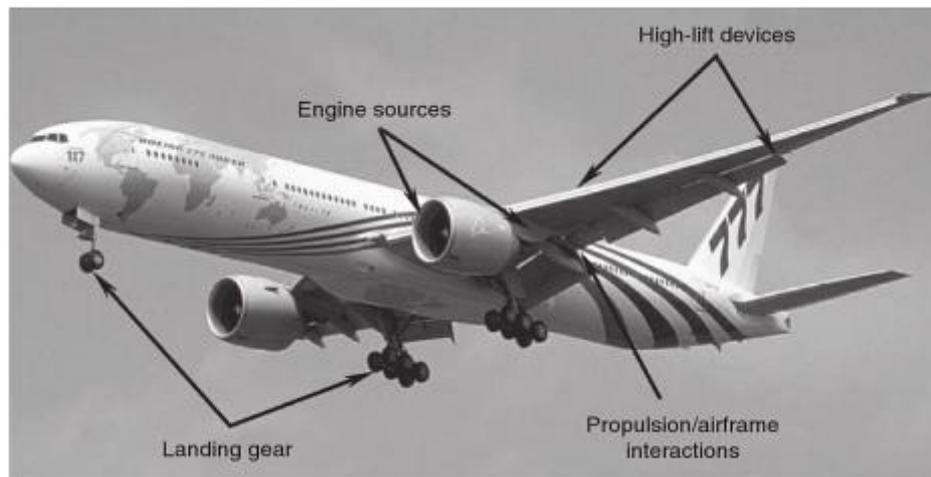


Figure 2. Noise sources on a landing aircraft

In contrast to this, the landing gear broadband noise is normally generated by the turbulence flow separation of the bluff-body components and the subsequent interaction of such turbulent wake flows with downstream located gear elements. The turbulence-related noise and interaction noise are normally governed by flow turbulence characteristics and local impinging flow velocity. Since sound intensity increases with flow velocity to the power of six, it can reveal that the beneficial effect of reduced local inflow velocity is more substantial than the adverse effect on noise of increased turbulence intensity, as mentioned by Zaporozhets et al. (2011).

Another major source of airframe noise are high-lift devices, including leading-edge slats and trailing-edge flaps. Other high-lift-related noise generating devices include spoilers if deployed during a steep approach operation. Although the spoiler noise may be subjectively important, it has little impact on airworthiness and thus has not received much attention from the noise research community, it will also not be addressed in this article. In order to gain physical insight, the local steady and unsteady flow conditions of both slats and flaps have been carefully investigated through numerical simulations and fluid experiments. Choudhari and Khorrami (2006) sketched a diagram to summarise potential noise sources of a slat, including the vortex flow developing in the slat cove, the unstable shear layer between the vortex and the undisturbed slot flow, the impingement of the vertical shear flow on the downstream cove surfaces and the unsteady flow shedding off the trailing edge. It is believed that vortices developing on the side edge of the flap and its interaction with the flap surface are major noise sources of the trailing-edge flap. Figure 2 shows all the noise sources of a landing aircraft (Zaporozhets et al., 2011, pp. 6).

The potential to reduce noise at source is limited and the land use measures are difficult to implement in densely populated zones. Operational procedures which depend on pilot behaviour may also lead to a reduction in the level of flight safety. The growth of air traffic is faster than the developments in new technologies and methods of noise reduction.

2. Aircraft Noise on Airports

The introduction of jet-propelled passenger transport aircrafts 55 years ago ushered in an era of unprecedented human mobility. Equally, it was associated with noise and local air quality issues that were painfully obvious to those living near airports. Today, these aircraft emissions are regulated with benefits which are immediately evident to the naked eye and ear when vehicles from the two eras are compared directly. Unfortunately, however, much of this improvement has been offset by the huge increase in air traffic over the years. As a result, the pressure to reduce noise remains high.

Although individual aircrafts have become 75% less noisy over the last 30 years, the growing amount of air traffic means that many European Union (EU) citizens are still exposed to high noise levels (Babisch et al., 2009). In order to ensure the sustainability of aviation, measures targeting the noise impact will remain necessary at a number of important airports. However, noise-related measures constrain not only the airport capacity at a particular airport but also the aviation system as a whole through knock-on effects. Therefore, decisions on noise measures and the desired level of noise protection must be balanced against the overall capacity implications. Environmental noise annoyance – especially from airport operation – is widely accepted as an end-point of environmental noise that can be taken as a basis for evaluating the impact of noise on the exposed population. People annoyed by airport noise may experience a variety of negative responses, such as anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion. There is sufficient evidence from large-scale epidemiological studies linking population exposure to environmental noise with adverse health effects. Figure 3 (Zaporozhets et al., 2011, pp. 2) shows all the environmental noise influences on an airport.

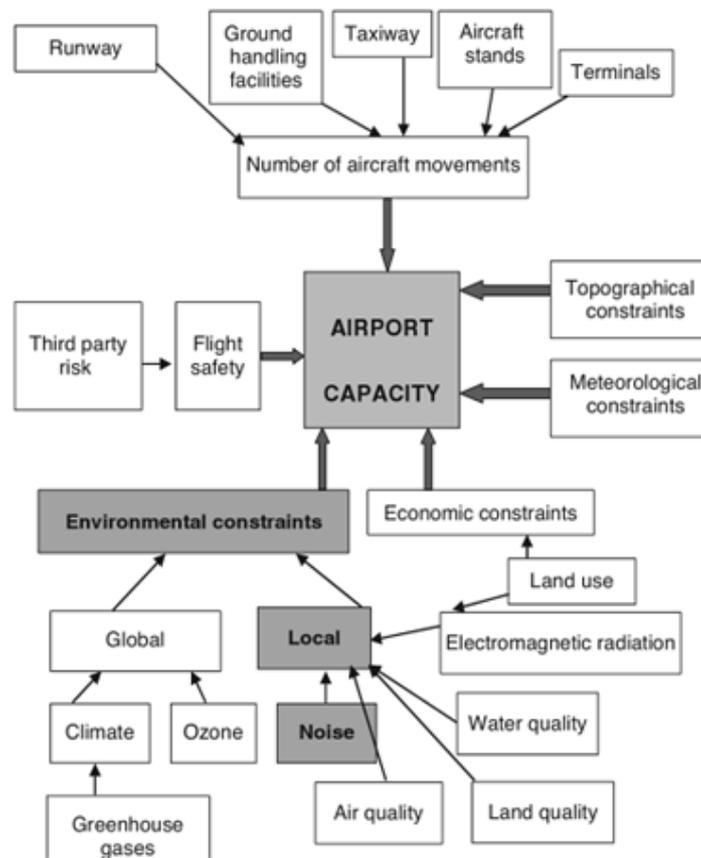


Figure 3. Environmental noise influences on an airport

Environmental noise should therefore be considered not only as a cause of nuisance but also as a concern for public and environmental health. Noise from all sources may be relevant to the assessment of risk, and hence it may be appropriate to assess the exposure of the population of interest to all of these sources (WHO-JRC, 2011). Furthermore, community surveys have found that high percentages of people in high-level aircraft noise areas reported “headaches”, “restless nights” and “feeling tense and edgy”.

WHO defines health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity, and recognises the enjoyment of the highest attainable standard of health as one of the fundamental rights of every human being (WHO-JRC, 2011).

As regards to aircraft noise, most of the exposure to relevant events occurs mainly during the day and evening period. Therefore, day time exposure is likely to have greater effects than night time exposure and relates mainly to disturbances in communication. However, in many of the airports night exposure to aircraft noise may have a greater impact on sleep disturbances

and stressful conditions during summer periods due to a heavy traffic volume arriving from European or overseas destinations.

The traditional approach to aircraft noise annoyance has been restricted to the definition of noise contours around airports. These contours indicate the maximum level of sound exposure according to the limits imposed by national legislation. This approach takes into account only the physical side of the problem and forgets about the social side of environmental tensions. In fact, a number of observers have stated that in some cases there is no correlation between the level of sound exposure and the number of complaints generated by aircraft noise (see results section for Vienna airport analysis).

Many airports and authorities define and follow certain procedures depending on their geographical location and capacity to reduce the noise impact. Few essential requirements were taken into account, however, while designing and making a procedure consisting of some of the following considerations (Zaporozhets et al., 2011, pp. 4):

- Noise source must be placed as far away as possible from inhabited areas.
- Noise should be reduced to the lowest level achievable in a given case.
- Noise abatement of aircraft involves several acoustic sources such as jet stream, engine fan, turbine, propellers etc. and the airframe.
- Since there are various types of aircrafts in operation at any airport, the aircraft noise in the vicinity of the airport depends on the type of aircrafts in service, the number of flights by each type, the times of the day and the meteorological conditions.
- There might be noise sensitive locations, which need to be considered for a short-term and long-term forecast of airport development.
- Noise abatement requires an identification of the noise sources, assessment of their contributions to the overall acoustic field and acquaintance with the accumulated knowledge of effectiveness of the available noise abatement methods along the propagation path and the receiver.

Although flight safety remains paramount in importance, the problems of flight operation of aircrafts and environmental protection including noise abatement are currently combined. Noise abatement by operational measures involves additional workloads for pilots and air traffic controllers and can also result in additional operational costs for the aircraft operators in levy for airport charges.

2.1 Noise at the Vienna International Airport

Noise has become an important topic for Vienna International Airport (VIE), Austria's largest airport in terms of annual passengers. With more than 260.000 aircraft movements each year the airport has a considerable noise footprint in its surroundings, which is inhabited by more than two million people and comprises Vienna and parts of Lower Austria (Flughafen Wien AG, 2013, pp. 23).

The airport started to deal with the aircraft noise issues around 40 years ago when the second runway (RWY) was constructed (Lenotti, 1987, pp. 79).

Since then there have been efforts to include residents of the surrounding communities into the airport's noise programme. For this reason, the airport has installed several institutions and taken various measures.

Probably the most relevant institution is the "Dialogforum – Flughafen Wien" (Dialogforum) which exists since 2004 (Dialogforum Flughafen Wien, 2013, pp. 5). Arbeitskreise (working circles) and Arbeitsgruppen (working groups) make up the Dialogforum. Each of them treats a certain topic. Depending on the focus of the Dialogforum some working groups and circles are active while others pause during certain years. As Table 1 shows, the Dialogforum deals with the noise topic at Vienna Airport holistically (Dialogforum Flughafen Wien, 2013, pp. 8). Representatives of the residential communities as well as airport stakeholders are part of the Dialogforum.

Working Circles		Working Circles
Evaluation and monitoring	Curved approach	Noise protection programme and environmental funding
Public relations	Air traffic events	Flight tracks on the web
Environmental impact	Landing RWY 34 and VFR	Noise charges
Noise protection programme	Noise protection wall	Editors air traffic events
Visual approaches	Basic topics	Liesing – District (40% reduction)
Landings	Traffic	
Agriculture	Procedure and mediation-contract	

Table 1. Working circles and working groups of the Dialogforum

Table 1 shows that noise monitoring and its evaluation is a major task of the Dialogforum. The main result from the Dialogforum's work is the publication of a yearly evaluation report which contains for example (Dialogforum Flughafen Wien, 2013, pp. 21)

- an overview of agreement compliance,
- milestones,
- air traffic data and the
- air traffic noise data.

The detailed air traffic and air traffic noise data can be used to monitor changes and to see how the actual execution of air traffic complies with the targeted agreements. Furthermore, it can be used to analyse the extent to which a certain area or community surrounding the airport is affected by the air traffic and its noise. Figure 4 shows the noise level from day instrument flight rules (IFR) flights at Vienna airport in 2012 (Dialogforum Flughafen Wien, 2013, pp. 99).



Figure 4. Air Traffic noise intensity from day-IFR flights at Vienna airport

The Dialogforum uses the equivalent noise level (LEQ) to describe noise affection. Smith (1989, pp. 15) notes that the LEQ value considers noise intensity and the duration of exposition. According to Smith (1989, pp. 19) and Burton (2004, pp. 19), the LEQ as a noise measurement unit becomes increasingly popular. In the evaluation report the LEQ is calculated for the day (06:00h-22:00h) and the night period (22:00h-06:00h).

With the original intention to compare subjective air traffic noise affection and actual penetration of airport residents, data from 2004 to 2013 of the evaluation report has been analysed. It should demonstrate that, due do the relatively constant numbers in aircraft movements, air traffic noise has remained at a certain level over the last four years. For this comparison four towns in the vicinity of the Vienna airport were selected which fulfil the following criteria:

- availability of air traffic noise measurements for the last few years and
- the location allows the conclusion that air traffic noise is caused only by aircrafts using one specific runway.

Figure 5 shows the location of the four selected towns in relation to the runways at Vienna airport.



Figure 5. Location of the towns used for the air traffic/air traffic noise comparison, clockwise, starting at the top: Groß-Enzersdorf, Fischamend, Schwadorf, Schwechat

The number of movements over a town results from the take-offs (T/O) and arrivals at a certain runway. The LEQ of a particular town is calculated by averaging and weighting the LEQ value for day and night time. The result can be seen in Table 2. It shows the correlation r for the four towns, where r is defined as

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

In this case y and x are the correlated air traffic noise and aircraft movements. The mean \bar{x} (and \bar{y}) respectively are calculated as follows:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

The number of years, n is four, as the period in question was from 2009 until 2012.

Per definition, r can have a value between -1 and $+1$, -1 stands for a perfect negative correlation, 0 for no correlation at all and $+1$ for a perfect positive correlation (e.g. Sharma, 2007, pp. 454). Although it is assumed that aircraft movements and air traffic noise would have a considerable positive correlation, Table 2 suggests a different result. The correlations for the four towns/runways differ significantly. Only Groß-Enzersdorf and therefore T/Os at RWY 34 and approaches at RWY 16 show high correlation. For Fischamend and Schwasdorf, however, even a negative r of -0.4 and -0.5 respectively are calculated.

Also on the change of air traffic noise alone no clear statement can be made. Table 2 clearly shows that the change over the last few years differs for each of the considered towns not only for the different periods, but also for night and day LEQ. Nevertheless, it can be concluded that the overall change of air traffic noise ranges from -1% and $+5\%$ and can thus be described as no or moderate change.

Town		2009	2010	2011	2012	r
Fischamend	Movements	21,037	21,769	21,463	19,434	-0.4259
	LEQ	33.43	32.67	36.43	35.67	
Schwechat	Movements	106,032	108,468	107,766	104,416	0.3472
	LEQ	50.62	49.07	50.10	48.24	
Groß-Enzersdorf	Movements	48,373	47,271	52,121	51,279	0.7410
	LEQ	50.03	50.83	51.40	51.70	
Schwadorf	Movements	84,854	86,269	82,633	95,197	-0.5251
	LEQ	50.74	49.64	50.28	49.79	
Total		270,326	263,983	263,777	260,296	

Table 2. Correlation between aircraft movements and aircraft noise at residential towns of Vienna airport

LEQ 0600-2200		2004-2008	2009-2012
Groß-Enzersdorf	absolute change between years	1.86%	1.86%
	percent change mean	0.47%	1.41%
Fischamend	absolute change between years	7.16%	7.16%
	percent change mean	2.00%	-5.38%
Schwadorf	absolute change between years	0.77%	0.77%
	percent change mean	0.19%	0.00%
Schwechat	absolute change between years	-1.54%	-1.54%
	percent change mean	-0.38%	0.03%
LEQ 2200-0600		2004-2008	2009-2012
Groß-Enzersdorf			
Groß-Enzersdorf	absolute change between years	-0.37%	-0.37%
Fischamend	percent change mean	-0.08%	1.76%
Fischamend	absolute change between years	6.21%	6.21%
Schwadorf	percent change mean	1.58%	-1.45%
Schwadorf	absolute change between years	-0.24%	-0.24%
Schwechat	percent change mean	0.22%	1.68%
	absolute change between years	28.00%	28.00%
	percent change mean	7.19%	-3.46%

Table 3. Change of air traffic noise for four selected residential towns

3. Methods

While the data analysis from the evaluation report (Dialogforum Flughafen Wien, 2013) is sufficient to obtain a comprehensive answer on how the actual air traffic noise has changed, more effort is required to determine the subjective perception of the airport's residents. This chapter describes the survey which was conducted within this project.

3.1 Study Concept

For data collection the project team conducted an online survey. The decision for this questioning method was made after time and resource constraints were taken in account. According to Foscht, an online survey has advantages and drawbacks, as it can be seen in Table 4 (Foscht, 2013, pp. 36).

Advantages	Drawbacks
Fast and simple conduction	Limited controllability of reliability
High answer willingness	Possibility of distorted answers due to anonymity
Low effort	
Low costs	
High reach à feasible for international operations	
Automatic data acquisition	

Table 4. Advantages and drawback of an online survey

As a tool the online survey platform Soscisurvey was used. As Kiedl (2014, pp. 19) states, this platform enables the creation of a free of charge online survey. After the creation of an

account, a new survey was created which contained the questionnaire for the participants and all the data from the survey returns. The survey itself was accessible via a link which needed to be distributed among the participants. Multiple participation of one respondent is a considerable risk when using online surveys. Thus, the internet protocol (IP) address of each participant was saved next to the answers. Additional data stored by the program consisted of the time needed for the questionnaire and the date and the time at which the participant took part in the survey.

3.2 Sample Size Determination

To successfully correlate the actual noise data from the various residential towns, a sufficient number of inhabitants was necessary to receive a valuable result. For this purpose the sample size for each residential town was calculated. The formula is given by von der Lippe (2011, pp. 6).

$$\frac{n}{N} \geq \frac{1}{1+e^2 N}$$

This shows the necessary sample size (in percent of the total sample) $\frac{n}{N}$, influenced by the total population N as well as by the absolute error e which is assumed to be 0.08 according to von der Lippe (2011, pp. 6). This formula can be used to find out how many participants are necessary for a certain population. With a high population the value converges to 156. Table 5 (Statistik Austria, 2013) shows the populations of the residential towns and thus the required sample number.

Town	Population	Number of required participants
Enzersdorf an der Fischa	2.959	148
Fischamend	4.798	151
Groß-Enzersdorf	9.613	154
Himberg	6.671	153
Kleinneusiedl	798	131
Mannswörth	part of Schwechat	
Rauchenwarth	658	126
Schwadorf	1.918	144
Schwechat	16.529	155
Zwölfaxing	1.572	142

Table 5. Population of the residential towns and the required sample sizes

3.3 Distribution

In order to receive the required number of returns it was intended to distribute the link by postal service to every household of the determined residential area. Cost constraints, however, made this approach impossible. As another method, the publication of an article on the study in a local newspaper was planned, but stopped due to concerns by the Vienna airport. Eventually, the link was distributed via e-mail to particular groups such as the Vienna Airport Friends (Flughafenfreunde Wien) and die Austrian Cockpit Association (ACA). Further selective mailshots were conducted by members of the project team.

Besides a flyer used for this mailshots. Additionally, a news article was posted in an online aviation forum. The survey was accessible via link for four months. Before this period a pre-test was available for certain informed people in order to determine any shortcomings in the design of the questionnaire.

3.4 Study Design

After the basic structure of the questionnaire had been defined, the questions were developed in cooperation with employees from the environmental department of VIE, who had a sustainable influence on the questions' order and formulation. As the survey was supposed to be answered by residents around VIE, the questionnaire's language is German. The questionnaire consists of four parts. The first part refers to air traffic noise and its perception. In the second part the participants are asked about their relation to the airport and its measures against air traffic noise. The last two sections of the questionnaires concern the living condition and biographical data of the participants.

The questions were designed according to the principles stated by Schnell, Hill and Esser (2013) and by Raab-Steiner, Benesch and Der Fragebogen (2012). High effort was put on coherence and one the questions' formulation. Especially questions dealing with the past were formulated with particular awareness as they proof to be more difficult to understand (Schnell et al., 2013, pp. 169). Only closed questions were used for the questionnaire. Compared to open questions, closed questions facilitate evaluation and are usually easier to answer for participants, as Raab-Steiner et al. (2012, pp. 50) state. The questions can be divided into three categories:

- rating scales,
- decision question and
- selective questions.

Questions with rating scales were designed according to the "forced-choice"-principle which implies that an equal number of answer possibilities is given. According to Raab-Steiner et al. (2012, pp. 57), this principle has a higher information content compared to a rating scale with an answer option between the two basic characteristics. Decision questions always required a yes/no answer from the participants and therefore only had two options. For some questions another option was added, however, in case the participant did not know an answer. Questions of the third category were used in order to determine to which out of several items a participant agrees or belongs. For each of these questions either one or more items could be selected. The entire survey consisted of 22 questions some of which contained up to three sub questions. The project team estimated a completion time of approximately five to ten minutes. In average, however, it took participants only three minutes to complete the survey.

4. Results

Noise monitoring continues to be one of the most important tools in noise management around airports as noise pollution is a serious problem for the surrounding communities. The monitoring units must be reliable and precise in order to ensure the quality of the results provided.

As a first step to achieve this, it is necessary to make an estimation of the uncertainty of the results, taking into account the contribution of every single element in the measurement chain. Among other contributions to uncertainty, as listed in ISO 20906, the events marking system has an influence on the measurement results on two different levels: the first one derives from the human factors affecting the event detection while the second one derives from the error rates of the classification-identification chain. Acoustic modelling around airports is intended to satisfy the needs of many users ranging between sophisticated noise spectrum and a pragmatic noise environment in terms of cumulative noise exposure or, by means of the size of a population annoyed by the noise in the area of concern. It must be noted that the form and structure of the noise indices, which must be assessed and investigated around the airport or under a flight path have a dominant influence on the method of their assessment. Methods for modelling noise radiation, propagation and attenuation include both analytical and semi-empirical techniques.

Based on the airport environment policy study (Suau-Sanchez, Pallares-Barbera & Paül, 2011), a theoretical framework for environmental noise annoyance was developed by considering it a form of psychological stress. This model was based on the psychological stress theory of Lazarus (1966).

Stallen (Suau-Sanchez et al., 2011) states that non-acoustic factors affect the relationship between sound exposure and annoyance. Noise disturbance creates difficulties for achieving a particular goal or action, including sensory and mental processes. Perceived disturbance is not the only determinant of annoyance; non-acoustic factors are also crucial in its generation (Figure 3).

Perceived control is a major factor identifying with the predictability of a noise situation, the accessibility of information and transparency, trust and recognition of concern, and voice. High disturbance and high control may be less annoying than moderate disturbance and no control.

Perceived control together with other factors influences the level of annoyance and the capacity to cope with it.

In addition to this, depending on the possibilities of standing up to the cause of dissatisfaction, the level of annoyance will be different. Coping with annoyance is essentially a reappraisal of the personal-environmental situation. This reappraisal involves mental change including the formation of new behavioural intentions and the undertaking of corresponding actions.

Subsequently, the generation of noise annoyance is essentially a dynamic process in which acoustic and non-acoustic factors are appraised and re-appraised by the individuals on the basis of their needs and the resources available to meet them. Measures of noise annoyance therefore represent temporary states. Figure 6 illustrates the noise annoyance framework of Stallen (Suau-Sanchez et al., 2011).

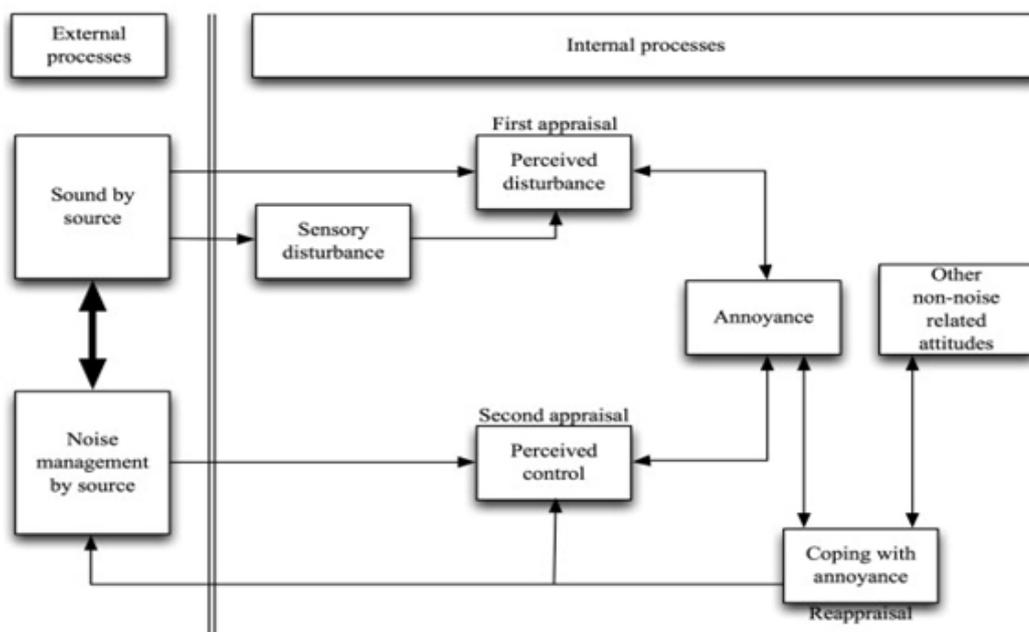


Figure 6. Noise annoyance framework

There has been another study similarly to the one above, specifically for Amsterdam airport that also described the effect of the transport noise level on the price of a house (Dekkers & van der Straaten, 2009). The calculation used was the hedonic pricing method. The first step in the analysis is to estimate a hedonic price function with the house price as the dependent variable. Next, the individual demand curve for each separate explanatory variable can be calculated. The basic regression model used in this analysis is formulated as follows (Dekkers & van der Straaten, 2009):

$$P = \alpha + \beta S + \gamma L + \tau G + \varepsilon$$

P is a (n×1) vector of house prices, S is a (n×i) matrix of transaction-related characteristics (e.g. free of transfer tax, year of sale), L is a (n×j) matrix of structural characteristics (e.g. number of rooms, quality of inside maintenance), G is a (n×k) matrix of spatial characteristics (e.g. accessibility, neighbourhood ethnicity, level of urban facilities), α ; β , γ and τ are the associated parameter vectors and ε is a (n×1) vector of random error terms. For this analysis, a log-linear model was considered, as this functional form is widely used in similar studies and, thus, allows for a straightforward comparison of results along with the presence of spatial dependence. The outcomes of the hedonic price analysis can be used to estimate the marginal and total benefits of aircraft noise reduction in the area around the airport. This is done by taking the model coefficient for aircraft noise and multiplying the related house price impact by the house value of each house for which noise reduction is accomplished. The marginal costs of the noise increase can be calculated in a similar way. This theory can be considered for an overall estimation and calculation for airport capacity and controlling but more attention can be paid here to the benefits of noise reduction. For one specific airport, there was a combined study, which needs to be taken into account for the layout of a noise abatement issue, called the HYENA study (HYpertension and Exposure to Noise near Airports) (Babisch et al., 2009). This study refers more or less to the concept which was also derived and used during the noise abatement findings with the Vienna airport for this paper.

With the HYENA study, the noise annoyances due to aircraft and road traffic were assessed for subjects who lived in the vicinity of six major European airports using the 11-point ICBEN scale (International Commission on Biological Effects of Noise). A distinction was made between the annoyance during the day and during the night. Lden and Lnight were considered as indicators of noise exposure. Pooled data analyses showed clear exposure–response relationships between the noise level and the noise annoyance for both exposures. Annoyance ratings due to aircraft noise were higher than predicted by the EU standard curves.

Lden and Lnight were calculated for both aircraft and road traffic noise according to the “European Environmental Noise Directive”, considering +5 dB(A) and +10 dB(A) weighing factors for the evening and night period, respectively Summaries of EU Legislation (2002).

Approximations were used to calculate L_{den} , when only $L_{Aeq, 24h}$ (considering a 10 dB(A) difference between $L_{day, 16h}$ and L_{night}) or $L_{day, 16h}$ and L_{night} (considering a 2 dB(A) difference between $L_{day, 16h}$ and L_{den}) were available for road traffic noise (Bite and Bite, 2004) and European Commission Working Group Assessment of Exposure to Noise (WG-AEN, 2006) (Babisch et al., 2009).

To minimise the impact of inaccuracies on the noise levels at the lower end, cut-off values of 40 dB(A) for L_{den} and of 30 dB(A) for L_{night} were introduced for aircraft noise. The lower cut-off levels for road traffic noise were set to 45 dB(A) and 35 dB(A), respectively. A distinction was also made between source-specific noise annoyances during the day and the night, and between the global noise annoyance with open and closed windows. As part of the findings, an analysis was carried out among the residents around the airport where both personality and behavioural factors were assessed, including noise sensitivity. The attitude towards the airport was assessed in order to identify differences between airports ("What is your attitude towards your local airport?") in association with the noise exposure and the annoyance.

In the HYENA study (Babisch et al., 2009) annoyance was assessed in the limited range of 45 to 70 year old subjects. In meta-analyses which comprised a much wider age range, an inverse U-shaped association was found between age and annoyance. The age group of 30 to 50 years was most annoyed by aircraft noise. Annoyance reactions were found to be lower in younger and older subjects. It was also seen here that, the age was negatively associated with annoyance by trend, which was in line with the findings and results from other countries not included in the study. This suggested that annoyance was more likely to be underestimated than overestimated in the study compared to the generalised EU curve. However, it was perceived as an overall conclusion, that people's attitudes towards aircraft noise has changed over the years, and that the EU standard curve for aircraft noise should be modified. With the variety of literature available and the case studies made on various airports regarding the noise abatement, it can be concluded from the before mentioned studies, that a successful model performance can be obtained in several zones around the airport. The validated noise model of the Vienna Airport can be utilized both for determining the noise levels and for producing new strategies which are about land use planning, operational considerations for air traffic management and noise abatement procedures.

4.1 Study Results

This chapter describes the data which was received from the online survey. Firstly, data on the general backflow and the participants are presented. The second part contains results from the particular research questions of the survey. Within the period in which the survey was accessible on the web (May, 2nd 2014 until June 2nd, 2014) 170 persons participated in the survey.

Out of the 170 participants 143 valid completions of the questionnaire were registered. As illustrated in Figure 7, the majority of the participants completed the survey at the beginning of the questioning period.

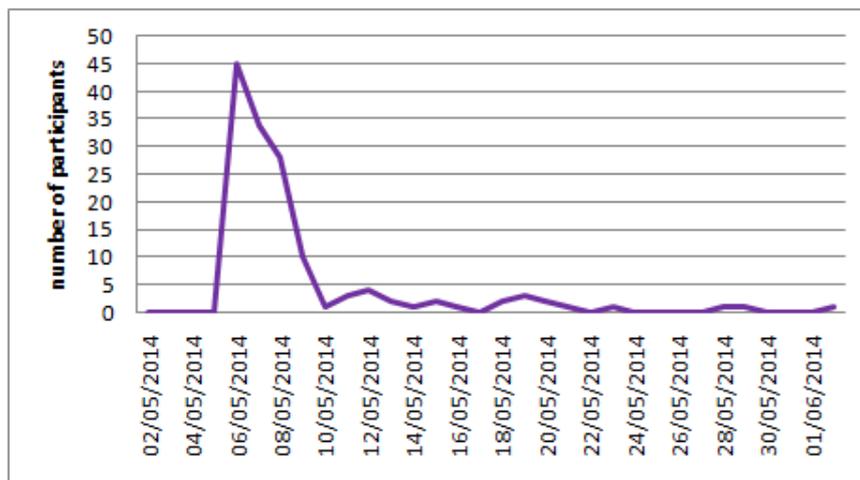


Figure 7. Study returns over the questioning period

Three types of biographical data were asked from the participants. The results of the first data, the age, show a relatively equal distribution with around 30 to 35 participants per age group except for the groups of below 20 years and over 65 years. As Figure 9 and Figure 10 show the remaining biographical items are not that equally distributed. The large majority of the participants are male and either completed an apprenticeship or a university education.

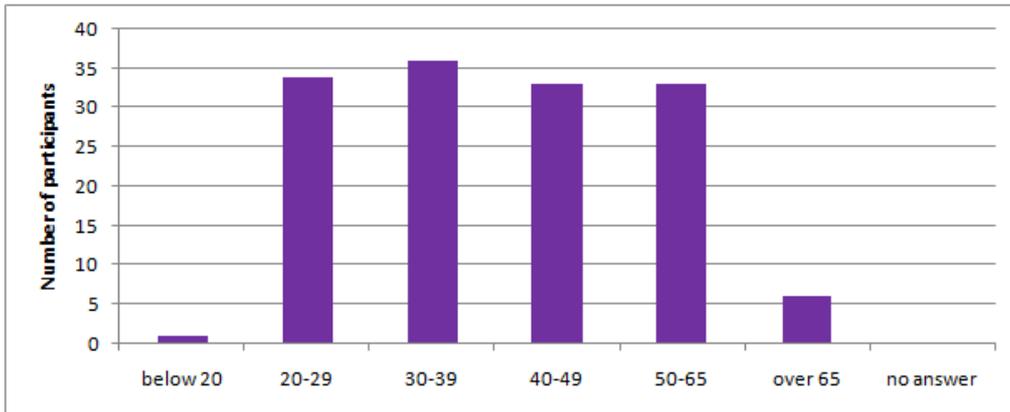


Figure 8. Age distribution of the participants

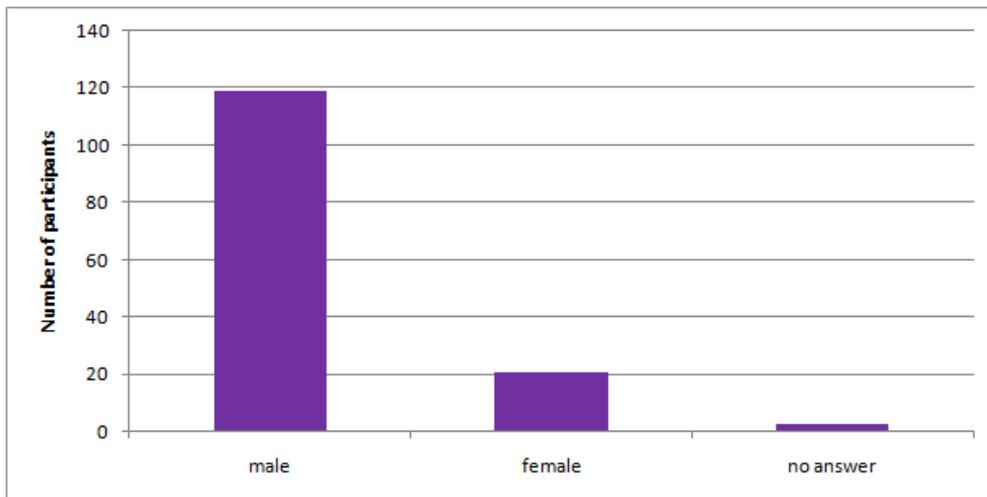


Figure 9. Sex distribution of the participants

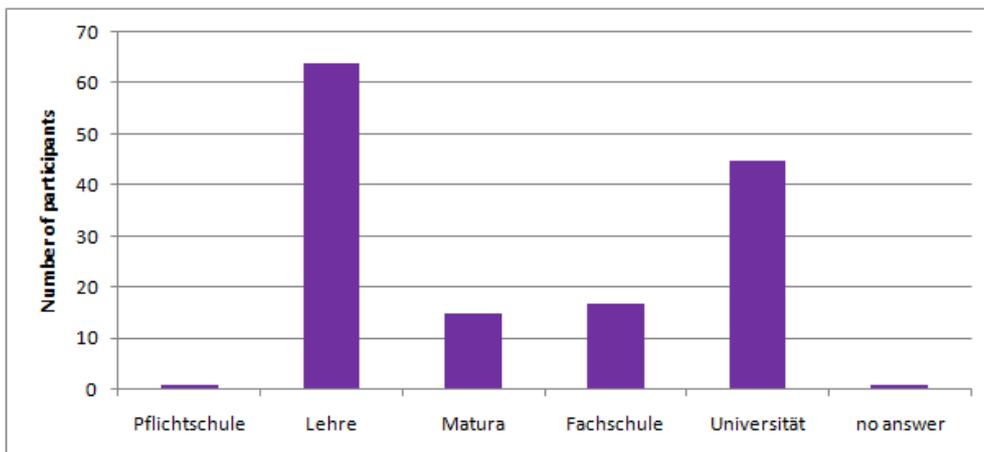


Figure 10. Highest education of the participants

The participants' origin is of great interest in relation to the scientific research question. While the target group of the survey was related to the residential communities of VIE, most of the participants came from somewhere else and less than one third of the returns originated from the target area. Almost 50% of the participants were from Vienna. Breaking down these results into a communal level reveals that a neglectable low number of participants from the single residential towns took part in the study.

If these figures are compared with the number of required participants per town it becomes obvious that a statistically significant statement cannot be made.

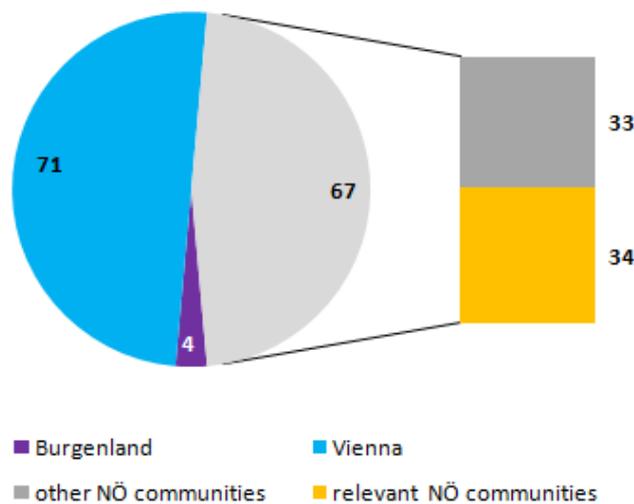


Figure 11. Distribution of the participant's place of residence

Like Table 5, Table 6 also shows the required number of participants for each town, but this time also in comparison with the actual returns from the respective town. In all of the ten towns less than 10% of the required participant number was reached.

Town	Population	Number of required participants	Number of actual participants
Enzersdorf an der Fischa	2.959	148	4
Fischamend	4.798	151	6
Groß-Enzersdorf	9.613	154	1
Himberg	6.671	153	1
Kleinneusiedl	798	131	3
Mannswörth	part of Schwechat		1
Rauchenwarth	658	126	0
Schwadorf	1.918	144	3
Schwechat	16.529	155	12
Zwölfaxing	1.572	142	1

Table 6. Population of the residential towns, required and actual participants

4.2 Results of the Research Questions

Although the original research questions could not be answered for the single residential towns due to the low number of participants, the study revealed several other findings of high significance. The answer on the noise affection of people experiencing air traffic noise from VIE revealed that only 35% (50 participants) are affected or disturbed respectively. Out of these 50 persons 36 have experienced a change as seen in Figure 12.

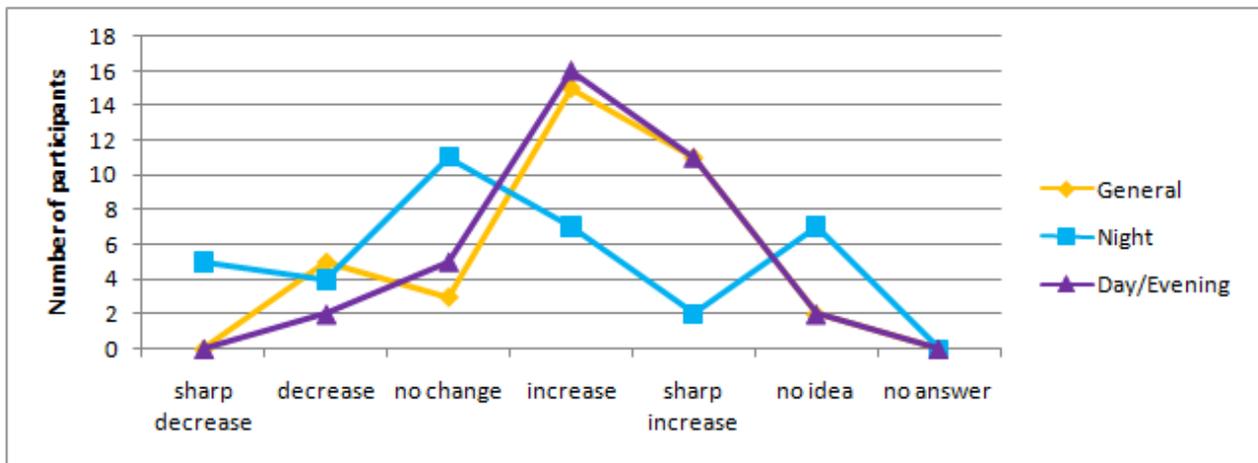


Figure 12. Participants` impression of noise change over the last five years

Also visible in Figure 12 is the fact the change of experienced air traffic noise during daytime (violet line) corresponds much more to the overall experience (yellow line) than the night time noise experience. For both of the items the majority of participants experienced an increase in air traffic noise over the last five years. Turning to the reason for air traffic noise participants state that, although they have experienced an increase in air traffic noise, neither the noise of a particular aircraft nor the number of flight movements has increased. Figure 13 visualises that none of the participants experienced either louder or more aircrafts within the last five years.

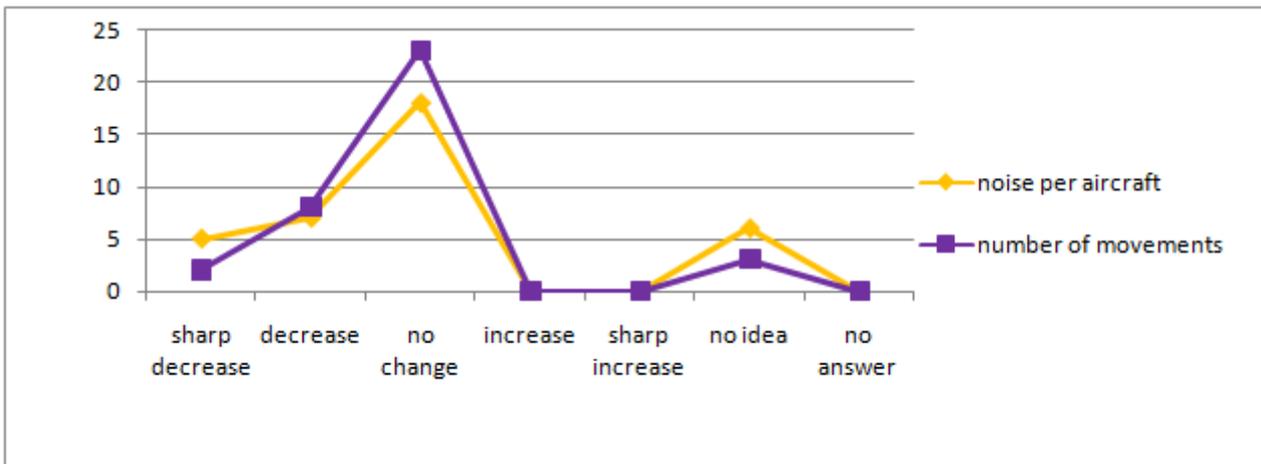


Figure 13. Participants' impression on the change of air traffic

Next to air traffic noise, participants experienced several other types of noise sources. Road traffic accounts for the most frequently mentioned noise among the participants. While 50 participants feel affected by air traffic noise, 84 participants experience it according to the results of the question for other noise. All the noise encounters can be seen in Table 7.

Commodity	Mentions
Road	116
Air Traffic	84
Rail	48
Other noise (children, neighbours, construction work, public transport)	29
Industry	10

Table 7. Mentions of other noise sources

Regarding the influence of air traffic noise on the quality of life, the affected participants provided a relatively consistent picture. More than 50% see themselves not, or rather not, influenced by air traffic noise in terms of life balance or life quality. Only five (life balance) respectively two (life quality) participants are highly affected as Figure 14 shows.

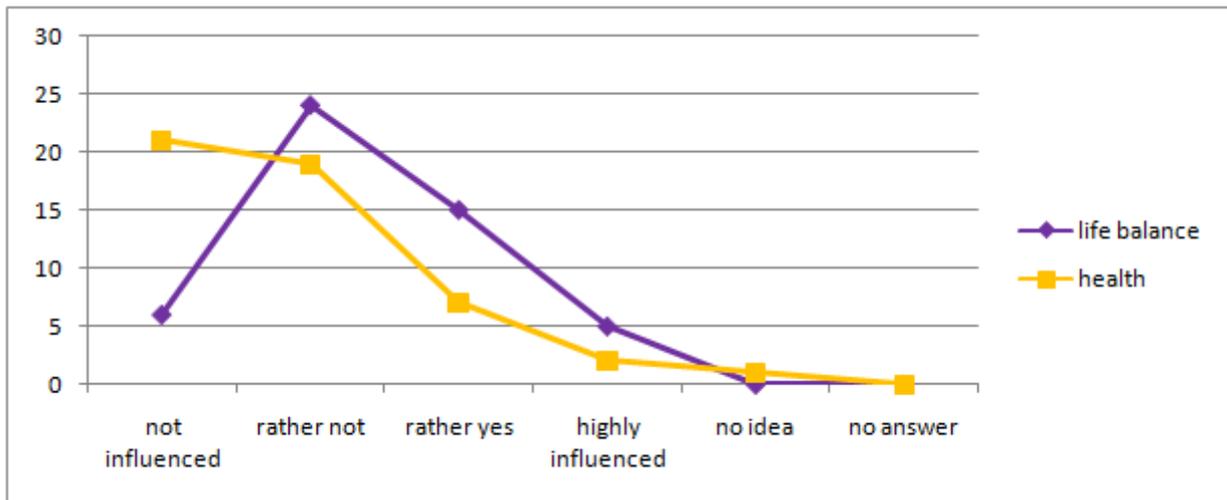


Figure 14. Participants' impression on the influence of air traffic noise on life quality

The combination of two questions blocks reveals how participants of a certain group are affected by air traffic noise. Clear differences are visible between the noise affection of participants with different residences. When considering the residents from the city (and state) of Vienna and the state of Lower Austria separately, a considerable difference can be observed: almost 50% of the participants in Lower Austria are affected by air traffic noise in comparison to less than one third of the residents from Vienna.

For both of the groups the number is relatively equal with 67 participants from Lower Austria and 71 Viennese participants. Figure 15 illustrates the difference.

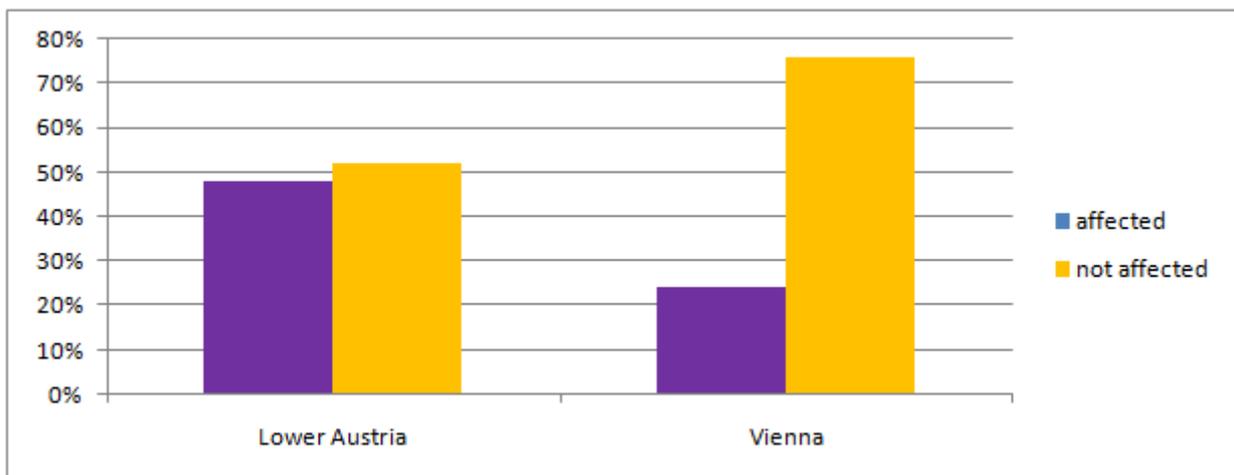


Figure 15. Percentage of noise affection of participants from Vienna and Lower Austria respectively

A more equally distributed outcome is given when the participants are grouped according to their relation to VIE. Participants are divided into three groups with the following frequencies:

- no airport relation: 57
- works at VIE: 46
- family member or friend works at VIE: 40

Although it might be assumed that the threshold for noise affection is lower for people with a relation to the airport, Figure 16 illustrates that no significant difference between the groups exists.

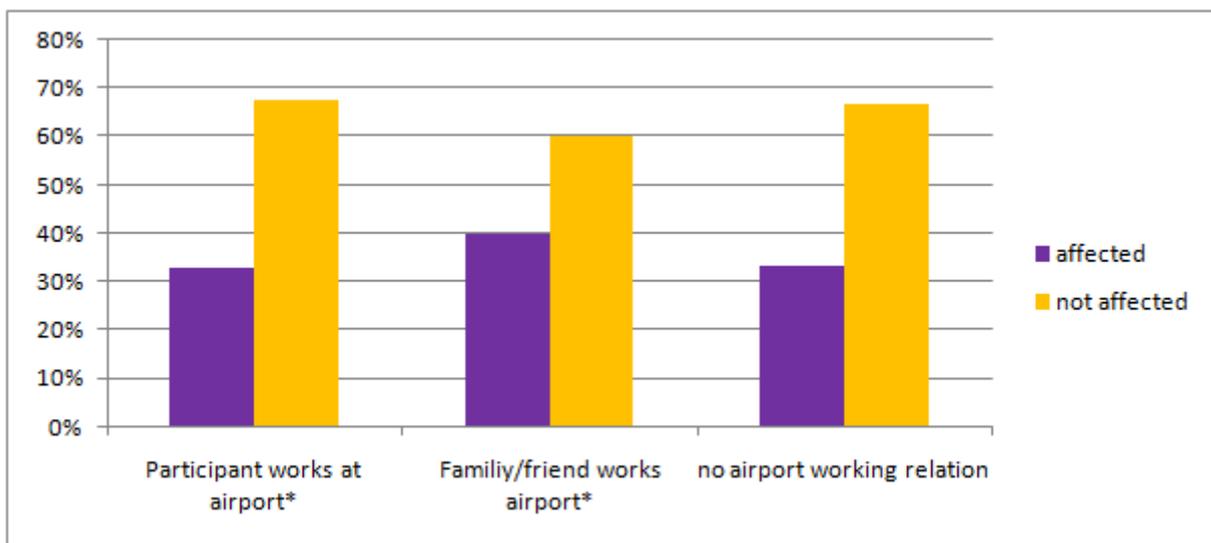


Figure 16. Noise affection of participants with different relations towards the airport

In order to see the impact of VIE’s efforts on the noise issue, participants were also asked about their knowledge of the programmes. Additionally, the participants were asked whether they use the noise protection programme and whether they are involved in the work of the Dialogforum. While 60% percent of the participants are aware of the noise protection programme, only 40% know the Dialogforum. The majority of other online forums on that topic are known even less.

Forums	No	yes	yes (%)
www.vie-umwelt.at	98	45	32%
www.flugspuren.at	74	69	49%
www.dialogforum.at	91	52	37%
www.laermschutzprogramm.at	123	20	14%
www.laerminfo.at	132	11	8%

Table 8. Participants` knowledge of various online forum on VIE air traffic noise

5. Discussion

5.1 Discussion of the Air Traffic Noise Data

As mentioned in the introduction section, almost no correlation between the air traffic noise in certain towns and the number of air traffic on the corresponding runways could be detected. Rather, the correlation factor changes from more or less 0 to around 1. Thus, no clear statement can be made in this study on any dependence between the air traffic volume and noise.

The most probable reason for these differences might be the fact that the measured noise in the particular towns does not correlate exactly to the noise corresponding to the indicated runway and its T/Os and arrivals.

For Fischamend, with a correlation factor of 0.49, not only T/Os from RWY 11 and approaches on RWY 29 account for the noise level - most probably movements on RWY 16/34 influence the noise level as well.

Also the Schwechat measurement might not reflect only the flights departing from RWY 29. As shown in Figure 17 all the standard instrument departures (SID) – the routes flown by almost all departing aircraft – of RWY 29 make a turn before the aircraft would fly over the noise measurement point of Schwechat. In Figure 17 this point is marked as a black and white dot with the number 11 next to it.

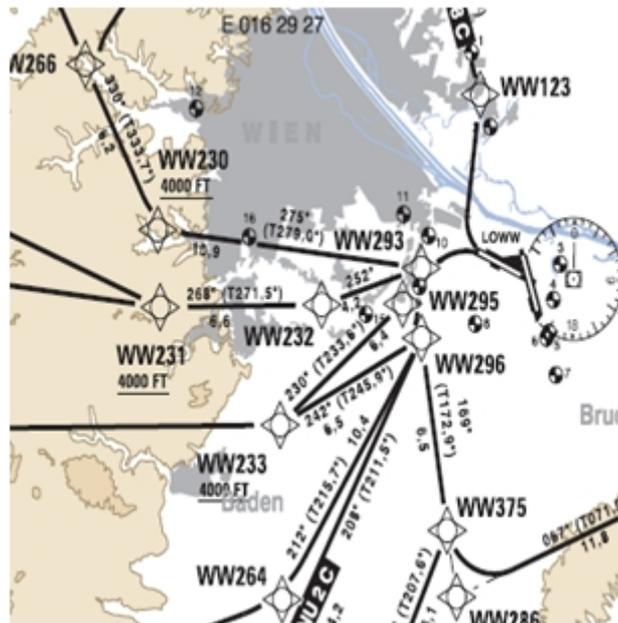


Figure 17. Standard Instrument departure (SID) routes from RWY 29

5.2 Discussion of the Study Design

The first aspect that clearly stands out from the results of the survey is the low number of returns. With only 143 participants the study can clearly not be used for a representative statement, but more as a pilot research project. A reason for the small number of participants can be found in the low level of promotion which had been done for the study. As stated in section 0, only mailings and forum postings were used. However, these small scale promotions showed satisfactory results, as Figure 18 illustrates. This figure also shows the returns over time, but this time with the promotion events which were carried out by the project team. It clearly becomes visible that these events had a considerable influence on the return rate.

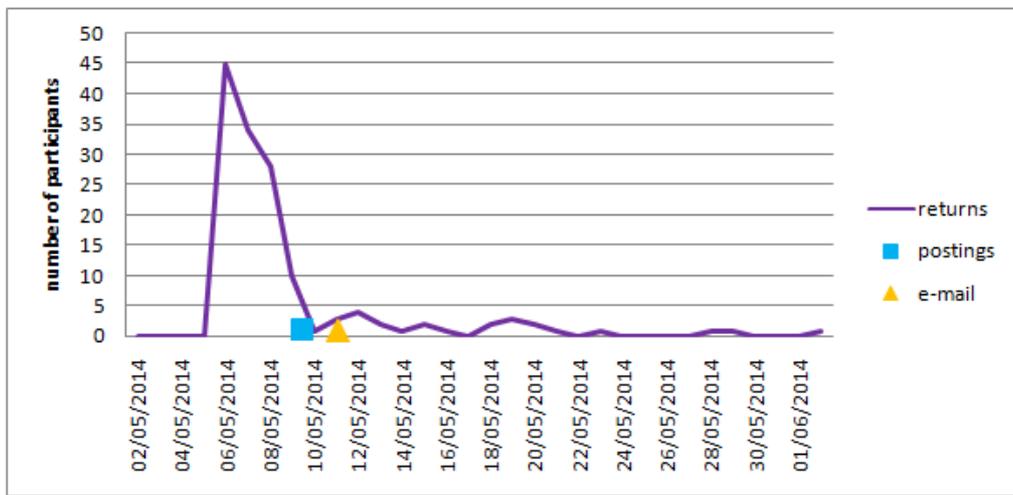


Figure 18. Returns for the online survey in respect to the promotion events

Interestingly, however, the manual mailshot, which was carried out in Schwadorf (ca. 120 pieces) and in Schwechat, did not show much response. According to the return time line, only one or two percent of the mailshots resulted in a study participant within the next few days. Another room for improvement was found in the question formulation. At the beginning of the questionnaire the participant had to answer two decisive questions, which both had to be answered with "yes", before the participants were asked the actual research questions. Table 9 shows that from the original 143 participants only 36 arrived to the research question.

Number	Question	Number of returns
1	Do you anticipate air traffic noise from which you feel influenced or annoyed?	143
2	Did the air traffic noise which you anticipated, have changed over the last years?	50
3	"Selective question" à Change of noise	36

Table 9. Return rates of the first three questions of the study

The first question can further be criticised for its suggestive formulation. Several participants might have understood the questions in a too negative way and thus answered with "no". Instead it would have been more fruitful to do not ask question number one but give short description that only people anticipating air traffic noise should participate in the study, instead.

5.3 Discussion of the Study Results

Even though, due to the low number of returns, no statistically relevant conclusions can be drawn, the results of the survey can be used to make some general statements. As the main focus of the survey was put on the noise affection, these findings are discussed primarily in this section.

As already stated, the difference between the participants from Vienna and those from Lower Austria is rather significant. According to Figure 15, residents of Lower Austria are two times more noise affected than their counterparts from Vienna. A possible reason for this difference might result from the exposition of the participants to other noise. It could be the case that city residents are surrounded by more noise in general and are therefore less affected by air traffic noise.

However, there are two indications that speak against this theory. On the one hand the results from the question on other noise sources show that on average both resident groups mentioned the same number of other noise sources per participant. On the other hand, the large majority (71%) of complaint calls received by the Dialogforum in 2011 (Dialogforum Flughafen Wien, 2013, pp. 59) came from Vienna. Another finding of interest can be identified in Figure 12. Here, the general impression of noise change is compared to the impression of noise change for day (06:00-22:00) and night (22:00-06:00) periods. Between the general and the day impression, the correlation factor r is comparably high with a value of 0.969. For the comparison of the general impression and the night period impression instead, r has a value of 0.071. This suggests that the participants' impression of air traffic noise is mostly influenced by day time air traffic.

On the one side this seems logical as most of the air traffic – and therefore most noise emission – happens during that time of the day. On the other side, however, night time is usually a period in which people, as they are supposed to sleep, are more susceptible to noise.

The comparison of these results to the times at which the participants are at home usually does not show significant differences. For both subgroups the general noise affection is about one third and the experience of air traffic noise change is about 25% of the total participants. Furthermore, it can be stated that the participants are at their residences at least most of the

time during the day and night periods. For VIE the results of the survey showed the potential for improved information about the air traffic noise topic, as the majority of websites and online platforms are not known by the participants. Only slightly more than 20% were aware of more than one of the websites mentioned in Table 8. All of the websites were known by one participant.

6. Summary and Outlook

On the topic of sustainable aviation a study was carried out to measure the difference between the actual change in air traffic noise and the airport's residents' perception of the noise change at Vienna International Airport. Therefore, a questionnaire was developed in cooperation with the airport and an online survey was conducted.

Although the survey results cannot be rated statistically relevant due to the fact that only 143 people participated, the study showed some interesting results. Primarily, it can be noted that only about one third of the participants are affected by air traffic noise in one way or another. The majority of these people live in Lower Austria, the federal state in which the airport is located.

It is also interesting to see that participants obviously judge air traffic noise during day time more importantly than air traffic noise at night. The participants' working relationship to the airport has no significant effect on the attitude towards air traffic noise. Concerning the knowledge of platforms and websites there is potential for improvement of people's awareness.

Any further steps of this project would include a detailed comparison of the survey's results with information from the Dialogforum which provides compressive data on air traffic noise and complaints of residents. This would allow validation of the study's viability and pinpoint shortcomings.

In addition to this, a more widespread study could be carried out in order to obtain statistically relevant data. However, more (financial) support would be required in order to organise an appropriate survey.

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