inter.noise 2010
noise and sustainability
13-16 June 2010 . Lisbon . Portugal
www.internoise2010.org

THE IMPACT OF ACOUSTICAL, OPERATIONAL AND NON-AUDITORY FACTORS ON SHORT-TERM ANNOYANCE DUE TO AIRCRAFT NOISE

Dirk Schreckenberg, Rudolf Schuemer

ZEUS GmbH, Sennbrink 46, D-58093 Hagen, Germany
e-mail: schreckenberg@zeusgmbh.de, schuemer@zeusgmbh.de

Abstract

Within the European research project COSMA (Community Oriented Solutions to Minimise aircraft noise Annoyance) re-analyses of data of the Frankfurt Noise Annoyance Study 2005 have been done in order to identify acoustical, operational and non-acoustical factors contributing to the explanation of short-term annoyance (hourly annoyance). Furthermore, the relationship between short-term annoyance and long-term annoyance and disturbances due to aircraft noise (last 12 months) has been analysed. Results indicate that beside the hourly sound level, the number of flyovers, operational factors (takeoffs/landings) and attitudinal factors such as expectations concerning future after airport expansion, aircraft-related fears and confidence in authorities have an impact on the hourly annoyance. Furthermore, hourly aircraft noise annoyance in combination with activities turned out to be valid indicators of long-term annoyance and activity disturbances due to aircraft noise.

Keywords: Aircraft noise, annoyance, non-acoustical factors, time of day.

1 Introduction

According to the study of ANOTEC [1] on current and future aircraft noise exposure owing to the continuous long-term growth of air traffic the number of people highly annoyed by aircraft noise is expected to increase at a rate of 1 to 4% per year. That is, a sustainable growth of air traffic makes it necessary to achieve further success in active noise control and the reduction of noise at source. For this, the European research project COSMA (Community Oriented Solutions to Minimise aircraft noise Annoyance) aims at improving the understanding of how aircraft noise affects residents in the vicinity of an airport on a short-term level (single event or series of aircraft noise events), how these short-term effects are related to long-term annoyance, and which are the factors that have additional to the sound characteristics of

aircrafts a decisive impact on both short-term and long-term annoyance. Based on this, techniques for modelling the impact of aircraft noise around airports as well as engineering guidelines and methods will be developed to implement suitable design and operating practices aimed at reducing the aircraft noise annoyance of residents living in the vicinity of an airport. Within COSMA the task is to improve the understanding on aircraft noise effects through an extensive literature review and the analyses of original data on aircraft noise annoyance and its determinants. The data come from a field study on aircraft noise annoyance carried out at Frankfurt Airport in 2005 and from new field and laboratory studies on annoyance due to aircraft noise carried out within the frame of COSMA. In this paper results of the reanalysis of the Frankfurt Noise Annoyance Study 2005 (FRA-S) [2][3] concerning both long-term and short-term (hourly) aircraft noise annoyance are presented.
Noise annoyance is regarded as a psychological key effect variable in noise effect research. There are numerous field studies showing the impact of environmental noise on annoyance in exposed population [4]. Noise annoyance as assessed in field studies is usually considered as a long-term effect of noise, “mediated by short-term reactions, and moderated by personal and social factors“ [5]. For example, the standardized annoyance question recommended by the International Commission on Biological Effects of Noise for the (ICBEN) for community noise surveys “seek to obtain general, persistent reactions that allow respondents to integrate their experiences over different times and locations in their home” [6].
Short-term reactions refer to primary reactions to noise like vegetative reactions, event-related activity disturbances and short-term annoyance, sometimes also called “functional annoyance”[7], or “acute annoyance”[8]. Short-term noise annoyance is usually assessed in laboratory studies. However, a few field studies also observed short-term annoyance. For example, in a field study by Stearns et al. [9] subjects living in the vicinity of airports completed five days a diary to assess their event-related noise annoyance and the currently interrupted activity and location. In a study done by Schomer and Wagner subjects recorded the noticeability of environmental noise and annoyance per event by means of a palm-top computer [10]. Hourly annoyance due to road traffic and railway noise at daytime in combination with activities and location in the respective hour was recorded by participants on four successive days by means of palm-top computer in the study of Schreckenberg et al. [11]. The same method was used in the field study on aircraft noise effects presented in this contribution in order to ascertain the hourly annoyance due to aircraft noise at daytime (7am to 11pm).
The main objectives of the study presented in this paper was to identify relevant acoustical and operational factors contributing to the explanation of short-term (hourly) aircraft noise annoyance; to analyze how short-term annoyance (last hour) is associated with long-term (last 12 months) annoyance and disturbances due to aircraft noise; and to analyze which acoustical and non-acoustical factors are related to long-term as well as short-term annoyance and to what degree they contribute to the prediction of short-term and long-term annoyance.

2 Method

2.1 Procedure and sample

The analyses on short-term and long-term aircraft noise annoyance base on data of the study FRA-S [2][3]. In this field study face-to-face-interviews on long-term noise annoyance, residential situation and health-related quality of life were done between April and December 2005 with 2312 residents of 66 areas in the vicinity of Frankfurt Airport (study part I). For each address aircraft sound indicators were calculated on the base of flight movements of the 6 busiest months of the year 2005. In the second part of the study a sample of 200 persons assessed every hour from 7am to 11pm their hourly annoyance due to aircraft noise together with the location, activity and – in case of indoor stay - window position in the respective hour on four successive days (including weekend) between August and November 2005 by means of a handheld computer (study part II). 196 persons of them did take part both in study part I and II whereas four persons did take part in study part II only. Therefore, in this study results concerning long-term and hourly aircraft noise annoyance base on field data of 196 participants of study part II.

2.2 Variables

2.2.1 Aircraft noise exposure

The long-term aircraft sound exposure based on the flight movements of the six busiest months of the year 2005 was indicated by the equivalent sound level (L_{Aeq}), the mean maximum sound level above 55 dB and 70 dB (L_{max55}, L_{max70}) and the number of flyovers above 55 dB and 70 dB (N_{55}, N_{70}) for daytime (6-22h) and for night-time (22-6h). The aircraft sound exposure per hour between 7am and 11pm based on the flight movements of the days of annoyance assessments in study part II was indicated by the hourly equivalent sound level ($L_{Aeq,1h}$), the mean maximum sound level ($L_{max,x,1h}$) and the number of flyovers ($N_{x,1h}$) with the thresholds (x) 45, 50, 55, 60, 65, and 70 dB. Each hourly noise indicator was ascertained in total per hour and separately for approaches and takeoffs. The short-term equivalent sound level in the sample of study part II ranged from 41 to 62 dB (mean: 52 dB) for aircraft sound at daytime and from 24 to 57 dB (mean: 45 dB) for aircraft sound at night-time.

2.2.2 Questionnaire variables

The variables in the questionnaires of study part I and II and used for the analyses described in this paper are listed in Table 1. A more detailed description of the variables can be found in [3].

Table 1 – Variables assessed in the questionnaires of study part I and II

Variable category	Variable	Items	Response scale of items	Assessed in study…	
				I	II
Aircraft noise annoyance	▪ … in the past 12 months	1	5-pt. intensity	x	
	▪ … in the past 12 months		11-pt. intensity	x	
	▪ … in the past hour	1	5-pt. intensity		x
Activities, location	▪ Main activity done in the last hour	7	7 categories		x
	▪ Main location in the last hour:	1	in/outdoor, away		x
Disturbances due to aircraft noise	▪ Activity disturbances (mean scores): communication indoor (3 items), relaxation indoor (2 items), communication outdoor (1), relaxation outdoor (1)	7	5-pt. intensity	x	
	▪ Sleep disturbances (mean score)	3	5-pt. intensity	x	
Coping with aircraft noise	▪ Measures taken in noise situation (mean score)	16	5-pt. frequency	x	
Window position	▪ …in warm seasons in the living room (daytime), in sleeping-room (night-time)	2	open, tilted, closed	x	
	▪ Main window position in the last hour	1			x
Air traffic related attitudes	▪ Fears concerning air traffic	4	5-pt. intensity	x	
	▪ Confidence in authorities' effort for aircraft noise reduction	6	5-pt. intensity	x	
	Expectation concerning airport expansion				
	▪ Negative expectation	6	5-pt. intensity	x	
	▪ Positive expectation	3	5-pt. intensity	x	
	▪ Economic expectation	2	5-pt. intensity	x	
Perceived environ. QoL	▪ Concern about environ./soc. problems	21	5-pt. intensity	x	
	▪ Residential satisfaction	12	5-pt. intensity	x	
Self-reported health	▪ Sleep quality (PSQI total index)		PSQI index	x	
	▪ Health complaints: exhaustion, stomach complaints, limb, cardiac complaints	24	GSCL24 index	x	
	▪ Self-reported diagnosed diseases: 18 diseases ever had / had in last 12 m.	18	yes / no	x	
	▪ Quality of life: vitality	4	Subscales of SF-36	x	
	▪ Quality of life: mental health I	5		x	
	▪ Quality of life: mental health II	6	Subscales of SF-12	x	
	▪ Quality of life: physical health	6		x	
Personal factors	▪ Noise sensitivity (single item)	1	5-pt. intensity	x	
	▪ Noise sensitivity (NoiSeQ scale)	36	4-pt. intensity		x
	Socio-demographics				
	▪ Age	1	age in years	x	
	▪ Gender	1	female/male	x	
	▪ House ownership	1	owner, tenant	x	
	▪ Socio-economical status: index including education, profession, income	3	index	x	

3 Results

3.1 Impact of maximum sound level and number of flyovers on annoyance

Table 2 shows the correlation between long-term aircraft noise annoyance (last 12 months) as assessed in the face-to-face interviews of study part I and the long-term equivalent sound level, the mean maximum sound level and the number of events above 55 dB and 70 dB both for daytime and night-time.
Short-term annoyance due to aircraft noise load was indicated by hourly annoyance judgements on 4 days, each day between 7am and 11pm (study part II). For correlation analyses between hourly aircraft noise annoyance and hourly indicators of aircraft sound exposure coefficients were calculated for each of 16 hours of four days. The results are shown in Table 3. (Because of limited space only the medians for the distributions of the coefficients are shown here.)

Table 2 – Correlation r between long-term aircraft noise annoyance (last 12 months) and indicators of long-term aircraft sound exposure.

Correlation	Equivalent sound level		Mean maximum sound level				Number of events above threshold			
	$L_{Aeq,}$ 6-22h	$L_{Aeq,}$ 22-6h	$L_{max55,}$ 6-22h	$L_{max70,}$ 6-22h	$L_{max55,}$ 22-6h	$L_{max70,}$ 22-6h	$N_{55,}$ 6-22h	$N_{55,}$ 22-6h	$N_{70,}$ 6-22h	$N_{70,}$ 22-6h
Long-term annoyance	.43	.37	.30	.24	.24	.22	.38	.33	.27	.27

All coefficients are significant on a level of $p < .01$; $n = 196$

Table 3 – Correlation r between short-term aircraft noise annoyance (past hour) and indicators of hourly aircraft sound exposure.

Correlation r		Mean maximum sound level L_{max} …						Number of events above threshold N …					
	L_{Aeq}	45	50	55	60	65	70	45	50	55	60	65	70
Hourly annoyance	.42	.34	.30	.28	.26	.23	.23	.35	.36	.37	.34	.29	.26

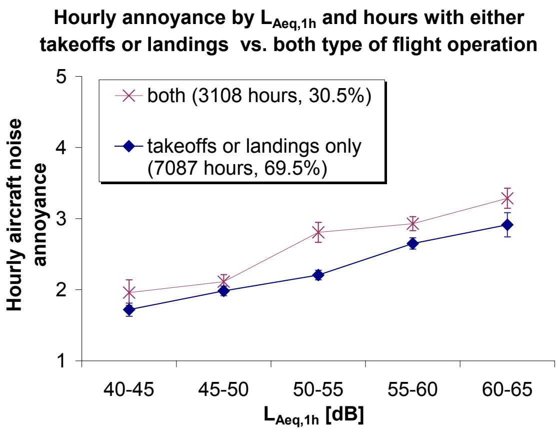
Correlation coefficients for the hourly annoyance are median coefficients of correlation calculated for each of 16 hours of four days. Coefficients are significant on a level of $p < .01$; n per hour = 58-144

Both for long-term and hourly annoyance it turns out that the annoyance-exposure correlations are highest for the equivalent sound level L_{Aeq}, followed by indicators of the number of flyovers (N_x) – in particular N_{55} – and the mean maximum sound level L_{max}.
The impact of the mean maximum sound level and number of flyovers on hourly annoyance was further investigated in regression analyses (not presented here). Both, the mean maximum sound level and the number of flyovers, contributed to the prediction of hourly aircraft noise annoyance. In all regression models the beta coefficients for the number of flyovers was higher than the coefficients for the mean maximum sound level indicating that the number of flyovers – in particular N_x with low thresholds (x) – seemed to have a stronger impact on the hourly annoyance than the maximum sound level.

3.2 Effects of types of flight operation (approaches, takeoffs)

It was analysed whether short-term annoyance is stronger related to the aircraft sound level of approaching than of starting planes. The results show that the correlations between hourly annoyance and equivalent aircraft sound levels were higher for landing than for departing aircrafts. However, in areas where the sound exposure due to both types of flight operation

could be perceived the aircraft noise exposure due to approaches was more dominant than due to takeoffs in terms of the number of events and hourly ΔL_{Aeq}. Therefore, it cannot be decided whether the stronger association between hourly sound levels due to approaches and hourly annoyance suggests stronger reactions to approaching than landing aeroplanes or whether it is the result of a reaction to the more dominant aircraft noise events regardless whether these are starting or landing aircrafts.
The impact of those hours including both types of operation, i.e. approaches and takeoffs (30.5% of all hours), and of the hours including only one type of operation (either approaches or takeoffs; 69.5% of all hours) on the hourly aircraft noise annoyance was than analysed.
It was hypothesized that aircraft noise from a mix of approaches and takeoffs include different sound characteristics coming from different directions (subjectively from 'all-around') which may hinder the habituation to and predictability of the noise load and, hence, the perceived control. In consequence, for the same equivalent sound level residents react stronger on aircraft noise from a mix of approaching and starting aircrafts in a given time period (one hour) than on noise of flight movements in constantly one direction. If this assumption is correct one would expect higher hourly aircraft noise annoyance in hours with flyovers of both, landing and starting aircrafts than in hours with either approaches or takeoffs only. The results presented in Figure 2 suggest that this seems to be true at least for hourly sound levels above 50 dB. That is, mean hourly aircraft noise annoyance was higher in hours with both approaches and takeoffs than in hours with only one of the two types of flight operation.



Test of significance:

- Sound level $L_{Aeq,1h}$: $F_{[4;4966]} = 138.4$; $p < .000$
- Type of operation: $F_{[1;5343]} = 68.3$; $p < .000$
- Level * type: $F_{[4;4959]} = 5.8$; $p < .000$

Figure 2 – Hourly aircraft noise annoyance by $L_{Aeq,1h}$ in hours including flight movements of landing and starting aircrafts and in hours with either approaches or takeoffs only.

3.3 Associations between non-acoustical factors and short-term and long-term aircraft noise annoyance

Multiple linear regression analyses with long-term and hourly aircraft noise annoyance as dependent variables and with the corresponding equivalent sound level and several non-acoustical factors as predictors have been done. The non-acoustical factors comprise source-related attitudes and expectations concerning the airport extension (opening of a 4th runway expected in 2011), the perceived environmental and health-related quality of life and the sensitivity to noise. Note that in this analysis self-reported health is conceptualized as a modifier of noise annoyance. In previous analyses of the data of FRA-S part I it was found that health variables were not directly associated with aircraft sound exposure but with aircraft noise annoyance. Thus, it was assumed that the self-reported health as assessed in this study may be prior to noise annoyance in terms of pre-existing health problems affecting psychological stress reactions to aircraft noise.

Table 4 – Results of regression analyses with long-term and hourly aircraft noise annoyance as criteria and equivalent sound level and several non-acoustical factors as predictors.

Results of regression analyses		Criterion:					
		Long-term aircraft noise annoyance			Hourly aircraft noise annoyance		
Predictors		β	r	$r_{partial}$	β	r	$r_{partial}$
Exposure	• $L_{Aeq,16h}$ (long-term)/$L_{Aeq,1h}$ (hourly)	**.25**	.40	.34	**.32**	.42	.35
Expectations concerning extention	• Negative expectation	**.33**	.67	.31	**.16**	.38	.12
	• Positive expectation	-.07	-.19	-.11	-.01	-.04	-.01
	• Economic expectation	.07	-.30	.10	.01	-.17	.01
Attitudes	• Fear concerning air traffic	**.37**	.69	.35	.05	.33	.04
	• Confidence in authorities' effort	**-.12**	-.45	-.17	**-.14**	-.28	-.14
Env. QoL	• Concern about environmental/ social problems	.10	.35	.12	**.16**	.33	.15
	• Residential satisfaction	-.03	-.32	-.04	.05	-.24	.05
Sensitivity	• Noise sensitivity (NoiSeQ)	-.01	.28	-.01	**.12**	.24	.14
Self-reported health	• Sleep quality (PSQI total index)	.03	.22	.04	.01	.14	.01
	• Health complaints (GSCL 24)	-.09	.12	-.11	-.08	.10	-.07
	• HQoL: vitality (SF-36)	-.04	-.14	-.04	-.02	-.18	-.01
	• HQoL: mental health (SF-36)	**.16**	-.16	.17	-.04	-.24	-.04
	R^2	.64			.39 (median)		

For regression models of hourly aircraft noise annoyance the median of coefficients calculated for each of 16 hours of four days is presented. Beta coefficients in **bold**: $p < .05$

In the regression model of long-term annoyance two non-acoustical variables, namely negative expectation concerning the airport expansion and aircraft-related fears, have higher beta coefficients than the $L_{Aeq,16h}$. That is, they contribute more to the prediction of aircraft noise annoyance than the aircraft sound level. One reason for this may be that both, the fears and the negative expectation, are also associated with the sound level and may reflect together with annoyance a general reaction to aircraft noise. Actually, according to partial correlation analyses the correlation of aircraft noise load (L_{Aeq}) with aircraft-related fears and expectations concerning the airport extension decreases from r = .28/.21 to r_{part} = .-03/-.13 after adjusting for aircraft noise annoyance. Hence, it is plausible to assume that fears and expectations are at least partly mediated by annoyance. Therefore, the interpretation of fears and expectations as modifiers of annoyance should be done with caution.

Further factors which contributed significantly to the prediction of long-term annoyance are the confidence in authorities' effort for aircraft noise reduction and the self-reported mental health as assessed with the SF-36 subscore. Other health variables were not associated with annoyance within this sample. Altogether, all predictors in the regression model described above explain 64% of the variance of long-term aircraft noise annoyance.

With regard to the hourly aircraft noise annoyance the main predictor is the hourly equivalent sound level. In addition, the negative expectation concerning the airport expansion, the confidence in authorities' effort, and the concern about local environmental and social problems contribute significantly to the explanation of hourly aircraft noise annoyance. Whereas noise sensitivity does not contribute significantly to the explanation of long-term annoyance it has a small but significant effect on the hourly annoyance within this set of predictors. Altogether the predictors explain 39% of the variance of hourly annoyance (median of variance explained, for all investigated hours). The equivalent sound level, the negative expectation and the confidence in authorities' effort to aircraft noise reduction are factors that contribute significantly to both long-term and hourly aircraft noise annoyance. Similar regression analyses were also done including socio-demographic variables (age, gender, house ownership, socio-economical status) as predictors. It turned out, that the socio-demographic factors are far less important for the explanation of long-term annoyance in comparison to the attitudinal factors. (There are weak tendencies for increasing annoyance with increasing age and for higher annoyance reported by women than male and by house owners than tenants.) The socio-demographic variables did not play any role for short-term annoyance.

Intercorrelations of the predictors make it difficult to interpret the beta coefficients presented in Table 4. Furthermore, high intercorrelations between the predictors may result in unreliable estimates of their regression coefficients. Therefore, further regression analyses were done with a selection of predictors, namely with those that have been found to be significantly associated with long-term and/or short-term annoyance, were almost uncorrelated with each other and represent different kinds of factors affecting the annoyance (exposure, source-related attitudes, noise-related dispositions). The selected predictors are the equivalent sound level, the confidence in authorities' effort for aircraft noise reduction and the noise sensitivity.

38% of the variance of long-term aircraft noise annoyance is explained by the regression to equivalent sound level for daytime ($L_{Aeq,16h}$), confidence in authorities' effort and noise sensitivity. Both the equivalent sound level and the confidence in authorities' effort have a similar impact on long-term aircraft noise annoyance which is somewhat stronger than the impact of noise sensitivity (Table 5). The three predictors also contribute significantly to the explanation of the hourly aircraft noise annoyance (explained variance is R^2 = .27), although the non-acoustical factors contribute somewhat less to the prediction of hourly aircraft noise annoyance than to the prediction of long-term annoyance.

Table 5 – Results of regression analyses with long-term and hourly aircraft noise annoyance as criteria and with selected predictors of regression analyses presented in Table 4.

Results of regression analyses		Criterion:					
		Long-term aircraft noise Annoyance			Hourly aircraft noise annoyance		
Predictors		β	r	$r_{partial}$	β	r	$r_{partial}$
Exposure	• $L_{Aeq,16h}$ (long-term) / $L_{Aeq,1h}$ (hourly)	.38	.42	.46	.39	.42	.42
Attitudes	• Confidence in authorities' effort	-.37	-.43	-.42	-.22	-.29	-.25
Sensitivity	• Noise sensitivity (NoiSeQ)	.23	.26	.28	.17	.22	.19
	Explained variance R^2 / median R^2	.38			.27		

For regression models of hourly aircraft noise annoyance the median of coefficients calculated for each of 16 hours of four days is presented. All beta coefficients are significant on the level $p < .05$.

3.4 Relationship between short-term annoyance and long-term annoyance and disturbances

The aircraft noise annoyance in the past hour as an indicator of short-term annoyance was ascertained in FRA-S part II together with the main activity done in the respective hour. This allows defining the annoyance during hourly (main) activities. These short-term annoyance judgements were then averaged for each participant across all hours of the four judgement days and correlated with the long-term annoyance and disturbance judgements (past 12 months) assessed in FRA-S part I (Table 6).

Table 6 shows that almost all of the mean short-term annoyances during hourly activities are associated with the long-term annoyance and long-term activity disturbances.

In addition, long-term disturbances are somewhat higher correlated with short-term annoyances referring to hours with corresponding main activities (i.e. communication disturbances correlate somewhat higher with short-term annoyances in hours with communication-related activities than with annoyance in hours with other activities).

Table 6 – Correlation between long-term annoyance / disturbances and mean short-term annoyances during main hourly activities

Long-term noise reactions	Hourly annoyance during hourly (main) activities …							
	Total	TV / Radio	Conver -sation	Home work	Eating	Rela-xing	Concen -trating	other
Number of cases	190 - 196	157 - 160	183 - 189	167 - 173	149 - 154	145 - 148	173 - 179	131 - 136
- Long-term disturbances indoor / hourly activities indoor -								
Noise annoyance 5pt	.53	.46	.45	.36	.52	.54	.43	.36
Noise annoyance 11pt	.50	.44	.43	.43	.52	.46	.41	.32
Disturbance of relaxation/concentration	.45	.40	.38	.39	.45	.41	.40	.32
Disturbance of communication	.47	.46	.41	.35	.46	.39	.41	.29
- Long-term disturbances outdoor / hourly activities outdoor -								
Number of cases	123 - 128	16 - 17	49 - 51	66 - 70	52 - 54	60 - 63	60 - 63	43 - 45
Noise annoyance 5pt	.53	.09	.54	.43	.35	.39	.37	.49
Noise annoyance 11pt	.50	.46	.48	.49	.44	.56	.50	.53
Disturbance of recreation	.46	.55	.48	.39	.42	.49	.45	.53
Disturbance of communication	.44	.62	.42	.35	.37	.51	.26	.50

4 Conclusions

The analyses of the impact of acoustical, operational and non-acoustical factors on the long-term and short-term (hourly) aircraft noise annoyance presented in this paper show:
Among the indicators of aircraft sound exposure the long-term equivalent sound level for daytime ($L_{Aeq,16h}$) correlated highest with the long-term aircraft noise annoyance and, similarly, the hourly equivalent sound level ($L_{Aeq,1h}$) with the hourly aircraft noise annoyance. Both the number of flyovers and the mean maximum sound level contributed independently from each other to long-term as well as hourly annoyance. It was found that the impact of the number of flyovers to the explanation of annoyance was higher than that of the mean maximum sound level, in particular with regard to the hourly annoyance. With regard to operational factors affecting short-term annoyance it could be shown that for the same equivalent sound level the hourly aircraft noise annoyance was higher in hours with both approaches and takeoffs than in hours with either approaches or takeoffs only.
Attitudes towards the source and towards authorities such as aircraft-related fears, the expectations concerning the airport expansion, and the confidence in authorities' effort for aircraft noise reduction were relative strongly associated with both long-term and hourly annoyance. However, in regression models of short-term annoyance the equivalent sound level was a more important predictor than the attitudes. In different regression models including sound level indicators, attitudinal factors and noise sensitivity as predictors the sensitivity has a weaker effect on the long-term annoyance as well as on the hourly annoyance than the other predictors.

Acknowledgments

The results presented in this paper base on data of the Frankfurt Noise Annoyance Study 2005 which was carried out on behalf of IFOK GmbH, Bensheim, Germany, in the framework of the Regional Dialogue Forum Frankfurt Airport (RDF). The extended analyses have been funded within the COSMA project by a grant from the European Commission within the 7th Framework Programme (ACP8-GA-2009-234118), and have been co-funded by the German Federal Environment Agency (FKZ 370955160).

References

[1] ANOTEC Consulting. *Study on current and future aircraft noise exposure at and around community airports – Final report*. Prepared for the European Community (DG-TREN). Doc N° PAN012-4-0. Madrid: ANOTEC, 2003.

[2] Schreckenberg D, Meis M. (2006). Effects of aircraft noise on noise annoyance and quality of life around Frankfurt Airport. Final abridged report. Bochum/Oldenburg. http://www.verkehrslaermwirkung.de/FRA070222.pdf.

[3] Schreckenberg, D.; Meis, M. *Belästigung durch Fluglärm im Umfeld des Frankfurter Flughafens. Gutachten im Auftrag des Regionalen Dialogforums Flughafen Frankfurt. Endbericht. (Annoyance due to aircraft noise in communities surrounding Frankfurt Airport)*. AG Fluglärmwirkung, Bochum, Oldenburg Germany, 2006. Available: http://www.verkehrslaermwirkung.de/RDF0911.pdf.

[4] Bassarab, R.; Sharp, B.; Robinette, B. *An Updated Catalog of 628 Social Surveys of Residents' Reaction to Environmental Noise (1943-2008).* Wyle Laboratories, Arlington (VA), 2009.

[5] Guski, R. Personal and social variables as co-determinants of noise annoyance, *Noise and Health*, Vol. 1(3), 1999, pp. 45-56.

[6] Fields, J.M.; DeJong, R.G.; Gjestland, T.; Flindell, I.H.; Job, R.F.S.; Kurra, S.; Lercher, P.; Vallet, M.; Guski, R.; Felscher-Suhr, U.; Schuemer, R. Standardized general-purpose noise reaction questions for community noise surveys: Research and a recommendation, *Journal of Sound and Vibration*, 242(4), 2001, pp. 641-679.

[7] Lavandier, C.; Terroir, J. Functional annoyance due to railway noise in a laboratory context. *Proceedings of Euronoise 2009,* Edinburgh, UK. In CD-ROM, Paper No. 300.

[8] Kuhnt, S.; Schürmann, C.; Schütte, M.; Wenning, E.; Griefahn, B.; Vormann, M.; Hellbrück, J. Modelling Annoyance from Combined Traffic Noises: An Experimental Study, *Acta Acustica united with Acustica*, Vol. 94(3), 2008, pp. 393-400.

[9] Stearns, J.; Brwon, R.; Neiswander. *A pilot study of human response to general aviation aircraft noise*. NASA contractor resport 166053, Hampton Virginia, 1983.

[10] Schomer, P.D.; Wagner, L.R. On the contribution of noticeability of environmental sounds to noise annoyance. *Noise Control Engineering Journal,* Vol. 44, 1996, pp. 294-305.

[11] Schreckenberg, D.; Guski, R.; Schmaus, I.; Moehler, U.; Schuemer, R. Annoyance and disturbances due to traffic noise at different times of day. *Proceedings of Inter-Noise 2004*, Prague, Czech Republic. In CD-ROM, Paper No. 527.