De effecten van vliegtuiggeluid op de woontevredenheid

Maarten Kroesen
Technische Universiteit Delft, Faculteit Techniek Bestuur en Management
m.kroesen@tudelft.nl

Henk M.E. Miedema
TNO Bouw en Ondergrond
henk.miedema@tno.nl

Henk Vos
TNO Bouw en Ondergrond
henk.vos@tno.nl

Bijdrage aan het Colloquium Vervoersplanologisch Speurwerk
19 en 20 november 2009, Antwerpen

Samenvatting

De effecten van vliegtuiggeluid op de woontevredenheid

In dit onderzoek bestuderen we de effecten van vliegtuiggeluid op de woontevredenheid, een belangrijke indicator voor algemeen welzijn. Door middel van een statistisch model worden de effecten van objectieve variabelen, en verschillende vormen van hinder op de woontevredenheid geschat. De achterliggende gedachte is dat het opnemen van andere determinanten van de woontevredenheid - naast de geluidhinder van vliegtuigen - ons inzicht kan verschaffen in de relatieve invloed van vliegtuiggeluid. Om het model te schatten wordt een reeds bestaand databestand gebruikt. Deze data zijn verzameld in het kader van de Gezondheidskundige Evaluatie Schiphol in de periode 1996/7. Op basis van de resultaten concluderen we dat het effect van geluidhinder van vliegtuigen op de woontevredenheid relatief klein is. Daarnaast blijkt de fysieke maat voor de geluidbelasting (Lden) een sterkere predictor te zijn van de woontevredenheid dan zijn subjectieve tegenhanger, de geluidhinder. Van de opgenomen variabelen blijken de volgende drie het sterkst van invloed op de woontevredenheid: geluidhinder van wegverkeer (<50km/u), leeftijd en geluidhinder van buren.

1. Introduction

To properly assess and understand the effects of aircraft noise exposure in residential areas its relationships with objective and subjective consequences need to be studied. In this study the relative importance of aircraft noise vis-à-vis other environmental stressors is studied. Via structural equation analysis we investigate the relationships between the objective level of aircraft noise, the negative subjective evaluation of aircraft noise (i.e. aircraft noise annoyance) and residential satisfaction. In addition, various personal and household variables as well as other noise-related subjective determinants of residential satisfaction, i.e. road, railway, construction and neighbor noise annoyance, are included in the model. The main idea is that by studying the effects of aircraft noise within such an integrated model, i.e. vis-à-vis other determinants and using multiple criterion variables like annoyance and residential satisfaction, its effects on subjective well-being can be properly assessed. To the best of the authors' knowledge no previous analysis has been conducted with this explicit focus. An additional benefit of this approach is that the indirect effects of various personal background variables on residential satisfaction can also be estimated and examined. Few previous studies have taken such indirect effects into account.

Residential satisfaction as the final criterion variable is selected for two reasons. Firstly, residential satisfaction has been shown to be associated with other important constructs like life satisfaction (Fried, 1984), psychological well-being (Phillips et al., 2005) and perceived health (Kroesen et al., 2008b). It can therefore be classified as an important indicator of subjective well-being. Secondly, even though other components (e.g. financial well-being, family life, health) are more salient in relation to the overall quality-of-life, the residential environment is subject to greater alteration by planning and design than these other components (Weideman et al., 1982). It is acknowledged by numerous authors that insight into the determinants of residential satisfaction can aid public authorities in their policy decisions (Parkes et al., 2002; Lu, 1999).

To satisfy the aim of this study a literature survey is conducted to develop a suitable theoretical framework for explaining residential satisfaction. Based on this theoretical framework a structural equation model is specified. A structural equation model is able to cope with the complex nature of the structural relationships between variables which operate at different levels in a causal chain (i.e. the possibility of modeling both direct and indirect effects between variables) as well as with the complexity of the used subjective constructs (i.e. latent variables) through the specification of a measurement model (Bollen, 1989).

To estimate the structural equation model a dataset from a community survey conducted in 1996/7 (TNO and RIVM, 1998, Miedema et al., 2000; Franssen et al., 2004) is used. The survey to acquire these data was originally meant to assess the consequences of aircraft noise on indicators like annoyance, health and residential satisfaction. However, next to the measurement of these variables, the questionnaire included items related to other noise annoyance variables (i.e. road, railway, construction and neighbor noise annoyance) and objective characteristics like sex, age, education level, number of household members and length of residence. In addition, the dataset contained one objective contextual variable, namely the level of aircraft noise exposure (calculated in dB(A) Lden). In the present study these variables are integrated into one theoretical framework.

The remainder of this paper is structured as follows. In the next section research related to the determinants of residential satisfaction will be reviewed. This review will conclude with the specification of an integral model to analyze the effects of objective attributes and noise-related variables on residential satisfaction. In the third section the research method and measures will be discussed. Section 4 will present and discuss the results of the structural equation model. The concluding section will summarize the main findings.

2. Theoretical background

2.1 Definition of residential satisfaction

Theories of residential satisfaction generally conceptualize this construct as a measure of the difference between the actual and desired housing and neighborhood situations (Galster and Hesser, 1981; Campbell et al., 1976). Morris and Winter (1975) use the notion 'housing deficit' to term this incongruence. They argue that individuals judge their housing conditions according to norms, which can originate from cultural values or from the households' own standards for housing developed through past experience. Amerigo and Aragones (1997) add to this that congruence can be regarded as a positive affective state which the individual experiences towards his/her residential environment and which will cause him/her to behave in certain ways intended to maintain or increase congruence with that environment.

2.2 Determinants of residential satisfaction

Research investigating the determinants of residential satisfaction initially focused on objective attributes of residents. In this respect variables like tenure status (home-owner/rental), income, education, race, presence of children and the duration of residence, have been found to significantly correlate with measures of residential satisfaction (Galster and Hesser, 1981; Parkes et al., 2002; Lu, 1999; Amerigo and Aragones, 1990). According to Lee and Guest (1983) such compositional variables represent a set of resources and incentives that affect a household's chances of winding up in a satisfying neighborhood. This point is also recently advanced by Parkes et al. (2002) who suggest that a key factor to neighborhood satisfaction may be an individual's financial resources, which provides the individual the power to choose and control the type of neighborhood environment inhabited.

However, the sometimes weak relationships between objective characteristics and residential satisfaction led to the belief that objective variables alone did not suffice as determinants of residential satisfaction (Weideman et al., 1982). Galster and Hesser (1981) formulated and tested (via path analysis) the idea that the effects of objective attributes, which they grouped into compositional (those relating to the individual household) and contextual variables (those relating to the physical conditions of the surrounding neighborhood), are (partially or wholly) mediated via subjective assessments of more limited aspects of the physical or social environment. Indeed, they found both indirect and direct effects of the included objective attributes. In a logistic regression analysis Parkes et al. (2002) found the influence of objective socio-demographic variables to be of little influence compared to subjective evaluations related to aspects like housing, crime, safety, neighbors, noise and appearance. This observation is also supported by a regression analysis of Lee and Guest (1983).

Overall, it can be concluded that the determinants of residential satisfaction include both objective attributes and subjective evaluations, both personal and environmental characteristics and both social and physical elements.

2.3 Model specification

As mentioned in the introduction the present study concerns a secondary analysis of previously gathered data. Two theoretical notions discussed in the previous paragraph are used to specify the present statistical model: [1] objective and subjective variables are both assumed to influence residential satisfaction and [2] objective variables can influence residential satisfaction either directly or indirectly via the subjective ones. Following these two notions the relevant variables present in the dataset are integrated into one model, which is depicted in Figure 1. In total, 18 personal background variables and 6 subjective variables are identified as relevant and included in the model to explain residential satisfaction. The 6 subjective variables relate to annoyance from the following noise sources in the residential environment: aircraft, slow road traffic (<31 miles per hour), fast road traffic (>31 miles per hour), railway, construction/demolition/renovation activities and neighbors.

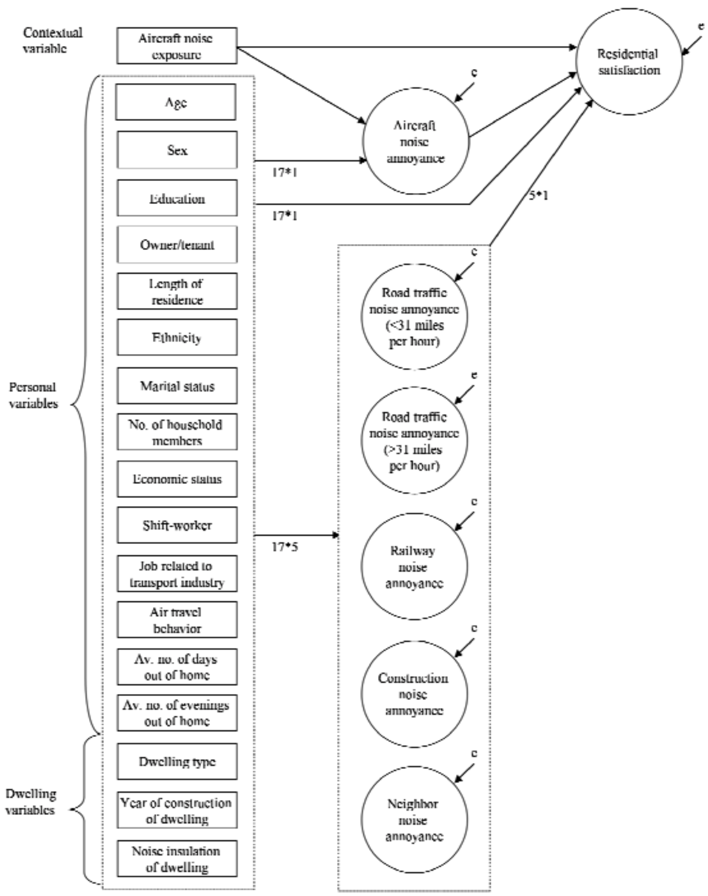

Figure 1. Theoretical model to study the effects of aircraft noise on residential satisfaction

Moving forward from the theoretical basis of the model we continue in an explorative fashion and do not hypothesize about the individual effects a priori. Instead all possible

relationships along the hypothesized causal direction (i.e. objective characteristics → subjective assessments → residential satisfaction) will be estimated. Via deletion of the insignificant paths the most parsimonious model will be derived. This model will be interpreted in light of specific existing theories and previous empirical results.
The above outlined strategy also entails that a direct relationship between aircraft noise exposure and residential satisfaction is estimated. This relationship is included to account for possible pathways, other than through aircraft noise annoyance, through which aircraft noise exposure might influence residential satisfaction. Since there is evidence that the range of subjective reactions to noise is broader than annoyance (covering aspects like fear, anxiety, anger, disappointment, etc.) the existence of these pathways is plausible (Job et al., 2001). Through inclusion of a direct effect between aircraft noise and residential satisfaction these pathways are accounted for.

3. Method

3.1 Data

Data from a community survey conducted in the period November 2006 till February 2007 in the vicinity at Schiphol Airport, the largest airport in the Netherlands, are used to estimate the hypothesized model in Figure 1. Within this study a stratified random sample of 31,000 addresses was drawn from the population living within the 16-mile radius around the airport. Stratification was necessary to adequately represent the full range of aircraft noise exposure. The strata were based on the combination of the distance from the airport and the level of aircraft noise exposure. In practice, this approach resulted in an over-sampling of people living close to the airport. To arrive at a sample which is representative for the population within the 16-mile radius of Amsterdam Schiphol the observations were therefore re-weighted to take the stratified study design into account.
Approximately 1.5 million people aged 18 or above inhabit the survey area. The data were gathered via a postal questionnaire and the response rate was 39% (N=11,812). Cases with more than 10% missing values are deleted (N=1,066). The remaining missing values on the variables used in the analysis, 1.2% of all entries, are imputed via the Expectation-Maximization algorithm of SPSS 14.0. The resulting dataset consisted of 10,746 complete cases.
For more detailed descriptions of this study we refer to TNO-RIVM (TNO and RIVM, 1998), Miedema et al. (Miedema et al., 2000) and Franssen et al. (Franssen et al., 2004).

3.2 Measures

3.2.1 Individual, household, dwelling and contextual characteristics

In Table 1 the 18 objective variables and their (re-weighted) sample distributions are presented. The variables cover a broad range of socio-demographic characteristics, characteristics related to a subject’s economic status and dependency on the aviation industry, household and dwelling characteristics and the level of aircraft noise exposure. Assuming that these variables are measured without measurement errors they are directly included in the structural equation model as observed variables.
For age non-linear relationships with dependent variables in the model were expected (Miedema and Vos, 1999; Groothuis-Oudshoorn and Miedema, 2006). Based on three

categories (1: 18-30 years, 2: 31-55 years and 3: ≥56 years) age was therefore recoded into two indicator variables using the effect coding principle.

All the variables, except the level of aircraft noise exposure (no. 18 in Table 1), are self-reported. Using a mathematical model the level of aircraft noise exposure around Schiphol airport was calculated by the Dutch National Aerospace Laboratory for all subjects in the dataset. This is done by a method which is legally prescribed in the Netherlands (Rijksluchtvaardienst, 1996). For all respondents various noise metrics were calculated. These calculations are based on the actual flight data (time, takeoff or landing, type of aircraft, flight path recorded by the flight tracking system) for each individual flight in the year preceding the survey. For the present study Lden (i.e. level day-evening-night in dB(A)) is selected as a measure of the level of aircraft noise exposure. Lden is an equivalent sound level of 24 hours expressed in decibels (dB) on the 'A' weighted scale dB(A). Sound levels during the evening (7 pm - 11 pm) and during the night (11 pm - 7 am) are increased by a penalty of 5 and 10 dB(A) respectively. This metric is also selected by the European Council to monitor and assess noise problems in its member states.

Table 1. (Re-weighted) Sample Distributions of Objective Variables in Dataset (N=10,746)

Observed variable	Range/Description	Freq.	%	Mean	S.D.
1. Age (years)	<20	160	1.5	46.2	15.7
	21-40	4279	39.8		
	41-60	3974	37.0		
	61-80	2039	19.0		
	>80	168	1.6		
	Missing	125	1.2		
2. Sex	Male	5668	52.7		
	Female	4992	46.5		
	Missing	86	0.8		
3. Education	No education	47	0.4		
	Primary school	468	4.4		
	Secondary school	4489	41.8		
	Higher education	3929	36.6		
	University	1408	13.1		
	Missing	404	3.8		
4. Dwelling ownership	Rental	4739	44.1		
	Owner-occupied	5887	54.8		
	Missing	120	1.1		
5. Length of residence (years)	0-10	5980	55.6	12.4	11.3
	11-20	2323	21.6		
	21-30	1368	12.7		
	31-40	879	8.2		
	Missing	196	1.8		
6. Ethnicity	Dutch	9871	91.9		
	Other than Dutch	585	5.4		
	Missing	290	2.7		
7. Marital status	Single	3453	32.1		
	Married/living together	7174	66.8		
	Missing	119	1.1		
8. Household size (no. of household members)	1	2667	24.8	2.4	1.2
	2	4100	38.2		
	3	1461	13.6		
	4	1673	15.6		
	≥ 5	693	6.5		
	Missing	150	1.4		
9. Economic status	(part-time/full-time) employed	7891	73.4		
	Unemployed	2684	25.0		
	Missing	171	1.6		
10. Shift-worker (working in evening/night time so one is forced to sleep during the day)	No	9633	89.6		
	Yes	952	8.9		
	Missing	160	1.5		
11. Job related to air transport industry	No	9975	92.8		
	Yes	637	5.9		
	Missing	134	1.2		
12. Air travel behavior	Did not fly in last two years	4550	42.3		

	Did fly in last two years	6137	57.1		
	Missing	58	0.5		
13. Average no. of days out of home per week	0	2616	24.3	2.9	2.2
	1	958	8.9		
	2	928	8.6		
	3	933	8.7		
	4	1020	9.5		
	5	3441	32.0		
	6	504	4.7		
	7	120	1.1		
	Missing	226	2.1		
14. Average no. of evenings out of home per week	0	3211	29.9	1.5	1.4
	1	2565	23.9		
	2	2468	23.0		
	3	1328	12.4		
	4	640	6.0		
	5	229	2.1		
	6	62	0.6		
	7	27	0.3		
	Missing	215	2.0		
15. Dwelling type (detachedness)	Flat or apartment	3832	35.7		
	Row house	5030	46.8		
	Semi-detached	816	7.6		
	Detached	781	7.3		
	Missing	288	2.7		
16. Year of construction of dwelling	Before 1900	699	6.5		
	1900-1944	2283	21.2		
	1945-1979	4572	42.5		
	1980 and later	2916	27.1		
	Missing	276	2.6		
17. Noise insulation of dwelling	No	6209	57.8		
	Yes	3540	32.9		
	Missing	997	9.3		
18. Aircraft noise exposure (dB(A) Lden)	<50	805	7.5	53.7	2.6
	50.1-55.0	6793	63.2		
	55.1-60.0	3017	28.1		
	60.1>	131	1.2		

3.2.2 Measurement model for noise annoyance constructs

The (negative) evaluations of noise in the residential environment are subjective in nature. In classical test theory it is assumed that variance in subjective measures can be decomposed into [1] the true variance one intends to capture and [2] measurement error (Bollen, 1989). The measurement errors can be systematic; relating to the issue of validity, i.e. the degree a set of measures accurately reflect the intended theoretical concept, or random, relating to the issue of reliability, i.e. the degree a set of measures consistently measure the intended concept. Through specification of a measurement model, which prescribes how constructs are operationalized by sets of measured variables (i.e. the relationships between the latent and observed variables), the true variance can be extracted. In doing so, the structural estimates between latent variables are corrected for (structural and random) measurement errors, and are therefore less biased. This generally leads to stronger estimates and larger portions of explained variance in the endogenous variables. In this study the subjective variables are therefore not measured directly but instead indirectly via a measurement model.

To develop the measurement model six latent variables are defined, one for each noise source in the residential environment: aircraft noise, road traffic noise (slow and fast), railway noise, construction noise and neighbor noise. Each latent variable is operationalized using two items. Preferably, three measures should be used per construct. However, within the present dataset only two were available. The two items related to the following questions: (item 1) 'How annoying or not annoying is the noise of the following sources according to you at home?' (response ranging from 0='not at all annoying' to 10='very annoying') and (item 2) 'to what extent is your sleep disturbed by the following noise sources?' (response ranging from 0='not at all disturbed' to 10='very much disturbed'). These items were measured for each noise source.

Now that the latent variables are defined and the measures are operationalized, the measurement model is specified as follows: [1] each set of two measures (relating to the two questions) is assumed to indicate its corresponding latent construct and [2] all latent constructs are allowed to correlate. This model is estimated using the structural equation modeling software package Lisrel 8.8.

To assess the validity of the specified measurement model both the overall model fit and the criteria for construct validity are examined. Since the chi-square statistic is sensitive to large sample sizes (N>500), and therefore expected to be significant (which would indicate a lack of fit), we included the following indices (independent on sample size) to evaluate the fit of the model: the Root Mean Square Error of Approximation (RMSEA) (Browne and Cudeck, 1993), which measures the discrepancy between the model implied and observed covariance matrix per degree of freedom, the Standardized Root Mean Residual (SRMR) (Bentler, 1995), which measures the mean of the squared residuals (the differences between the sample and model-implied covariance matrices) divided by the standard deviations of the respective manifest variables, and the Comparative Fit Index (CFI) (Bentler, 1990), which provides a comparison between the specified model and a baseline model with zero constraints. A well-fitting model is defined as having values below .06 and .08 for RSMEA and SRMR respectively and a CFI value greater than .95 (Hu and Bentler, 1999).

Based on these cut-off values it can be concluded that the initial measurement model fits the data reasonably (S-B scaled $\chi 2d.f.=39=2848.53$, RMSEA=.082, CFI=.944, SRMR=.0290). The CFI is just below the recommended minimum value of 0.95 and the SRMR is well below its maximum value of .08. The RMSEA, however, is above its recommended maximum value of .06 and its 90% confidence interval (.079 ; .085) also lies outside the .06 threshold. Review of the modification indexes indicates that significant improvements in model fit can be accomplished through specification of additional correlations between the second items of the latent variables (i.e. the items relating to the 'sleep disturbance' questions). Theoretical justification for these correlations lies in existing evidence that people vary in their sensitivity to be awakened by noise (Anderson and Miller, 2007), causing the additional structural covariation between these items. After specification of these correlations (15 in total) and re-estimation of the model, the model fit improved significantly (S-B scaled $\chi 2d.f.=24=142.96$, RMSEA=.021, CFI=.998, SRMR=.0102). All indices indicate an acceptable model fit.

3.2.3. Residential satisfaction

Lastly, we will focus on the operationalization of the main dependent variable, i.e. residential satisfaction. This variable also represents a subjective evaluation. However, the reason that it is not included in the measurement model developed in the previous paragraph is that only one item, found suited to indicate this concept, was available in the dataset (making it impossible to define a multiple item construct). This item related to the question: 'how satisfied are you with living in this residential environment?' The (re-weighted) sample distribution in response to this question was: 8.9% (N=956) extremely satisfied, 29.2% (N=3140) very satisfied, 50.4% (N=5421) satisfied, 8.4% (N=898) not so satisfied, 2.0% (N=213) dissatisfied and 1.1% (N=117) missing.

Since only one indicator of residential satisfaction is available it is not possible to provide an estimate for its reliability. However, instead of assuming its reliability to be 100%, the item is assumed to be measured with the same reliability as the average reliability of the 6 subjective noise annoyance constructs (=.767), an assumption more likely to reflect its true reliability. The reliability is taken into account by including the item into the model as an observed variable of a corresponding latent variable and fixing its error variance at (1 - .767) multiplied by the variance of the observed item (Kelloway, 1998). As a result, the reliability of the latent variable (i.e. residential satisfaction) is fixed and the structural relationships which are estimated between residential satisfaction and its predictors are corrected for measurement error.

4. Results and discussion

4.1 Estimation of the full structural equation model

The objective characteristics, as directly observed variables, the subjective noise annoyances, as indirectly observed latent variables, and residential satisfaction, as single-indicator latent variable, are included in the structural equation model as specified in Figure 1. All objective attributes, which are exogenous variables, are allowed to correlate. As a result, the effects of each exogenous variable on (endogenous) variables later in the causal chain are controlled for the effects of all other exogenous variables. Similarly, at the level of the subjective noise annoyance variables, which are endogenous (and thus have error terms), the error terms of these variables are allowed to correlate. Again to ensure that the effect of each noise annoyance variable on residential satisfaction is controlled for the effects of all other noise annoyance variables.

The first step is to estimate a fully saturated structural model in which all possible paths between structural variables are estimated. This leads to the estimation of 139 structural parameters: 19*7 parameters between the 19 objective variables (18 observed variables plus an extra indicator for age due to the effect coding) and the 7 subjective endogenous variables plus 6*1 parameters between the 6 noise annoyance constructs and residential satisfaction. The fit of this initial model is very acceptable (S-B scaled $\chi^2_{d.f.=144}=882.44$, RMSEA=.022, CFI=.994, SRMR=.0098). To arrive at a more parsimonious model all insignificant estimates are deleted (Byrne, 1998). Considering the large sample size and the increased capitalization on chance for finding a significant relationship due to the large number of parameters reviewed, the conventional alpha level of .05 was lowered to .001. This criterion leads to the deletion of 73 insignificant paths. The re-estimated model also shows an acceptable model fit (S-B scaled $\chi^2_{d.f.=217}=1090.52$, RMSEA=.019, CFI=.993, SRMR=.0134).

The standardized total effects between the predictors, the six noise annoyance constructs and residential satisfaction are presented in Table 2 (in descending order based on their total effect size on residential satisfaction). The effects are standardized in order to reduce them to a comparable unit, namely the number of standard deviations. As a result their relative magnitude can be assessed.

Table 2. Standardized Total Effects on Dependent Variables (all sign. at p<.001) and Proportions of Explained Variance

	Direct effects on noise annoyance constructs						Effects on residential satisfaction			
	Aircraft noise annoyance	Road traffic noise annoyance (< 31 mph)	Road traffic noise annoyance (> 31 mph)	Railway noise annoyance	Construction noise annoyance	Neighbor noise annoyance	Direct	Indirect	Total	Rank
Road traffic noise annoyance (< 31 mph)	-	-	-	-	-	-	-.254	-	-.254	1
Age (18-30) → age1	-.119	.090	0	.036	.190	.260	-.072	-.063	-.135	2
Age (31-55) → age2	.204	.182	.077	.070	.120	.210	.051	-.104	-.053	
Age (≥ 56) → -age1 + -age2	-.085	-.272	-.077	-.106	-.310	-.470	.021	.167	.188	
Neighbor noise annoyance	-	-	-	-	-	-	-.180	-	-.180	3
Aircraft noise exposure	.307	0	0	.035	0	0	-.123	-.021	-.144	4
Dwelling ownership (owner-occupied)	.066	0	0	0	0	-.108	.127	.016	.143	5
Year of construction of dwelling	-.057	-.142	0	0	-.120	0	-.138	.039	-.099	6
Dwelling type (detachedness)	.041	0	.093	0	-.175	-.236	.061	.035	.096	7
Length of residence	-.043	0	0	0	0	.107	-.072	-.017	-.089	8
Air travel behavior (did fly in last 2 years)	-.068	0	0	0	0	0	.072	.004	.076	9
Aircraft noise annoyance	-	-	-	-	-	-	-.064	-	-.064	10
Av. no. of evenings out of home per week	0	0	0	0	.070	0	.054	0	.054	11
Road traffic noise annoyance (> 31 mph)	-	-	-	-	-	-	-.048	-	-.048	12
Shift-worker (yes)	.030	0	0	0	.037	.044	-.034	-.010	-.044	13
Household size	0	-.103	0	0	-.079	-.100	0	.044	.044	14
Marital status (married/living together)	.059	.102	0	0	0	.076	0	-.043	-.043	15
Railway noise annoyance	-	-	-	-	-	-	-.040	-	-.040	16
Education	.118	.037	0	0	.140	.071	0	-.030	-.030	17
Economic status (unemployed)	0	.059	0	0	.093	.069	0	-.027	-.027	18
Noise insulation of dwelling (yes)	-.065	0	.041	0	0	-.054	0	.012	.012	19
Sex (female)	0	0	0	-.034	.064	.043	0	-.006	-.006	20
Job related to air transport industry (yes)	-.036	0	0	-.047	0	0	0	.004	.004	21
Av. no. of days out of home per week	0	0	0	0	-.109	0	0	0	0	22
Ethnicity (other than Dutch)	0	0	0	0	0	0	0	0	0	22
Construction noise annoyance	-	-	-	-	-	-	0	-	0	22
Percentage of variance explained (%)	17.2	6.1	1.6	1.1	17.6	21.6			24.4	

0 = Non-significant (fixed at zero)

4.2 Effects of aircraft noise on residential satisfaction

It can be concluded that the effect of aircraft noise annoyance on residential satisfaction, -.064 (rank 10), is smaller than the effects of road traffic noise annoyance (<31 mph), -.254 (rank 1), and neighbor noise annoyance, -.180 (rank 3), but larger than the effects of road traffic noise annoyance (>31 mph), -.048 (rank 12), railway noise annoyance, -.040 (rank 16), and construction noise annoyance, non-significant (rank 22).

Secondly, a surprising result is that the total effect of aircraft noise exposure (-.144) ranks higher (rank 4) than the effect of aircraft noise annoyance (-.064) (rank 10). In addition to an expected indirect effect via aircraft noise annoyance (.307*-.064) a large direct effect remains (-.123). Hence, with respect to aircraft noise the objective physical condition is a stronger predictor of residential satisfaction than its subjective counterpart. As has been suggested before, a plausible explanation is that aircraft noise annoyance does not capture all negative feelings in response to aircraft noise (Job et al., 2001). The remaining strong direct effect provides additional evidence for this assertion. Another explanation might be that aircraft noise is confounded with other negative aspects which affect the residential environment. However, within this particular study this risk is minimized because the effects are controlled for variables relating to subjects' socio-economic status.

The results indicate that, in comparison to other environment stressors, aircraft noise is not a strong predictor of residential satisfaction. Since the analysis is based on a representative sample of residents living within the 16-mile radius of a large international airport, this finding is quite remarkable. The relatively weak link between aircraft noise and residential satisfaction has also been confirmed in a previous study among residents around Schiphol airport (Marsman and Leidelmeijer, 2001). Stallen and Van Gunsteren (2002) explain this finding by speculating that annoyance caused by aircraft noise is part of a different, more political domain of frustrations than residents' feelings about their residential quality.

4.3 Effects of personal background variables

In the following the effects of the other model variables on residential satisfaction and the noise annoyance constructs are discussed. The variables are treated in descending order based on their relative importance in relation to residential satisfaction.

After road traffic noise annoyance (<31 mph) age is the second largest determinant of residential satisfaction. In line with previous research the total effect shows that as one grows older one is most positive about the residential environment (age(18-30)= -.135, age(31-55)=-.053, age(≥ 56)=.188). The direct effect of age on residential satisfaction is curvilinear (age(18-30)= -.072, age(31-55)=.051, age(≥ 56)=.021), whereby the middle class is most satisfied with their residential environment. This finding aligns with the general hypothesis of Parkes et al. (2002) that those people with more resources, which are those in the middle class age group, have more control over the type of neighborhood they inhabit and are therefore more satisfied. Age also has six indirect effects with residential satisfaction via the noise annoyance constructs. The effects of age on aircraft, road traffic and railway noise annoyance are also curvilinear, with those in the middle class age reporting most annoyance, a result that has been previously established for aircraft noise annoyance (Miedema and Vos, 1999; Groothuis-Oudshoorn and Miedema, 2006). The causal mechanism involved might be that, because of a relatively high level of daily mental workload, the adaptive resources of middle-aged people are pushed to the limit by the presence of noise. The effect of age on construction and neighbor noise shows that older people, aged 56 or above, are generally less annoyed by these noise sources as opposed to the younger age categories. It can be speculated that this effect can be explained by the mechanism that older people hold more favorable relationships with their neighbors causing them to be less annoyed by the neighbors' noise.

The effect of dwelling ownership indicates that home-owners are more satisfied than tenants (.143). Evidence for the existence and significance of this effect has been provided by numerous authors (Parkes et al., 2002; Lu, 1999; Galster and Hesser, 1981; Lee and Guest, 1983; Rohe and Stewart, 1996), and has been explained by existing incentives for home-owners to maintain their properties at a higher standard and to join organizations that protect the collective interests of home-owners resulting in higher levels of residential satisfaction (Rohe and Stewart, 1996). The indirect effects of dwelling ownership run through aircraft noise annoyance and neighbor noise annoyance. A theoretical justification for the positive effect on aircraft noise annoyance (.066) is that home-owners are concerned about property devaluation due to the aircraft noise, a factor shown to affect the negative appraisal of aircraft noise (Kroesen et al., 2008a). However, the validity of this explanation is questionable since this mechanism would also apply to the other transportation noise sources (road and railway) for which no effects are found on the respective noise annoyance constructs. A plausible explanation for the negative effect of dwelling ownership on neighbor noise annoyance (-.108) is that home-owners hold more positive relationships with their neighbors to be able to maintain the property standard (Rohe and Stewart, 1996), which reduces the likelihood of being annoyed by their noise. Yet, existing empirical evidence for this relationship is contradictory (Rohe and Basolo, 1997).

The effect of year of construction of the dwelling shows that people in older houses express a higher degree of residential satisfaction (-.099). This finding is consistent with a study of McHugh et al. (1990) who reason that that older neighborhoods are more established in community sense and are in better locations relative to jobs and services. In contrast, newer neighborhoods contain more fluid populations and weaker community ties. The indirect effects of year of construction via aircraft, road traffic (<31 mph) and construction noise annoyance, result in a positive contribution to residential satisfaction (.039). A possible explanation is that newer houses are generally better (noise) insulated. However, based on this explanation negative effects of year of construction on road traffic (>31 mph), railway and neighbor noise annoyance should also be expected, yet none of these were found to be significant.

The dwelling type (i.e. degree of detachedness) has a positive indirect (.061) and direct effect (.035) on residential satisfaction. The positive sign of the total effect (.096) is consistent with previous research (Marans and Rodgers, 1975). A plausible explanation for the direct effect is that, moving along the dimension of detachedness, the houses are generally bigger resulting in higher levels of housing satisfaction, which, in turn, leads to greater residential satisfaction (Parkes et al., 2002). The indirect effects between dwelling type and residential satisfaction run through aircraft, road traffic (>31 mph) construction and neighbor noise annoyance. For neighbor noise annoyance an obvious explanation is that higher detachedness leads to lower proximity to neighbors which decreases the perceived noise caused by them.

The remaining relationships have an absolute total effect size smaller than .09. These effects can be considered less practically relevant and are therefore not discussed. Overall, it can be concluded that the signs and sizes of most of the remaining effects are intuitively correct and in line with previous research findings. There is one remaining specific findings which is remarkable. This finding relates to the effect of noise insulation, which is relatively small (.012) and only affects residential satisfaction via aircraft, road traffic (>31 mph) and neighbor noise annoyance. This finding is remarkable because a subset of individuals in the sample (N=670) even received government funded noise insulation measures especially designed to mitigate the effects of aircraft noise.

4.4 Proportions of explained variance

Via examination of the proportions of explained variance it can be assessed how well the endogenous variables in the model are predicted. These figures are presented in the bottom row of Table 2.

In total 24.4% of the variance in residential satisfaction is explained, which is reasonably high considering the range of other variables, not included in the present study, which can play a role (e.g. safety, air quality, housing attributes, neighborhood appearance/services, social network, and accessibility).

Related to the noise annoyance variables, the objective variables can explain substantial portions of variance in the variables aircraft noise annoyance (17.2%), construction noise annoyance (17.6%) and neighbor noise annoyance (21.6%). For aircraft noise annoyance the strongest determinants are aircraft noise exposure, age and education. These effects have been previously established in an analysis of Miedema and Vos (1999). However, these findings should not be regarded as additional evidence since the analysis of Miedema and Vos was (partly) based on the same dataset as the one used presently.

The large portion of unexplained variance in aircraft noise annoyance (=100-22.4=77.6%) can probably be attributed to the existence of so-called non-acoustical factors which not included in the model. These variables have, next to the noise exposure level, been shown to affect aircraft noise annoyance. Examples of some known factors are the attitude towards the noise source authorities, the level of perceived control and noise sensitivity (Kroesen et al., 2008a; Guski, 1999). These social-psychological variables are also likely to play a role in the explanation of the other noise annoyance constructs in which also large portions of variance remain unexplained.

In relation to construction and neighbor noise annoyance it can be concluded that the largest determinants are age, dwelling type (the level of detachedness) and education.

The objective variables are unable to explain (substantial) portions of the variance in road traffic noise annoyance (<31 mph 6.1% and >31 mph 1.6%) and railway noise annoyance (1.1%). These kinds of annoyances are only weakly related to the objective characteristics.

5. Conclusion

In this study the effects of aircraft noise on residential satisfaction are studied within a holistic framework that includes exogenous objective variables relating to the individual, the dwelling and the context as well as the mediating role of subjective noise annoyance constructs. Data to estimate the model is acquired through a survey among residents around Amsterdam Schiphol conducted in 1996/7. The structural model provides a good fit to the data. Based on the results it is concluded that aircraft noise annoyance is a relative weak predictor of residential satisfaction. In addition, aircraft noise exposure is found to be a stronger predictor than its subjective counterpart (i.e. aircraft noise annoyance). The model shows that, of the included variables, the following are the most important determinants of residential satisfaction: road traffic noise annoyance (<31 mph), age and neighbor noise annoyance.

It is concluded that the level of explained variance in residential satisfaction is relatively high (24.4%). In addition, the objective variables are able to explain substantial portions of the variance in aircraft, construction and neighbor noise annoyance, but not in road traffic (<31 mph and >31 mph) and railway noise annoyance. Overall, however, large portions of variance in the noise annoyance constructs remain unexplained. Finally, the model yielded two unexpected results. Firstly, a strong direct effect between aircraft noise exposure and residential satisfaction remained after accounting for the indirect relationship via aircraft noise annoyance. This observation supports the conclusion that aircraft noise annoyance is not likely to fully capture all negative reactions in response to aircraft noise. And secondly, the effect of sound insulation was very small, indicating that this is only a partial ameliorating action when attempting to increase residential satisfaction.

Acknowledgements

The Schiphol Airport study was funded by grants from the Dutch Ministry of Housing, Spatial Planning and the Environment, the Ministry of Transport and the Ministry of Public Health and carried out by TNO and the National Institute for Public Health and the Environment (RIVM). We acknowledge the research work of all people involved in designing, organizing and analyzing the survey around Schiphol Airport (1996), especially the contribution of Ellis Franssen (RIVM) and Ronald de Jong (TNO).

References

Amerigo, M. and Aragones, J.I., 1990. Residential satisfaction in council housing. Journal of Environmental Psychology, 10, 313-325.

Amerigo, M. and Aragones, J.I., 1997. A theoretical and methodological approach to the study of residential satisfaction. Journal of Environmental Psychology, 17(1), 47-57.

Anderson, G.S. and Miller, N.P., 2007. Alternative analysis of sleep-awakening data. Noise Control Engineering Journal, 55(2), 224-245.

Bentler, P.M., 1990. Comparative fit indexes in structural models. Psychological Bulletin, 107(2), 238-246.

Bentler, P.M., 1995. EQS structural equations program manual, Multivariate Software, Encino, CA.

Bollen, K.A., 1989. Structural equations with latent variables, Wiley, New York.

Browne, M.W. and Cudeck, R., 1993. Alternative ways of assessing model fit. In: Bollen, K.A. and Long, J.S. (Eds.) Testing Structural Equation Models, Sage publications, London, pp. 136-162.

Campbell, A., Converse, P.E. and Rodgers, W.L., 1976. The quality of American life: Perceptions, evaluations, and satisfactions, New York, Russell Sage.

Cutter, S., 1982. Residential satisfaction and the suburban homeowner (New Jersey). Urban Geography, 3(4), 315-327.

Franssen, E.A.M., Van Wiechen, C.M.A.G., Nagelkerke, N.J.D. and Lebret, E., 2004. Aircraft noise around a large international airport and its impact on general health and medication use. Occupational and Environmental Medicine, 61(5), 405-413.

Fried, M., 1984. The structure and significance of community satisfaction. Population and Environment, 7(2), 61-86.

Galster, G.C. and Hesser, G.W., 1981. Residential satisfaction - compositional and contextual correlates (Ohio). Environment & Behavior, 13(6), 735-758.

Groothuis-Oudshoorn, C.G.M. and Miedema, H.M.E., 2006. Multilevel grouped regression for analyzing self-reported health in relation to environmental factors: The model and its application. Biometrical Journal, 48(1), 67-82.

Guski, R., 1999. Personal and social variables as co-determinants of noise-annoyance. Noise & Health, 3, 45-56.
Hu, L. and Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling, 6(1), 1-55.
Job, R.F.S., Hatfield, J., Carter, N.L., Peploe, P., Taylor, R. and Morrell, S., 2001. General scales of community reaction to noise (dissatisfaction and perceived affectedness) are more reliable than scales of annoyance. Journal of the Acoustical Society of America, 110(2), 939-946.
Kelloway, E. K. (1998). Using Lisrel for Structural Equations Modeling, A Researcher's Guide. California: Sage.
Kroesen, M., Molin, E.J.E. and Van Wee, B., 2008a. Testing a theory of aircraft noise annoyance: a structural equation analysis. Journal of the Acoustical Society of America, 123(6), 4250-4260.
Kroesen, M., Stallen, P.J.M., Molin, E.J.E., Miedema, H.M.E., Vos, H., Janssen, S.A. and Van Wee, B., 2008b. Assessing the role of mediators in the noise-health relationship via Structural Equation analysis. 9th International Congress on Noise as a Public Health Problem (ICBEN) 2008. Foxwoods, CT.
Lee, B.A. and Guest, A.M., 1983. Determinants of Neighborhood Satisfaction: A Metropolitan-Level Analysis. Sociological Quarterly, 24, 287-303.
Lu, M., 1998. Analyzing migration decisionmaking: relationships between residential satisfaction, mobility intentions, and moving behavior. Environment and Planning A, 30(8), 1473-1495.
Lu, M., 1999. Determinants of residential satisfaction: ordered logit vs. regression models. Growth and Change, 30, 264-287.
Marans, R.W. and Rodgers, W., 1975. Toward an understanding of community satisfaction. In: Hawley, A.H. and Rock, V.P. (Eds.) Metropolitan America in community perspective, Wiley, New York.
Marsman, G. and Leidelmeijer, C., 2001. Leefbaarheid Schiphol: meer dan geluid alleen. Amsterdam, RIGO.
Mchugh, K.E., Gober, P. and Reid, N., 1990. Determinants of short- and long-term mobility expectations for home owners and renters. Demography, 27(1), 81-95.
Miedema, H.M.E. and Vos, H., 1998. Exposure-response relationships for transportation noise. Journal of the Acoustical Society of America, 104(6), 3432-3445.
Miedema, H.M.E. and Vos, H., 1999. Demographic and attitudinal factors that modify annoyance from transportation noise. Journal of the Acoustical Society of America, 105(6), 3336-3344.
Miedema, H.M.E. and Vos, H., 2007. Associations between self-reported sleep disturbance and environmental noise based on re-analyses of pooled data from 24 studies. Behavioral sleep medicine, 5(1), 1-20.
Miedema, H.M.E., Vos, H. and De Jong, R.G., 2000. Community reaction to aircraft noise: Time-of-day penalty and tradeoff between levels of overflights. Journal of the Acoustical Society of America, 107(6), 3245-3253.
Morris, E.W. and Winter, M., 1975. A theory of family housing adjustment. Journal of Marriage and the Family, 37, 79-88.
Parkes, A., Kearns, A. and Atkinson, R., 2002. What makes people dissatisfied with their neighbourhoods? Urban Studies, 39(13), 2413-2438.
Phillips, D.R., Siu, O.L., Yeh, A.G.O. and Cheng, K.H.C., 2005. The impacts of dwelling conditions on older persons' psychological well-being in Hong Kong: The mediating role of residential satisfaction. Social Science and Medicine, 60(12), 2785-2797.
Rijksluchtvaardienst, 1996. Voorschrift voor de berekening van de LAeq-geluidsbelasting in dB(A) ten gevolge van structureel uitgevoerd nachtelijk vliegverkeer. RLD/BV-02. Den Haag, Rijksluchtvaardienst.
Rohe, W.M. and Basolo, V., 1997. Long-term effects of homeownership on the self-perceptions and social interaction of low-income persons. Environment and Behavior, 29(6), 793-819.
Rohe, W.M. and Stewart, L.S., 1996. Homeownership and neighborhood stability. Housing Policy Debate, 7(1), 37-81.
Speare, A., 1974. Residential satisfaction as an intervening variable in residential mobility. Demography, 11(2), 173-188.
Stallen, P.J. and Van Gunsteren, H., 2002. Schiphol and the illusion of a no-annoyance society. The Hague, Ministry of Transport.
TNO and RIVM, 1998. Hinder, Slaapverstoring, Gezondheids en Belevingsaspecten in de Regio Schiphol, Resultaten Van Een Vragenlijstonderzoek. Leiden, The Netherlands.
Weideman, S., Anderson, J.R., Butterfield, D.J. and O'donell, P.M., 1982. Residents perception of satisfaction and safety. Basis for change in multifamily housing. Environment and Behavior, 14, 695-724.