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Environmental Impact Assessment Review
22 (2002) 633–653

Environmental Impact Assessment Review

www.elsevier.com/locate/eiar

# Assessing health consequences in an environmental impact assessment The case of Amsterdam Airport Schiphol

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Received 1 November 2001; received in revised form 1 April 2002; accepted 1 April 2002

**Abstract**

In this article a comprehensive approach for the evaluation of possible health effects in an environmental impact assessment (EIA) is described, illustrated with the example of Amsterdam Airport Schiphol. Unlike many EIAs, we estimated quantitatively the impact of aircraft-related pollution in terms of the number of affected people for aircraft noise annoyance, odour annoyance and hypertension. In addition, an analysis of health registry data on cardiovascular and respiratory diseases and a short survey on annoyance and risk perception were carried out. The scope of a health impact assessment depends on the situation, available knowledge and data, concern in the population about the impact and the number of people concerned. It is important to pay attention to the perception of risks and concerns from all parties involved. Moreover, the results demonstrate that far more people outside the area for which standards apply were affected than inside.


*Keywords:* Airport; Aircraft; Health; Impact assessment; Method; Complaints; Registries; Annoyance; Hypertension; Heart disease; Respiratory disease; Risk perception; Noise; Odour

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0195-9255/02/$ – see front matter 
PII: S0195-9255(02)00015-X


Fig. 1. Location of Schiphol airport and study area.

## 1. Introduction

Health aspects in an environmental impact assessment (EIA) are usually described as part of an inventory of environmental consequences of a planned activity. Reviews of EIAs in the Netherlands, Germany, Canada and the UK show that coverage of human health aspects in EIAs still tends to be limited and there is a lack of a systematic approach or methodology (Grontmij, 1993; Fehr, 1999; British Medical Association, 1998; Eyles, 1999; Passchier et al., 2000). The evaluation of health risks is often limited to a qualitative risk assessment, including the evaluation of available scientific literature and a comparison of pollution levels with available environmental standards or guidelines (Grontmij, 1993; Davies, 1991). One of the reasons for the lack of quantification of health risks in EIAs is that data needed for a quantitative risk assessment are usually lacking, e.g., exposure–response relations or population-based health data. Furthermore, there is usually little attention for indirect health aspects such as mental and social health effects (e.g., risk perception, residential satisfaction), despite recent developments in this area.

In this paper a comprehensive approach for health impact assessment as part of an EIA is described. The assessment of the health impact of aircraft-related pollution around Amsterdam Airport Schiphol is given as an example. A full report of this assessment is available in Dutch (Staatsen et al., 1993, 1994).

Schiphol ranks fourth in Europe, behind London, Paris and Frankfurt, in terms of passenger totals, freight traffic and commercial traffic (Schiphol Group, 2000). The airport is situated in a densely populated area on the outskirts of Amsterdam (Fig. 1). For the expansion of the airport with a fifth runway, an EIA was mandatory, in which the impact of different expansion scenarios on the environment was evaluated. In the terms of reference for the EIA, assessment of the health impact of aircraft-related pollution was limited to a qualitative risk assessment (evaluation of the available scientific literature and comparison of aircraft-related pollution levels with available standards or guidelines) (Minister van Verkeer en Waterstaat, 1992). However, health effects can also occur at exposures below standards or exposure limits. Therefore, the State Inspectorate of Public Health, as a legal advisor in EIA procedures, recommended more extensive health impact assessment (Staatstoezicht van de Volksgezondheid, 1991). In addition to physical health effects such as cardiovascular diseases, the perception of health risks was considered important because this may be a determinant of psychosomatic disease. The recommendations were based on expert meetings and public concern about possible health effects of aircraft as expressed in consultations of local environmental groups and the local population. Following these recommendations we quantified the impact of aircraft-related pollution (number of people affected) in addition to a qualitative risk assessment. This was combined with a study of available health registry data and a small questionnaire-based survey on annoyance and risk perception.

## 2. Scope of the health impact assessment

Following the recommendations of the State Inspectorate of Public Health, four steps in the health impact assessment were identified:

- assessment of the current health status and potential health risks of the population in relation to environmental pollution from Schiphol airport;
- identification of gaps in knowledge about health effects from airport-related environmental pollution;
- development of proposals for future research into the gaps in knowledge;
- preparation of a programme to monitor the health status of the population in relation to expansion of the airport.

In the EIA only the health status in 1990 was described. The EIA guidelines required the use of existing data. Given the uncertainties in the impact estimates at the time, it was not possible to predict health effects for the different airport expansion scenarios evaluated in the EIA. The study area was defined as an area of $55 \times 55$ km around Schiphol (Fig. 1). The total population in this area is approximately 2 million.

## 3. Selection of indicators for environmental quality and health

Exposure to environmental pollution from Schiphol airport was studied for aircraft noise, air pollution, odour and radar installations around the airport. These were selected on the basis of a screening exercise combined with consultations of local stakeholders and expert groups.

Levels of local air pollution and odour were primarily derived from dispersion modelling. Results were compared to earlier measurements of air pollution at the airport's platform and runways and with observations by odour panels (Van den Anker et al., 1989; Huygen, 1990; Cleveringa and Harssema, 1992). The dispersion model calculations for local air pollution and odour included air and road traffic emissions (most important roads in direct surroundings of the airport from a distance of 5 km from the airport including local traffic to and from the airport). However, airport-related sources such as ground service vehicles and traffic to and from the airport could not be included adequately in the models for local air pollution. These were, nonetheless, taken into account in the earlier measurements, and results of the model calculations agreed well with the measurements (Van den Anker et al., 1989). Local air pollution levels in residential areas in an area of $20 \times 20$ km around the airport were comparable to levels in urbanised areas, with only a relatively small contribution ($< 10\%$) from air traffic. Exposure to typical airport-related emissions in an area of $10 \times 10$ km around the airport did not exceed exposure limits. The contribution

of the airport varied from 3% to 12% and was lower than that for road traffic (20–80%) (Den Boeft et al., 1993).

In the calculations of odour emissions at the airport, typical airport-related sources have been taken into account (e.g., storage and transfer of kerosene, power units at platforms, air and road traffic at the airport). Odour panel measurements showed that kerosene can be smelled up to a distance of 8 km from the airport.

Health in the EIA context is defined as a status of general physical, mental and social well-being and not merely a long lifetime or the absence of a disease or infirmity (WHO, 1992). The extent to which normal social performance is possible is also of concern. Annoyance and concern about possible health effects can affect the mental and social well-being and normal performance and are therefore considered relevant effects.

The causal pathways and interrelation of health effects due to noise exposure are still poorly understood. Some effects may directly and independently follow exposure, while other (indirect) effects are believed to be mediated by stress (Passchier-Vermeer, 1993; Berglund and Lindvall, 1995). For instance, blood pressure may be directly affected by exposure to noise, but may also increase through stress caused by noise annoyance. Therefore, a variety of health indicators were studied in parallel. They are a combination of direct and indirect effects of environmental exposure, including indicators of (patho)physiological functioning (e.g., health complaints, hypertension, performance, awakenings), well-being (perceived health, risk perception, annoyance) and medical consumption (hospital admissions, medication use). Important criteria for the selection of relevant health indicators were:

- (biological) plausibility of possible effects;
- evidence for an exposure–response relation based on the scientific literature;
- number of people potentially affected, given current noise and air pollution levels in relation to airport activities;
- concern in the population about the effect.

Expert meetings and consultations of local environmental action committees and the local population, which were held during the preparation of the terms of reference for the EIA, resulted in a substantial list of matters of concern (e.g., respiratory diseases, heart diseases, gastrointestinal complaints, cancer, congenital defects). A selection of these effects was made based on the above mentioned criteria. During the EIA no relevant information on cancer around the airport was available. A study on cancer was being conducted at that time by the Comprehensive Cancer Centre Amsterdam (Visser et al., 1997). Therefore, cancer was not included in the health impact assessment. The results of the Comprehensive Cancer Centre Amsterdam study were not published in time to be included in the health impact assessment.

## 4. Quantification of the number of people with health effects

The quantification of the scope of the health effects involved three steps: estimation of exposure; assessment of the number of people at risk; and calculation of the number of people affected. Quantification of the affected number of people with health effects was only possible for aircraft noise annoyance, hypertension (as a risk factor for cardiovascular disease) and odour annoyance. For other relevant aircraft-related pollutants (e.g., air pollution and radiofrequent radiation of radars around the airport) only a qualitative risk assessment was made. This qualitative assessment indicated that pollutant levels around the airport did not exceed available standards or guidelines.

### *4.1. Estimation of exposure*

Aircraft noise contours for 1991 were used to quantify aircraft noise exposure. These were calculated by the National Aerospace Laboratory using a calculation model for determining the annual exposure to (night time) aircraft noise around Schiphol in B65 (expressed in Kosten units) and $LAeq_{,23\text{-}06\ hours}$. The Kosten unit (Ke) is a commonly used aggregate measure for aircraft noise in the Netherlands, developed by the Kosten Committee in 1963 (Adviescommissie Geluidhinder door Vliegtuigen, 1967). It is a yearly average, representing outdoor noise levels. The Kosten unit is defined by the maximum noise levels during flights, the total number of flights and the time at which these flights take place. Flights in the evening and night have more weight in the calculations than flights during the day. In calculating the B65 measure, the level of 65 dB(A) is taken as a threshold; only that part of each aircraft movement during which the calculated noise level at ground level is higher than 65 dB(A) is included in the model. At the time the fifth runway becomes operational (expected in January 2003) the Ke will be replaced by the Lden.

Odour levels were estimated for an area of $20 \times 20$ km around Schiphol using a dispersion model combined with a limited number of odour measurements at different aeroplane engines (Den Boeft et al., 1993). Volatile organic compounds were used as an indicator for kerosene odour. In addition, odour panel measurements were carried out (Cleveringa and Harssema, 1992).

### *4.2. Assessment of the number of people at risk*

The number of people exposed to aircraft noise was estimated by combining aircraft noise contours with demographic data for 1991 aggregated on a four-digit postal code level ($\pm 1900$ addresses on average per four-digit postal code) in a Geographic Information System (GIS). Noise exposure classes were defined in intervals of 5 Ke. The location of homes within the postal code area was taken into account in the estimation of the number of people per noise exposure interval. The range of exposure levels in a postal code area can vary consid-

erably, especially in densely populated areas where aircraft noise contours are close.

For the estimation of the number of people exposed to odour, contours (of 1–10 and >10 odour units) were combined with demographic data for 1991 and the location of dwellings.

### 4.3. Estimation of the number of people with aircraft noise annoyance

The number of people annoyed by aircraft noise was estimated by combining the number of people exposed to aircraft noise with available exposure–response relations representative for the Dutch population. We derived exposure–response relations from the literature. Two exposure–response relations were used. The first was the relation by Bitter, on which the Kosten unit was originally founded. This relation was derived from community surveys around Schiphol airport by Bitter in the sixties and seventies and based on B65 (Bitter, 1980). Secondly, an exposure–response relation from Miedema (1992) was used. This relation was derived from a compilation of three European annoyance studies (about 1750 observations) and based on Ldn.

Both the Bitter and Miedema exposure–response relations are based on studies in adults. The analyses were therefore restricted to adults ($\geq$20 years), about 77% of the total population living around Schiphol airport.

Based on Bitter, the number of severely annoyed adults in the area with aircraft noise levels of about 20 Ke or more was estimated at about 100,000 (Table 1). Using the exposure–response relation from Miedema, the number of severely annoyed people in the whole study area was smaller than that based on Bitter.

Table 1
Estimated number of people with aircraft noise annoyance

| Aircraft noise exposure (Ke) | % Severely annoyed[a] | Total population ($\geq$20 year) | Number of severely annoyed people |
|---|---|---|---|
| <20 | 5 | 927,790 | 46,390 |
| 20–24 | 10–15 | 406,390 | 50,800 |
| 25–29 | 15–20 | 206,750 | 36,180 |
| 30–34 | 20–25 | 71,160 | 16,010 |
| 35–39 | 30 | 15,370 | 4,610 |
| 40–44 | 45 | 7,170 | 3,230 |
| 45–49 | 45 | 3,770 | 1,700 |
| 50–54 | 45 | 320 | 140 |
| 55–59 | 50–55 | 310 | 170 |
| 60–64 | 60 | 70 | 40 |
| >65 | 65–75 | 90 | 70 |
| Total | | 1,639,190 | 159,340 |

[a] Exposure–response relationship from Bitter (1980).

Table 2
Estimated number of people with hypertension attributed to aircraft noise

| Aircraft noise exposure (Ke) | Total population ($\geq$20 year) | Prevalence of hypertension in total population ($\geq$20 year) | Relative risk[a] | Attribution of hypertension to aircraft noise (95% CI) |
|---|---|---|---|---|
| <30 | 1,540,930 | 149,700 | 1.00 | 0 |
| 30–35 | 71,160 | 8,640 | 1.07 | 530 |
| 35–40 | 15,370 | 1,670 | 1.22 | 370 |
| 40–45 | 7,170 | 780 | 1.39 | 310 |
| 45–50 | 3,770 | 410 | 1.59 | 240 |
| >50 | 800 | 80 | 1.70 | 60 |
| Total | 1,639,200 | 160,280 | | 1,510 |

[a] Based on a multiplicative model assumption ($\beta$=0.1267 per aircraft noise class of 5 Ke, standard error=0.0282).

In areas with aircraft noise levels >35 Ke, the available standard for aircraft noise in 1990, based on Bitter, it was estimated that about 10,000 people were highly annoyed. If sound insulation scenarios were taken into account (about 50% and 80%, respectively, of the houses have double glazing) the number of highly annoyed people exposed to aircraft noise levels >35 Ke averaged 8000 and 6000, respectively.

### 4.4. Estimation of people with hypertension caused by aircraft noise

The number of people with hypertension due to aircraft noise was quantified using an exposure–response relation from Knipschild (1977). Knipschild studied the prevalence of cardiovascular diseases in a population of about 6000 people (35–64 years) living around Schiphol airport. Based on this study, hypertension is expected to occur at aircraft noise levels >50 Ke with a relative risk[1] of 1.7, compared to a 'no effect' level of 30 Ke. The results of this study were interpolated using a multiplicative model assumption ($\beta$=0.1267 per aircraft noise class of 5 Ke, standard error=0.0282) and applied to the aircraft noise class-specific sex- and age-adjusted background prevalences of hypertension in the Dutch population ($\geq$20 years) (Kromhout et al., 1992).

As Table 2 shows, about 1500 extra cases of hypertension might occur due to aircraft noise in adults living in areas within the study area with aircraft noise levels >30 Ke (this is 1.5% of the population $\geq$20 years living in these areas).

[1] The relative risk (RR) represents the ratio between the probability that a health complaint will occur in the exposed versus that in the nonexposed group. If the RR is 1.00, the probabilities in the two groups are equal. If the RR>1.00, the probability that a health complaint will occur is greater in the exposed group.

### 4.5. Estimation of people with aircraft-related odour annoyance

The expected number of people annoyed by odour from airport activities was quantified by combining the number of people exposed with an exposure–response relation which was derived from a compilation of several odour studies by Miedema (1992). Around 108,000 residents were exposed to odour levels above the odour concentration standard for industry and agriculture (one odour unit per cubic metre of air (98 percentile, 1-h average)). Based on the available exposure–response relation, on average 36,000 residents were expected to be (at least) slightly annoyed by odour emission from airport activities. The results of additional odour panel measurements indicated that kerosene odour could be observed up to a distance of 8 km from the airport.

## 5. Analysis of health registry data

Available health registries were used to explore the spatial distribution of health effects (cardiovascular and respiratory diseases) and complaints about aircraft noise and odour around Schiphol airport. The quality of available health registries and their suitability for use in the health impact assessment was evaluated first (Franssen, 1994). Health registries were evaluated on five criteria: geographical reference (postal code), data quality, completeness, coverage and validity aspects. Of the 10 registries, only hospital admission data (cardiovascular and respiratory diseases) and complaint registries met these criteria.

### 5.1. Spatial distribution of cardiovascular and respiratory diseases

Spatial distribution of hospital admission rates was studied to get an indication of a possible role of airport-related pollution on the health status of the population living around the airport. Cardiovascular diseases (myocardial infarction, hypertension, ischemic heart diseases and cerebrovascular diseases), respiratory diseases (acute airway infections, upper respiratory symptoms, bronchitis, asthma and emphysema) and a control disease (diabetes mellitus) were studied. For privacy reasons it was not possible to obtain health registry data at the individual level, so we were confined to the analysis of aggregated data. The four-digit postal code was the lowest aggregation level at which hospital data were available. Population data per postal code area were collected from the 62 municipalities in the study area. Aggregated data on patients living in the study area who were hospitalised for the selected diseases in 1991 were collected from the Dutch Information System for Hospital Care and Day Nursing. Standardised morbidity rates (SMRs) for the selected diseases were calculated and mapped per postal code area. SMRs were calculated by a regression model that takes into account small area variability in the data using Bayesian smoothing techniques (Clayton and Kaldor, 1987; Bernardinelli and Montomoli, 1992). In the model


Fig. 2. Example of the spatial distribution of hospital admission rates for acute myocardial infarction (1991). SMR per postal code area, after Bayesian smoothing.

used, both the disease rate in the individual postal code areas and the average disease rates of all the areas were taken into account to reduce random variation in the data. The analyses were adjusted for age and sex. Information on other important determinants such as socioeconomic status and smoking were not available at the required spatial resolution. At the time, it was not yet possible to include exposure data into the model. The maps were judged by visual examination. A nonhomogeneous distribution of disease rates in the immediate vicinity of Schiphol airport was considered to be a first indication for a possible role of pollution caused by airport activities. The maps showed that there was wide spatial variation in cardiovascular and respiratory disease rates in the study area (see Fig. 2 for an example). No clustering of these diseases in areas close to the airport could be seen. There were no consistent patterns observed for men or women. Thus, there is no indication of a relation of cardiovascular or respiratory diseases with Schiphol airport. Acute myocardial infarction (ICD 410)[2] and hypertension (ICD 401–405) also did not show a specific pattern; both high and low values are homogeneously distributed over the study area. Hospital admissions for respiratory diseases (bronchitis, ICD 490–491 and asthma, ICD 493–496) occurred more frequently in areas with industrial activity like the IJmondregion, the Amsterdam west harbor area and the Zaanregion. The pattern, however, is not consistent.

Heisterkamp et al. (2000) reanalysed the hospital admission data for acute myocardial infarction and bronchitis with a spatiotemporal model for a period of 3 years (1991–1993). For these analyses, exposure data (aircraft noise and distance, as an indicator of aircraft-related air pollution) were included as

[2] International Classification of Diseases, 9th edition.

covariates into the model. The results of this study showed that discharges of bronchitis are clearly clustered in the area between the port of IJmuiden at the west side of the North Sea canal and Amsterdam at the east side. High acute myocardial infarction displayed a more dispersed pattern. The results of these analyses were consistent with our findings.

### 5.2. Spatial distribution of complaints

Complaints about aircraft noise and kerosene odour were mapped to explore their spatial variation around Schiphol airport. Aircraft noise complaints were registered by the Environment Advisory Committee Schiphol, which was installed by the Ministry of Transport, Public Works and Water Management in 1968 to provide a discussion platform and information on the quality of the environment around Schiphol airport (Hulshof and Noyon, 1997). Complaints about odour were obtained from the Environment Information Centre of the Province of North Holland.

About 60,000 complaints about air traffic noise were registered at the Environment Advisory Committee Schiphol in 1992. Only about 25 complaints about kerosene odour were reported at the Environment Information Centre of the province of North Holland. The number of complaints about air traffic noise was much higher than in previous years (Fig. 3). The number of complainants, however, did not increase as much as the number of complaints. This increase was due to the fact that several runways are more frequently used during peak load of the airport. As a result, less preferential runways, i.e., the ones causing the most annoyance, are also used more frequently (CGS, 1992). It was concluded that the complaint density, as expected, was highest close to the airport (Fig. 4).

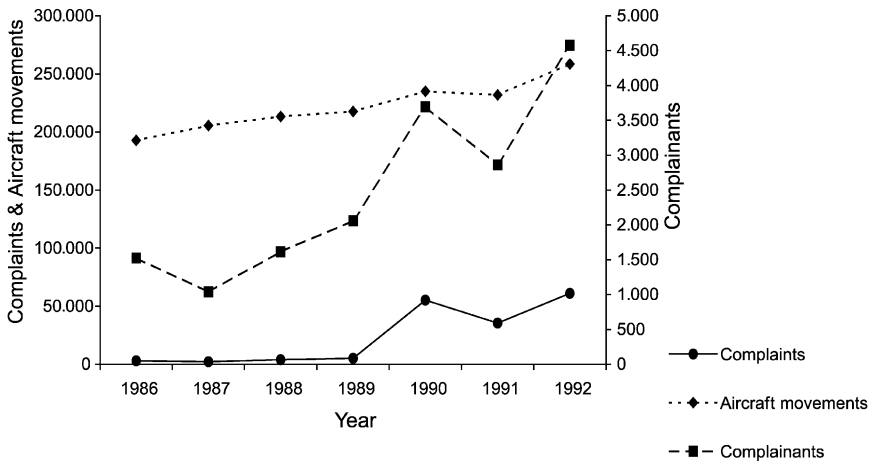


Fig. 3. Aircraft movements, complaints and complainants (1986–1992).

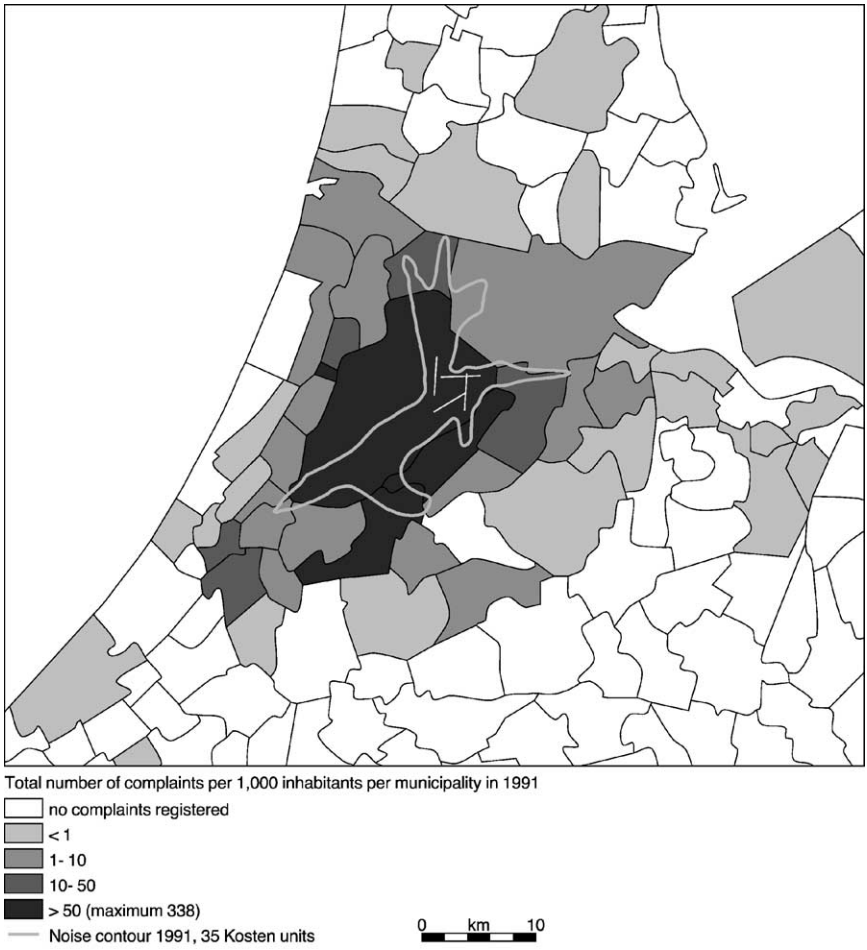


Fig. 4. Number of aircraft noise complaints per number of inhabitants per municipality (1991).

However, aircraft noise complaints were also reported from locations at larger distance from the airport, with noise exposure levels of less than 35 Ke. Odour complaints were reported from locations up to a distance of maximum 12 km from Schiphol airport.

## 6. Questionnaire survey and interviews on risk perception and annoyance

To gain insight into the public's concern about health and safety risks of air traffic, an interview-administered questionnaire-based survey and open interviews on annoyance and risk perception were held among adults ($\geq 18$ years)

living in the vicinity of Schiphol airport (Steenbekkers and de Jong, 1993). The survey was conducted in a sample of the Dutch population (936 persons) and a sample of the population living in the Schiphol study area (479 persons). This survey was conducted between March and April 1993, half a year after an El Al freight plane crashed on a block of flats in Amsterdam, killing 43 people. Due to the short time frame, the survey was combined with an ongoing periodical survey on the perception of health risks so as to get reference data for people living outside the study area. The sample was stratified for aircraft noise. People were asked to what extent they were annoyed or concerned about their health and safety. In addition to the questionnaire, a subgroup of the Schiphol sample has been interviewed. This group consisted of 66 people who (as indicated in the survey) judged the residential environment of an airport as hazardous ($n = 31$) or, in contrast, not hazardous at all ($n = 10$). Interviews were also held with 26 persons of 14 municipalities in the Schiphol area who were well acquainted with matters of public concern (e.g., general practitioners, town councillors). They were asked about their concern about health and safety risks, social–economical factors that could influence the perception of health risks and the living environment (such as the recent plane crash) and the information supply about these topics. In contrast to the questionnaire, the questions in the structured interviews were explicitly related to Schiphol airport.

Almost 75% of the respondents in the Schiphol study area mentioned air traffic as the most important source of noise. Sixty percent mentioned air traffic as an important source of air pollution. Only 6% of the Dutch sample mentioned air traffic as a noise source. The annoyance due to noise and air pollution was considerably higher in the Schiphol sample as compared to the Dutch population-based sample. The concern about health effects attributed to noise and air pollution was also higher among respondents in the Schiphol sample than in the Dutch population. Residents of the Schiphol area were more often afraid that their health would be affected by noise (41%, vs. 19% in the Dutch sample) and air pollution (51%, vs. 27% in the Dutch sample). In response to the open question ‘Which health effects can be caused by the noise in your neighbourhood?’ respondents in the Schiphol area most often mentioned sleep disturbance, nervousness and heart disease as possible health effects related to aircraft noise (Table 3). Seven percent mentioned cancer as a possible health effect of aircraft noise exposure. For air pollution possible health effects mentioned were respiratory complaints and lung cancer. Nonspecific complaints were also mentioned frequently as possible health effects of both aircraft noise and air pollution. Some possible health complaints (e.g., nervousness, reduced concentration and respiratory diseases) were mentioned more often by respondents from the Dutch population than by the Schiphol sample. Residents living in the vicinity of Schiphol were more afraid of plane crashes compared with the general Dutch population. They also reported living in the vicinity of an airport or under an approach route as more dangerous.

Table 3
Perceived health complaints related to aircraft noise and air pollution

| Effect | Aircraft noise | | Air pollution | |
|---|---|---|---|---|
| | Schiphol sample ($n=194$) | Dutch population ($n=182$) | Schiphol sample ($n=243$) | Dutch population ($n=248$) |
| Sleep disturbance | | | – | – |
| Problems falling asleep | 38 | 36 | | |
| Waking up | 36 | 17 | | |
| Nervousness | | | – | – |
| Stress | 44 | 62 | | |
| Tension | 26 | 35 | | |
| Reduced concentration | 8 | 10 | – | – |
| Respiratory complaints and allergy | – | – | 28 | 29 |
| Chronic nonspecific lung disease | | | 20 | 27 |
| Asthma | | | 15 | 19 |
| Bronchitis | | | 37 | 32 |
| Shortness of breath | | | 17 | 15 |
| Allergy | | | 10 | 13 |
| Irritation of eyes, nose, throat | – | – | | |
| Sore throat | | | 12 | 12 |
| Dry eyes | | | 16 | 15 |
| Heart diseases | 17 | 14 | 3 | 3 |
| Cancer | | | | |
| Lung cancer | | | 12 | 3 |
| Other cancers | 7 | 0 | 20 | 6 |
| A-specific complaints | | | | |
| Headache | 12 | 16 | 17 | 25 |
| Earache | 16 | 2 | – | – |

The question was 'Which health effects do you think can be caused by the noise in your neighbourhood?'
Respondents could report more than one complaint; only reported complaints >10% are shown.

The interviews showed that the plane crash of October 1992 made people more aware of the possibility of a such a calamity in their surroundings. The extent to which feelings of fear occurred differed from place to place. Intense emotional reactions were observed among some residents in the northern part of Aalsmeer and the Haarlemmermeer, but these reactions diminished very fast. Particularly children who witnessed the crash showed a strong fear for air traffic, especially in the evening. Some people are permanently afraid, whereas others worry about the increasing number of flights, or are concerned in case of unusual events. Respondents who lived at a greater distance from the airport, however, felt safe most of the time. The 'key persons' stated that they experience the development of Schiphol airport as an inevitable process in which the residents' interests are not, or only partially, taken seriously. Residents, however, are not much inclined to leave the region, because of social and economical ties. Information on safety risks provided by the airport authorities is looked upon

with considerable distrust. Some people believe that information about the risks of air traffic is withheld on purpose.

## 7. Discussion

We described a comprehensive approach for the evaluation of possible health effects in an EIA, illustrated with the example of Amsterdam Airport Schiphol. The health impact assessment consisted of an evaluation of the available scientific literature and a comparison of aircraft-related pollution levels with available standards or guidelines. Unlike many EIAs, we also quantitatively estimated the impact of aircraft-related pollution in terms of the number of affected people for several health effects. This quantitative risk assessment was combined with a study of available health data and a short survey on annoyance and risk perception.

Critical elements in this health impact assessment were the uncertainty and lack of information on the relation between aircraft-related pollution and specific health effects, the use of aggregated data at the small area level and limitations of available (health and complaints) registries.

The number of studies on health effects of aircraft-related pollution, with the exception of aircraft noise, were limited. Most aircraft noise studies reported in the literature were carried out at high exposure levels, often under experimental laboratory conditions. Therefore, the extrapolation of effects to low exposure levels, i.e., levels to which the general population is exposed has a large margin of uncertainty.

For the quantification of the number of people affected by aircraft-related pollution we derived exposure–response relations from the literature. Exposure data or exposure–response relations for the Dutch population, and specifically for Schiphol, were only available for aircraft noise annoyance, hypertension and odour annoyance. However, these data were not very recent and applied to situations with less air traffic, but noisier airplanes than were expected for Schiphol at the time the EIA was conducted.

Since the EIA guidelines and time frame precluded the collection of new data, we had to rely on existing health data. It was the first time that health registries were used for an environmental health impact assessment in the Netherlands. The quality of available health registries and their suitability for use in the health impact assessment was therefore evaluated beforehand. The health registries evaluated often did not register the diseases or complaints of interest. Of the 10 registries, only data from hospital admission (cardiovascular and respiratory diseases) and complaint registries were suitable and available in time. Other registries which were potentially suitable to study health aspects around Schiphol airport (but not available in time) were the obstetrics registry (birth weight) and pharmacy registry (medication use). Results of studies based on these registries were conducted and published after the EIA (van Willigenburg et al., 1996; Franssen et al., 1997).

Another important drawback of using health registry data is that data on disease determinants (e.g., social economical status, life style) are usually not or only partly registered. This may lead to false positive or negative disease patterns (Greenland and Morgenstern, 1989). For privacy reasons it was not possible to obtain health registry data at the individual level, so we had to confine to the analysis of aggregated data. The use of aggregated data is usually regarded as having hypothesis-generating potential only and precludes conclusions about the causes of observed health differences (Morgenstern, 1998). Therefore in the health impact assessment health registries were considered to have a sentinel function. They signal the presence of possible effects worthy of further study.

Hospital admissions are restricted to health effects for which hospital treatment is required. In the Netherlands, people with mild health complaints will contact (and will be treated by) a general practitioner in the first place. However, a uniform health registry for general practitioner data was not available at the time.

Although registered complaints might give an impression about annoyance due to aircraft noise or odour, the significance of complaints as an indicator for the extent of aircraft noise effects on a population is equivocal. Some studies find that these complaints are related to the aircraft noise exposure (Stockbridge and Lee, 1973; Gillen and Levesque, 1994), while others conclude that they do not represent the community response to aircraft noise (Brosky, 1979; Luz et al., 1983). Complaints might give an over- as well as an underestimation of the actual community impact of Schiphol airport. Some causes of underestimation could be economical alignment to the airport or feelings of distrust of authorities among residents. The formation of an ‘alternative’ information centre, after the crash of a Boeing on a block of flats in Amsterdam, illustrates this latter point. Some causes of overestimation could be the organised submission of complaints as a means of political pressure or out of feelings of distrust. Unfamiliarity with the provincial Environment Information Centre may be a reason for the few complaints about kerosene odour registered. In addition, odour complaints are reported to different authorities, which leads to fragmentation.

The survey on annoyance and risk perception only gives a first indication of the perception of annoyance and risks related to Schiphol airport. Due to the short time frame, we had to join a periodical survey, which was already planned. Therefore, only a selection of questions could be asked. An important limitation of this study is the lack of information on the risk perception before the plane crash in Amsterdam. Also, the Schiphol sample was not representative for the total population in the study area. Despite these restraints, the survey provided more insight in the perception of health and safety risks in people living around a major international airport. It also showed that the interpretation of risks by the public and by scientists diverges. For instance, respondents living around Schiphol airport reported cancer as a possible health effect of aircraft noise whereas plausibility for this association is not described in the literature. These perceptions should be given attention in the communication of the EIA results and in projects that will be evaluated in an EIA in the future.

In the health impact assessment only the health status in 1990 was described. Given the uncertainties in the impact estimates at the time, we did not predict health effects for the different airport expansion scenarios evaluated in the EIA. The applied method, however, can be used to assess the impact of different expansion scenarios on public health when information on exposure and population development for the different scenarios is available and the relation between airport-related environmental pollution and health effects is known.

The Dutch Health Council's international Committee on the Health Impact of Large Airports evaluated the way health issues are being dealt with in the expansion plans of three major European airports (Heathrow, München and Berlin). In these cases, only a limited assessment of the public health impact was part of an EIA. The Committee stated that the (integrated) approach of the health impact assessment Schiphol should be normal practice in assessing the public health impact of large airports. On the basis of these studies, measures to safeguard public health effectively and efficiently can be implemented (Health Council of the Netherlands, 1999).

## 8. Conclusion

The scope of a health impact assessment depends on the situation, available knowledge and data, concern in the population about the impact and the number of people concerned. Preceding an EIA, thorough consideration of concerns from all parties involved is important. For the EIA Schiphol this resulted in a comprehensive approach, as described in this article.

The results of this health impact assessment indicated that exposure to aircraft noise will affect the health status of the population living around the airport in terms of annoyance, sleep disturbance, cardiovascular diseases and reduced performance. It is unlikely that local air pollution levels will cause respiratory effects or cancer. From the qualitative risk assessment, it was concluded that no standards for aircraft noise and air pollution exposure were exceeded. However, the quantitative risk assessment and the analysis of complaints showed that effects were also reported in areas outside the available standards for aircraft noise and odour.

Further research was recommended for the following health indicators: medication use, birth weight, cancer, cardiovascular diseases, annoyance, sleep disturbance and neurobehavioural effects. Exposure measurements for, e.g., noise, odour, polyaromatic hydrocarbons and PM10, and the assessment of indoor air quality of noise insulated houses were recommended for better exposure estimations. Based on local air pollution levels around the airport in 1993, there was no indication for an increased risk in respiratory diseases. Thus, no study on the health effects of air pollution was recommended. However, a provision was made that public concern by itself might justify a study on

respiratory disease. Indeed, some years later, indications from general practitioners through the municipal health services led to political pressure. This resulted in a study on respiratory disease and respiratory functioning in schoolchildren, following the EIA.

Furthermore, this health impact assessment has positively influenced the risk communication process (more attention for concern in the population), the dialogue between policymakers, scientists and the population, and the selection of indicators for further research. Before this study was conducted, the discussion concentrated on the lack of data on health effects and on which effects could possibly occur; a large list of possible effects was mentioned, with varying severity and scale. After the EIA, discussions were focussed on the content and significance of the study results instead.

## 9. After the EIA

The Committee for Environmental Impact Assessment has endorsed the conclusions of the health impact assessment and adopted the recommendations (Commissie voor de Milieu-effectrapportage, 1994). Given the Committee's advice, following the EIA, a long-term research programme into health effects of environmental pollution around Schiphol airport was designed: the HIAS. This programme consists of research into the deficiencies in knowledge identified in the EIA and the development of a health monitoring system to study the health status of the population periodically in relation to expansion of the airport. These studies are being carried out during the period 1995–2002. They include:

- analyses of data from existing health registries on the use of sleeping pills and medication for respiratory diseases, on birth weight and on cardiovascular and respiratory diseases;
- epidemiological field studies concerning annoyance, sleep disturbance, perceived health, medication use, risk perception and residential satisfaction (questionnaire survey), aircraft noise and neurobehavioural effects in children, respiratory complaints in children in relation to air pollution measurements and aircraft noise and sleep disturbance in adults.

The proposals for these studies have been reviewed by independent (inter)-national experts (Franssen et al., 1995). Results of these studies are summarised by Franssen et al. (1999).

The Dutch Health Council's international Committee on the Health Impact of Large Airports underlined the importance of monitoring changes in exposure and health as planned in the HIAS. The monitoring programme will be commissioned to start in 2002.

The HIAS is coordinated by the National Institute of Public Health and the Environment (RIVM). The studies are conducted by the RIVM in cooperation

with other research institutes and universities. A Steering Committee, existing of representatives of the Ministries oversees the project. Two advisory bodies are periodically consulted, consisting of policymakers and representatives of local and regional action groups, municipal health services, district general practitioners association, KLM and the local population. Studies are scientifically reviewed by an ad hoc advisory committee, with experts from research institutes and universities who are not involved in the studies.

## Acknowledgements

The health impact assessment for the EIA Amsterdam Airport Schiphol was commissioned by the Dutch Ministry of Housing, Spatial Planning and the Environment, the Ministry of Public Health, Welfare and Sport and the Ministry of Transport, Public Works and Water Management. It was conducted by the National Institute of Public Health and the Environment (RIVM), the Institute for Environmental Studies, TNO Prevention and Health and TNO Voeding.

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