Public health impact of large airports

Gezondheidsraad **Vice Voorzitter**
Health Council of the Netherlands

De Minister van Volksgezondheid,
Welzijn en Sport

Onderwerp : aanbieding advies
Uw kenmerk : GZB/C&O/98344
Ons kenmerk : U 2511/WP/MK/610-C2
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Mevrouw de Minister,

Hierbij bied ik u — gehoord de Beraadsgroep Gezondheid en Omgeving en de Beraadsgroep Geneeskunde — het advies 'Public health impact of large airports' aan. Met dit advies beantwoordt de Gezondheidsraad uw brief van 13 februari 1998. Ik heb het bijgevoegde rapport heden eveneens aangeboden aan uw collega's van Volkshuisvesting, Ruimtelijke Ordening & Milieubeheer en van Verkeer & Waterstaat.

Het advies is opgesteld door een door mij voorgezeten internationale commissie van deskundigen. Zij heeft de gezondheidsrisico's die zijn verbonden aan het bedrijven van een grote luchthaven, niet alleen beschouwd als een optelsom van afzonderlijke relaties tussen bepaalde milieufactoren en bepaalde effecten. Die relaties beïnvloeden elkaar namelijk, terwijl de bevolking op en rondom luchthavens steeds de invloed van een samenloop van diverse factoren ondervindt. Een meer integrale benadering, waartoe dit advies een poging doet, is niet alleen nodig bij het in kaart brengen van de positieve en negatieve invloeden op de gezondheid van het luchthavenbedrijf, maar tevens bij het nemen van maatregelen om de voordelen te maximaliseren en de gezondheidsnadelen in te perken. Op dit punt beperkt de rol van de wetenschap en van adviescolleges als de Gezondheidsraad zich tot het verschaffen van kennis en inzicht. Ik onderschrijf de zienswijze van de Wetenschappelijke Raad voor het Regeringsbeleid in zijn advies over duurzame risico's, dat met het beoordelen van risico's en het kiezen van maatregelen om die risico's te beteugelen, onlosmakelijk normatieve elementen zijn verbonden, waarover door beleidsverantwoordelijken moet worden beslist.

Het advies bevat op verscheidene plaatsen aanbevelingen voor onderzoek. Ik wil enkele van die aanbevelingen via deze brief onder uw aandacht brengen.

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In het kielzog van de aanbeveling om de risico's voor de gezondheid van het luchthavenbedrijf als regel op samenhangende wijze te beoordelen, volgt de aanbeveling nader onderzoek te doen naar de hiervoor geëigende methoden. De huidige Gezondheidskundige Evaluatie Schiphol (GES) biedt hiervoor een goed startpunt. Een tweede belangrijk onderwerp van onderzoek betreft de gevoeligheid van individuen en groepen voor bepaalde milieufactoren. In het bijzonder in de hoofdstukken over luchtkwaliteit en geluid wordt hierop gewezen. Aandacht vraagt de commissie ook in dit verband voor de gevoeligheid van kinderen. Verder wijst het advies op enkele andere lacunes in onze kennis over de gevolgen van langdurige blootstelling aan geluid en aan luchtverontreiniging, in het bijzonder wat betreft de precisering van het verband tussen blootstelling en respons (geluid: cardiovasculaire aandoeningen, luchtverontreiniging: voortijdige sterfte en luchtwegaandoeningen).

Het advies bepleit ook het leggen van een verband tussen maatregelen die de negatieve invloed van factoren als geluid en luchtverontreiniging kunnen verminderen en maatregelen op het gebied van de ruimtelijke ordening, in het bijzonder waar het de voorzieningen in en het aanzicht van de omgeving betreft. Het betreft hier naar mijn mening een nog in belangrijke mate onontgonnen terrein. Tenslotte wijs ik u op de rol van informatie en communicatie. De commissie staat een open benadering voor. Daarbij denkt ze aan het informeren van alle betrokkenen, inclusief de lokale bevolking, over de ontwikkelingen op de korte en lange termijn die bij het luchthavenbedrijf spelen. De commissie bepleit ook een open uitwisseling van informatie over ongevallen, bijna-ongevallen en voor gezondheid en veiligheid relevante zaken. Een open informatie uitwisseling kan bijdragen tot het vergroten van de kwaliteit en veiligheid van het luchthavenbedrijf. Ook hier doet zich de noodzaak van nader onderzoek gevoelen om te kunnen komen tot een doelmatig rapportage- en informatiesysteem.

Hoogachtend,

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Gezondheidsraad **Vice President**
Health Council of the Netherlands

The Minister of Health,
Welfare and Sport

Subject	: advisory report
Your reference	: GZB/C&O/98344
Our reference	: U 2511/WP/MK/610/C2
Enclosure(s)	: 1
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Mrs Minister,

Please find enclosed the report 'Public health impact of large airports', prepared by a committee of the Health Council, having heard the Standing Committee on Medicine and the Standing Committee on Health and Environment. The report responds to your request of 13 February 1998. I have also submitted it today to the Minister of Housing, Spatial Planning and the Environment, and the Minister of Transport, Public Works and Water Management.

The report has been prepared by an international group of experts. The committee did not just consider the health risks associated with the operations of a larger airport as a simple sum of relationships between certain environmental effects and certain health effects. Those relationships are not mutually independent and, furthermore, the population at and in the vicinity of airports is inevitably exposed to a variety of environmental factors in a cumulative way. The integrated approach, advocated in the report, should not only be applied to a description of the positive and negative impacts of airport operations on health, but also be used as guidance in selecting measures to maximise the benefits and limit the health risks. In this respect the role of science and of expert gremia such as the Health Council is limited to providing knowledge and judgement scientific concur with the view expressed by the Netherlands Scientific Council for Government Policy in its report on 'sustained risks' that the assessment of risks and the choice of measures to limit those risks has inevitably normative aspects, that belong to the domain of policy makers.

The report contains several research recommendations. Here I like to summarise some of these.

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The committee's recommendation to subject the health risks associated with airport operations on a regular basis to an integrated assessment, is followed by the proposal to study suitable methods for such an assessment. The health risk assessment project at Amsterdam Schiphol (GES) would be a good starting point for research into this matter. Another study subject is the susceptibility of individuals and population groups for certain environmental factors. Especially the chapters on air quality and on noise contain proposals in this respect. More in particular, the committee would like to draw your attention to the special position of children. Furthermore, the report points to other gaps in knowledge on the effects of long term exposure to noise and air pollution, particularly the determination of the relationships between exposure and response (in the case of noise — cardiovascular disorders; in the case of air pollution — premature death and respiratory conditions).

The report proposes to integrate measures to reduce the negative impacts of environmental factors such as noise and air pollution, and spatial planning policies, especially with respect to landscaping and to services and provisions in residential areas. In my opinion such an integration is relatively new and needs further study. Finally I like to address the subject of information and communication. The committee advocates an approach characterised by openness. This would apply to the exchange of information between all parties concerned, including the local population, on the short and long term developments of the airport operations. Furthermore, an open exchange of information on accidents, near-accidents and other incidents in the airport operations systems is of importance. This information exchange may be instrumental in increasing the quality and safety of the airport operations. Several questions have to be answered — an thus should be subject for study — to attain an effective and efficient reporting and information system.

Sincerely Yours,

(signed)
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Public health impact of large airports

Health Council of the Netherlands

To:

the Minister of Health, Welfare and Sport

the Minister of Housing, Spatial Planning and the Environment

the Minister of Transport, Public Works and Water Management

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Contents

Executive summary

Civil aviation

Civil aviation represents a growing industry and most economists expect this growth to continue. It is developing into a truly global industry, with a few conglomerates of airlines serving a world-wide network of large 'hub' airports. In 1997 the scheduled airlines carried 1,5 billion passengers and 26 million tons of freight.

The economic gains of the aviation industry and the possibility of reaching far away locations may be beneficial for health and quality of life, probably mainly so for affluent populations in the industrialised parts of the world. However, aviation affects the environment both globally and locally in a negative sense and consequently has also negative impacts on health.

Request and report

This report responds to a request of the Ministers of Health, of Transport and of the Environment of the Netherlands Government to assess the health impact of large airports.* The request was related to the public and political debate about the future of the Dutch aviation infrastructure and about the expansion of Amsterdam Schiphol airport in particular, although a specific assessment for the Dutch National Airport was

* These Cabinet Ministers are officially denoted by, respectively, Minister of Health, Welfare and Sport, Minister of Housing, Spatial Planning and the Environment, and Minister of Transport, Public Works and Water Management.

not called for. To prepare the report the President of the Health Council appointed an international committee of experts.

Three case studies were carried out to provide the committee with background material on the way public health plays a role in airport development. The cases chosen were; a new passenger terminal at London Heathrow, Munich International Airport that opened at a new location in 1992, and the planning process for an airport in Berlin, to replace the three existing airfields in the beginning of the next century. The committee was also informed on the progress with the health impact assessment studies at Amsterdam Schiphol.

The committee focused on the public health impact of local changes in environmental factors. 'Public health impact' has been defined by the committee as to include impacts on 'quality of life'. Effects of aviation on climate and thereby health and indirect positive and negative public health effects through economic mechanisms, transport possibilities and tourism are outside the scope of the present report.

Airport operations system

The committee has approached the relationship between airport operations and public health in an integrative manner. It evaluated public health impacts in airport operations systems encompassing the area up to a few tens of kilometres distance from the airport. Apart from the direct aviation related operations the system also includes the activities of businesses that are attracted to the airport region, as well as the infrastructure necessary to serve to airport, other businesses and the residential locations in the area. Even when airports are originally located in remote areas, then over of the years the airport region becomes more and more urbanised and settled with freight handling industries, catering and hotel activities, high-tech industries and offices that prefer to be located close to the airport.

The impacts of all these activities within an airport operations system on public health are only partly specific for the system. Aircraft noise, kerosene odour and aircraft crash risk are specific factors. Air pollution, landscape changes by transport infrastructure, road traffic and industrial noise and occupational health risks are, however, also encountered in other urbanised and industrialised settings.

Environment and public health

The committee has considered the impact of several environmental factors on health separately:

- air pollution
- noise

- accidents
- soil and water pollution at the airport
- importation of infectious diseases
- appearance of the environment
- occupational health risks at the airport.

In the concluding chapters the committee has tried to integrate these findings and suggests approaches for improving public health protection.

Does the airport operations system affect public health? This central question is answered by the committee with; yes. Considering the relationship between environmental factors and public health, infringements on the quality of life, such as sustained odour and noise exposure, also have a potential of causing clinically observable disease in the long run. This depends on a variety of factors such as individual susceptibility, social-economic status and life style, and the simultaneous exposure to a variety of environmental factors. Some of these factors may aggravate the public health effects, but others could reduce or offset them. The relationships between environment and health are fraught with uncertainties, not in answer to the question about whether factors such as environmental noise and air pollutants do affect public health negatively, but to the questions as to what extent and which population groups are most vulnerable.

In determining the impact of environmental factors the committee uses classification schemes for:

- evidence for the causal relationship between the exposure to an environmental factor and a public health effect
- severity of the effect (slight, moderate, severe)
- number of people affected.

The classes for causal evidence are; sufficient, limited or inadequate evidence, or evidence for the lack of a causal relationship. Severe effects seriously impair day-to-day functioning and usually require professional medical care. A public health effect is rated as ‘slight’ if the impact on daily functioning is not very significant, or is reversible, or has a small effect in the long run. Moderate effects are in between these two extremes. The number of affected people can only be very roughly indicated. Classes are: susceptible individuals, specific subgroups, substantial part of the exposed population, and are only given if the causal relationship is deemed to be supported by sufficient evidence.

Air pollution

The contributions from aircraft, other airport operations, road traffic to or from the airport or to other destinations to the public health effects of air pollution in an airport operations system are intricately mixed. This is due to the spread of air pollutants in the atmosphere by dispersion processes, whereas total pollution is also determined by sources outside the system, possibly far away. The important conclusion is that air pollutant levels around large airports are similar to those in urbanised areas and are to a large extent determined by road traffic emissions. At such concentrations public health effects are to be expected, even though the concentrations are generally below official guideline values.

The present understanding of air pollution effects is that exposure will impair respiratory functions, for most people in a reversible way. Effects become more invalidating in the case of sustained exposure. The table below lists the effects of air pollution for which there is sufficient scientific evidence for a causal relationship:

response	severity [1]	number affected [2]
premature death (response after an episode in susceptible groups)	***	*
aggravation of respiratory and cardiovascular disorders after an episode (resulting in hospital admissions)	***	*
affected lung function after an episode	*	?
premature death (decrease in life expectancy) due to chronic exposure	***	*
reduced lung function due to chronic exposure	**	**
increase in chronic respiratory conditions (bronchitis) due to chronic exposure	**	**
odour annoyance from chronic exposure	*	***

1 * = slight, ** = moderate, *** = severe

2 * = susceptible individuals, ** = specific subgroups, *** = substantial part of exposed population

Effects, related to an air pollution episode, for which there is limited evidence are respiratory symptoms and aggravation of asthma. These effects are rated by the committee as slight and severe, respectively.

Epidemiological studies of the prospective, cohort and case-control variety have linked long-term exposure to air pollution with survival, increased lung cancer mortality, reduced lung function and increases in chronic respiratory conditions, especially bronchitis. The committee rates this evidence as sufficient, even though more work need to be done to elucidate exposure-response relationships and to what extent the effects observed are due to exacerbation of existing disorders. There is to date only inadequate evidence to link long term exposure to community air pollution to the prevalence of allergy ands asthma. As yet no airport specific carcinogenic compounds have been identified.

The number of epidemiological studies on air pollution and public health near airports are scarce. Morbidity and mortality levels, related to diseases that may be air pollution related, do not appear to differ between airport regions and cities. A study at Amsterdam Schiphol has provided evidence for a decrease in the prevalence of respiratory complaints with increasing distance from the airport. To what extent air pollution levels and other factors play a role is subject of further study.

Chronic exposure to odour has been reported to induce, apart from annoyance, a variety of moderate somatic and psychosomatic effects. The evidence for a causal relationship is rated as limited.

With respect to controlling air pollution the committee notes that in most industrialised nations industrial and road traffic sources of air pollution are subject to regulatory control, contrary to aircraft emissions. An integrated approach to combat air pollution is at odds with a system in which one important source, *i.e.* aircraft emissions, is exempt from such control.

Noise

Aircraft noise is one of the most noticeable environmental factors of airport operations and is specific to the system. Although there are other noise sources in the system, noise from aircraft taking off and landing, from aircraft braking and taxiing at the airport and from aircraft engine testing are dominant ones. At the airport, noise from ground traffic can be considerable and will in particular affect airport workers. In the vicinity of an airport one will usually find residential locations where air traffic noise is a dominant source of environmental noise exposure. Aircraft noise levels are determined by the position of the runways and the flight patterns. Outdoor aircraft noise exposure in residential areas around large airports may exceed 60 and occasionally 70 dB(A) (day-night or day-evening-night exposure level).

Hearing impairment is a well-documented effect of noise exposure. In an airport operations system it is of concern at operations at the airport, especially in ground handling and in engine testing. Only in very exceptional cases will environmental noise exposure induce hearing loss. The other effects for which there is sufficient evidence for a causal relationship with noise exposure are listed in the table below. Effects are only observed in exposed populations at noise levels above the observation threshold. ‘Sleep disturbance’ in the table denotes a conglomerate of effects, including awakening, sleep stage and sleep pattern changes, heart rate changes, and effects on mood the next day. Limited evidence exists for the effects of night-time noise exposure on performance the next day and changes in hormone levels.

response	severity [1]	number affected [2]	observation threshold
hypertension	**	**	eq. outdoors sound level (06-22 h) of 70 dB(A)
ischaemic heart disease	***	*	eq. outdoors sound level (06-22 h) of 70 dB(A)
annoyance	*	***	outdoors day-night level of 42 dB(A) [3]
sleep disturbance	**	***	depending on effect, indoors SEL of 35-50 dB(A) [4]
performance at school	**	**	eq. outdoors sound level (school hours) of 70 dB(A)

1 * = slight, ** = moderate, *** = severe

2 * = susceptible individuals, ** = specific subgroups, *** = substantial part of exposed population

3 threshold for 'high annoyance'; the day-night level is the equivalent sound level over 24 hours, with the sound levels during the night (period of 23-07 h) increased by 10 dB(A).

4 SEL is the equivalent sound level during the noise event normalised to a period of one second

A variety of other effects has been linked to noise exposure, such as decreased general performance, biochemical effects, deterioration of the immune system, decrease in birth weight, psychiatric disorders and negative effects on psycho-social well-being. The committee considers the evidence for the causal relationship of these phenomena with noise exposure to be limited. With the exception of psychiatric disorders (severe), and effects on birth weight and psycho-social well-being (moderate), the committee rates the other effects as slight. There is evidence that congenital effects do not result from the exposure of pregnant women to environmental noise.

The understanding of the committee is that, hearing impairment excepted, the public health effects of noise depend on both the (psychological) appraisal of the noise exposure by the organism and the vegetative reactions induced. Some of the somatic and psychosomatic effects, such as hypertension and cardiovascular disease may be a direct consequence of this processing of noise exposure by the organism, others are possibly a consequence of noise-related annoyance. Annoyance is defined here as a feeling of resentment, displeasure, discomfort, dissatisfaction or offence which occurs when an environmental factor interferes with a person's thoughts, feelings or activities.

Noise exposure is only one of the determinants of annoyance. Studies have shown that aircraft noise is more annoying than road and rail traffic noise at the same day-night exposure levels. Aircraft noise-induced annoyance is influenced by the degree of anxiety associated with the possibility of aeroplane crashes. Other so-called non-acoustical factors that modify annoyance are the degree of openness on the part of the airport authorities or the government concerning the developments at the airport and the way in which the authorities enforce environmental standards. These latter factors can work both ways, i.e. they can be instrumental in reducing (more openness, strict enforcement) or increasing annoyance.

Recent studies appear to confirm older work on the negative impact of aircraft noise on the cognitive abilities of children. The committee deems this to be a subject that warrants further study to elucidate exposure-response relationships and to assess the possible long term impacts.

Safety

Aircraft crashes come first to mind when mentioning safety in relation to airport operations. However, accidents, such as fires, may also occur (and have occurred) at fuelling operations and aircraft maintenance. Fires not related to fuelling can have severe consequences, especially those at the air, rail and bus passenger terminals. Also terrorist actions have been recognised as a serious risk associated with airports. Elsewhere in the airport operations system traffic accidents, accidents at industries, fires, etcetera can occur.

The present report focuses on aircraft crashes. The landing and takeoff stage are the most critical parts of a flight as far as crash risk is concerned. The probability of an accident further depends on the type of aircraft, its weight and its state of maintenance and the weather conditions. The management quality of the systems and organisations involved in aviation and in accident control, and the quality of the managed personnel are components determining the accident risk. This holds for flight personnel, air traffic control, airlines and rescue and other safety services alike.

In the past decades world-wide, on average, 50 crashes occurred per year, resulting in about 1500 fatalities per year, among which 35 individuals of the general population. These data show that the primary victims are the crew and passengers. The services of the large airlines are associated with considerably less fatalities per aircraft hour than, e.g., general aviation (non-commercial aviation). Aircraft crashes are rare events given the large number of flights. At present the crash frequency in the vicinity of a large airport is roughly one to two crashes per ten million movements (takeoffs and landings). This implies that a rough estimate of the average crash rate in the vicinity of larger airports is one to two per decade.

Using the evidence, severity and number affected classifications accidents do occur (sufficient evidence), the health consequences are always severe and the whole population in the airport operations system is at risk, be it that only a small number of people will be actually affected.

The individual risk levels for people living, working and travelling in the vicinity of a large airport are low (being hit by a crashing aircraft is a very extraordinary event) and will vary strongly geographically depending on the flight paths. Calculated individual risks (probability per year of dying due to an accident at a given location) exceeding 1 per 10 thousand per year are confined, within the airport territory, to places close to the runways. Locations with calculated individual risks between 1 per 100 thousand and 1 per million per ear that encompass residential zones, have been identified around large airports. In the Netherlands around industrial installations new houses would only be allowed in zones with individual risk levels not exceeding 1 per million per year.

Soil and water pollution

Leaking underground storage tanks and pipes, fuel spillage or leakage during ground handling of aircraft, washing of aircraft and vehicles and fire-training for which flame-retardant chemicals are used, are sources of water and soil pollution at airports. If policies to prevent such pollution are in force and effective, the public health impact is minor. A pollution pathway specific for airports is related to de-icing operations to prevent, for safety reasons, the formation of ice on aircraft parts and runways. Effects on humans due to exposure to all these compounds appear to be unlikely in practice.

Importation of infectious diseases by air traffic

World-wide air traffic increases the potential for transmission of infectious diseases from one country to another. An example is ‘airport malaria’, that occurs when mosquitoes infected with *Plasmodium falciparum*, originating at airports in regions where malaria transmission frequently occurs, contaminate people around airports elsewhere. The number of documented cases at present is small, but giving the growth of air transport the committee recommends airport authorities and airline companies to be vigilant.

Occupational health risk

In general the nature of the work in the vicinity of the airport is not expected to have characteristics specific to the airport operations system. This is different for work at the airport and for the operation of aircraft, although for aviation ground personnel only the incidence of musculo-skeletal disorders appears to be higher than what might be generally expected. Accident mortality among pilots is increased, but flight crew mortality from other causes is not exceptionally different from what would be expected. Fatigue and job stress would be expected among air traffic controllers and flight crew, but research data do not point to specific problems. Although activities within the airport operations system do affect occupational health, the situation is not out of line with the situation in comparable industries.

Comprehensive public health impact assessment

Environmental factors in an airport operations system operate in a cumulative way: people are exposed to, e.g., air pollution, noise and accident risk at the same time. People living in the vicinity of airports are not able to avoid exposure when performing everyday activities such as working, shopping, going to school, etcetera. Furthermore, the factors interact; for example anxiety related to aircraft crashes may enhance noise-induced annoyance and vice-versa. Other factors will modify the cumulative impacts. The visual appearance of the environment may act both in a positive and a negative sense, depending, e.g., on how well the traffic infrastructure has been embedded in the natural landscape. The availability of facilities, such as shops, public transport, parks, schools, will influence the way people rate their living environment and will also influence the public health impacts of factors that primarily or partly act via psycho-social mechanisms, such as noise and odour. Measures that increase the perceived control of people over their living environment may be beneficial in this respect.

Published results of comprehensive assessments of the public health impact of large airports, that would have allowed a definitive and complete answer to the Ministers' request, are lacking. In fact, the health impact assessment study in progress at Amsterdam Schiphol is an exceptional example of what, in the opinion of the committee, should be normal practice. On the basis of such studies measures to safeguard public health effectively and efficiently can be implemented. The committee strongly recommends that public health impact assessment, to guide the further international development of the civil aviation system, become the norm instead of the exception.

Way ahead

Airport and aviation development affect the lives of many people. Decisions to be taken are of a strategic nature and therefore require carefully and specifically designed procedures in which all stakeholders involved, including the people living in the vicinity of the airport in question, play a role. Although differing views on the significance of health and health effects, including impacts on quality of life, will make it difficult to reach consensus on the necessity and desirability of developments, a decision making structure in which those views can be discussed and are accounted for is preferable to autocratic decision making. The nature of the decisions to be made also require that mobility policies have to be discussed with the aim to let air transport be an integrated part of a sustainable mobility strategy.

Two approaches to reduce public health risk can be distinguished. On the one hand environmental quality standards can be set on a geographical basis ('zoning') and enforced by the government. In a different approach stakeholders 'negotiate' a comprehensive package of measures in which the negative effects of factors like noise, apart from being reduced by exposure limiting measures, are offset by improvements in the natural landscape, the quality of facilities in residential areas and an open communication between all parties concerned about developments at the airport and elsewhere in the system and about the measures taken to reduce noise exposure and air pollution. In practice a mix of both approaches will probably be used, depending on the prevailing political culture.

Aviation technology will have to innovate if the growth in air transport continues at its present rate. Already now large airports are congested and accident and near-accident frequencies might rise. Furthermore new technology is needed in order to lessen the public health impact of the expanding airport activities or in any case not aggravate it. The committee recommends that the technology development is accompanied by a technology assessment process that explicitly considers the short and long term environmental and health impacts of changes in technology.

Given the many parties involved in an airport operations system and given the interactions between different measures to reduce public health effects, the committee recommends that all developments are monitored and assessed on their public health consequences in an integrated manner. How such an integrated risk management structure reaches this goal is to be decided through the political process, but in order to be effective all parties involved should support such a structure and be willing to provide the necessary data in good time.

Samenvatting, conclusies en aanbevelingen

Burgerluchtvaart

De burgerluchtvaart is een groei-industrie en volgens de meeste economen blijft ze dat voorlopig. Ze ontwikkelt zich tot een bedrijfstak van wereldwijde afmetingen waarin, via een handvol samenwerkingsverbanden, luchtvaartmaatschappijen een mondiaal netwerk van knooppunt-luchthavens of 'hubs' bedienen. In 1997 vervoerden de reguliere luchtvaartmaatschappijen 1,5 miljard passagiers en 26 miljoen ton vracht.

De opbrengsten van de luchtvaart in economische zin en het binnen handbereik brengen van bestemmingen ver weg kunnen gezondheid en welzijn bevorderen, zij het vermoedelijk vooral voor de bevolking in het geïndustrialiseerde deel van de wereld. Maar de luchtvaart heeft, zowel op lokale als mondiale schaal, ook een negatieve invloed op het milieu en daardoor op de gezondheid.

Adviesaanvraag en advies

Het voorliggende advies geeft het antwoord van de Gezondheidsraad op een adviesaanvraag van de bewindslieden van Volksgezondheid, Welzijn en Sport, van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer en van Verkeer en Waterstaat naar de gezondheidseffecten van grote luchthavens. Het verzoek van de drie ministers hangt samen met het publieke en politieke debat over de Nederlandse luchtvaartinfrastructuur en het bijzonder met de uitbreiding van de Luchthaven Schiphol, hoewel niet werd gevraagd om een oordeel over de situatie bij en rond de Nederlandse nationale luchthaven. De Voorzitter van de Gezondheidsraad verzocht een internationale commissie van deskundigen het gevraagde advies op te stellen.

Tevens verstrekte de Raadsvoorzitter opdracht om de situatie bij drie andere vliegvelden in ogenschouw te nemen ten einde informatie te verzamelen over de wijze waarop gezondheidsaspecten een rol spelen bij de ontwikkeling van luchthavens. Deze ‘case studies’ omvatten het voorstel voor een nieuwe passagiersterminal op Heathrow, de internationale luchthaven van München die in 1992 op een nieuwe locatie in bedrijf is genomen, en het plan voor een vliegveld in Berlijn ter vervanging van de drie huidige vliegvelden in het begin van de volgende eeuw. Tevens beschikte de commissie over een ‘up to date’ overzicht van de Gezondheidskundige Evaluatie Schiphol.

De commissie concentreerde zich op gezondheidseffecten ten gevolge van lokale milieufactoren. Het door haar gehanteerde begrip ‘gezondheidseffect’ omvat ook aantasting of bevordering van de kwaliteit van leven. De invloed van de luchtvaart op het klimaat (en zo op gezondheid) en indirecte positieve en negative invloeden op de gezondheid via economie, mobiliteit en toerisme vallen buiten het voorliggende advies.

Groot-vliegveldsysteem

De commissie heeft gekozen voor een integrale benadering van het verband tussen een luchthavenbedrijf en de gezondheid. Zij heeft nagegaan hoe de gezondheid wordt beïnvloed in een zogeheten groot-vliegveldsysteem, dat het gebied bestrijkt binnen een straal van enkele tientallen kilometers rond een luchthaven. Naast de activiteiten die rechtstreeks met het luchthavenbedrijf samenhangen, omvat het systeem ook de bedrijvigheid in de nabijheid van de luchthaven, de infrastructuur die nodig is om de luchthaven in stand te houden, en woonwijken. Ook de omgeving van luchthavens die oorspronkelijk in afgelegen streken werden gesitueerd, blijkt namelijk in de loop van de jaren te verstedelijken door vestiging van vrachtvervoersbedrijven, bevoorradingsbedrijven en, hotels, ‘high-tech’-bedrijven en kantoren.

De invloed van de activiteiten in een groot-vliegveldsysteem op de gezondheid is maar ten dele systeem-specifiek. Specifieke factoren zijn vliegtuiggeluid, kerosine-stank en de kans op vliegtuigongevallen. Maar luchtverontreiniging, aantasting van het landschap door de vervoersinfrastructuur, hinder van wegverkeers- en industriegeluid, en arbeidsrisico’s komt men in elk stedelijk en geïndustrialiseerd gebied tegen.

Milieu en gezondheid

De commissie wijdt een afzonderlijke bespreking aan de invloed van de volgende milieufactoren op de gezondheid:

- luchtverontreiniging

- geluid
- ongevallen
- bodem- en waterverontreiniging op de luchthaven
- import van infectieziekten
- verandering in het landschap
- arbeidsrisico's op de luchthaven.

In concluderende hoofdstukken waagt zij een poging om haar bevindingen te combineren en doet zij voorstellen ter verbetering van de bescherming van de gezondheid.

De centrale vraag van het advies luidt: beïnvloeden de activiteiten in een grootvliegveldsysteem de gezondheid? De commissie beantwoordt deze vraag met: ja. De visie van de commissie op de relatie tussen gezondheid en milieu houdt in, dat ook een aantasting van de kwaliteit van leven, zoals door voortdurende blootstelling aan geluid of geur, mogelijk op den duur tot ziekte leidt, zij het afhankelijk van allerhande factoren, waaronder individuele gevoeligheid, sociaal-economische status en leefstijl, en de gelijktijdige blootstelling aan andere milieufactoren. Sommige factoren verergeren de gezondheidseffecten, terwijl andere in omgekeerde richting werken of de effecten ten dele teniet doen. Over het verband tussen milieu en gezondheid is nog veel onbekend, maar niet ter discussie staat dat factoren als omgevingsgeluid en luchtverontreiniging de gezondheid aantasten. Vragen over de mate van aantasting en over de kwetsbare groepen in de bevolking zijn echter moeilijk te beantwoorden.

Om de mate van invloed van milieufactoren op de gezondheid aan te duiden, gebruikt de commissie classificatieschema's voor:

- de bewijskracht voor een oorzakelijk verband tussen blootstelling aan een milieufactor en een gezondheidseffect
- de ernst van het effect (licht, matig, ernstig)
- het aantal getroffen mensen.

Voor de bewijskracht voor een oorzakelijk verband onderscheidt de commissie vier klassen: voldoende, beperkt, niet adequaat of overtuigende aanwijzingen voor het ontbreken van een verband. Een 'ernstig' effect belemmert in belangrijke mate het dagelijks functioneren en vereist in het algemeen professionele hulp. Een effect op de gezondheid wordt 'licht' genoemd als het dagelijks functioneren van mensen nauwelijks wordt beïnvloed, of als de invloed hetzij tijdelijk is, hetzij op de lange termijn gering te achten. Een matig effect ligt tussen deze twee uitersten in. Het aantal getroffen personen kan slechts zeer grof worden aangeduid. De commissie gebruikt drie klassen: gevoelige mensen, bepaalde subgroepen in de bevolking, een belangrijk deel van de blootgestelde bevolking. Deze aanduidingen worden alleen vermeld als er voor het oorzakelijk verband tussen blootstelling en effect voldoende bewijs is.

Luchtverontreiniging

De bijdragen van vliegtuigen, die van het wegkeer van en naar het vliegveld en die van verkeer met andere bestemmingen aan de gezondheidseffecten van luchtverontreiniging zijn nauw met elkaar verweven. Dat komt door de verspreiding van de verontreinigende stoffen in de atmosfeer, terwijl de luchtverontreiniging ook nog wordt bepaald door bronnen elders, mogelijk zelfs ver weg. Een belangrijke conclusie is dat de niveaus van luchtverontreiniging rond grote luchthavens overeenkomen met die in stedelijke gebieden en vooral hun oorzaak vinden in uitstoot door het wegverkeer. Bij dergelijke concentraties zijn effecten op de gezondheid te verwachten, ook indien de concentraties in het algemeen onder de officiële richtwaarden blijven.

Volgens de huidige inzichten verstoort luchtverontreiniging de ademhaling, zij het bij de meeste mensen niet blijvend. Bij voortdurende blootstelling kunnen de gevolgen meer invaliderend zijn. In de nu volgende tabel is aangegeven voor welke effecten er voldoende bewijskracht is voor een oorzakelijk verband met luchtverontreiniging.

gevolg	ernst [1]	getroffenen [2]
voortijdige sterfte (effect in gevoelige groepen na een episode)	***	*
verergering van luchtwegklachten en cardiovasculaire klachten na een episode (met ziekenhuisopname als gevolg)	***	*
longfunctievermindering na een episode	*	?
voortijdige sterfte (vermindering van levensverwachting) door chronische blootstelling	***	*
longfunctievermindering door chronische blootstelling	**	**
toename luchtwegaandoeningen (bronchitis) door chronische blootstelling	**	**
geurhinder door chronische blootstelling	*	***

1 * = licht, ** = matig, *** = ernstig

2 * = gevoelige personen, ** = speciale groepen, *** = aanzienlijk deel van de blootgestelden

In beperkte mate bewezen effecten die optreden na een episode van luchtverontreiniging, zijn luchtwegklachten en verergering van astma. De commissie beoordeelt deze effecten respectievelijk als licht en ernstig.

Epidemiologisch onderzoek van verschillend type heeft aanwijzingen opgeleverd voor een verband tussen langdurige blootstelling aan luchtverontreiniging en vermindering van levensverwachting, toegenomen sterfte aan longkanker, longfunctievermindering en een toename van luchtwegaandoeningen, in het bijzonder van bronchitis. De bewijskracht voor deze verbanden acht de commissie voldoende, zij het dat de relatie tussen blootstelling en respons opheldering behoeft. Ook is onduidelijk in welke mate er sprake is van verergering van bestaande aandoeningen. De huidige gegevens over een verband tussen chronische blootstelling aan luchtverontreiniging en het vóórkomen van allergieën en astma hebben volgens de commissie een beperkte bewijskracht. In de lucht rond luchthavens zijn tot op heden geen voor het luchthavenbedrijf specifieke carcinogene stoffen aangetoond.

Rond luchthavens zijn slechts enkele onderzoeken uitgevoerd naar het verband tussen luchtverontreiniging en gezondheid. Ziekte- en sterftecijfers voor aandoeningen die zouden kunnen samenhangen met luchtverontreiniging, verschillen niet van die voor stedelijke gebieden. Een onderzoek in de omgeving van Schiphol toonde aan dat het aantal luchtwegklachten afneemt met toenemende afstand tot de luchthaven. Of dat samenhangt met de heersende niveaus van luchtverontreiniging, en in welke mate andere factoren een rol spelen, is onderwerp van nader onderzoek.

Onderzoek naar de gevolgen van chronische blootstelling aan geur leverde niet alleen gegevens op over hinder, maar ook aanwijzingen voor het optreden van allerhande matig ernstige somatische en psychosomatische aandoeningen. De bewijskracht voor een oorzakelijk verband tussen geur en deze aandoeningen acht de commissie beperkt.

De commissie constateert dat om luchtverontreiniging aan banden te leggen de industrie en het wegverkeer aan wettelijke regels zijn onderworpen. Dat geldt niet voor het vliegverkeer. Een geïntegreerde aanpak van het tegengaan van luchtverontreiniging is niet mogelijk als een belangrijke bron, te weten de uitstoot van vliegtuigen, buiten de regels blijft.

Geluid

Vliegtuiggeluid is een van de meest opvallende milieufactoren van het luchthavenbedrijf en specifiek voor een groot-vliegveldsysteem. Hoewel het systeem ook andere geluidsbronnen kent, domineert het geluid van stijgende en landende vliegtuigen, van remmende en taxiënde toestellen op de luchthaven en van het testen van vliegtuigmotoren. Op de luchthaven zelf kan ook het geluid van het grondverkeer aanzienlijk zijn en in het bijzonder voor het luchthavenpersoneel gevolgen hebben. In de omgeving van de luchthaven zal op sommige locaties wegverkeer de overheersende bron van omgevingsgeluid zijn. De ruimtelijke verdeling van de geluidniveaus veroorzaakt door vliegtuigen hangt af van de vluchtroutes en de ligging van de start- en landingsbanen. In woonwijken nabij grote luchthavens kan het geluidniveau een waarde van 60 dB(A) en in een enkel geval van 70 dB(A) (dag-nacht- of dag-avond-nachtniveau) te boven gaan.

Gehoorbeschading is een uitgebreid beschreven gevolg van blootstelling aan geluid. Binnen een groot-vliegveldsysteem is dit verschijnsel een bron van zorg voor het luchthavenpersoneel, vooral voor de mensen die belast zijn met de vliegtuigafhandeling en die motoren testen. Slechts in uitzonderlijke gevallen zal niet-beroepsmatige blootstelling aan omgevingsgeluid tot gehoorbeschadiging leiden. De overige effecten waarvoor de commissie de bewijskracht voor een oorzakelijk verband met geluidblootstelling voldoende acht, zijn in onderstaande tabel genoemd. Effecten in blootgestelde bevolkingsgroepen worden pas bij geluidniveaus groter dan de zogeheten waarnemingsdrempel waargenomen. In de tabel staat 'slaapverstoring' voor een veelheid van verschijnselen, waaronder ontwaken, veranderingen van slaapstadium en slaappatroon, veranderingen in hartslag en invloed op de stemming de volgende dag. Voor een beïnvloeding van de prestaties de volgende dag en veranderingen in hormoonspiegels ten gevolge van nachtelijk geluid is de bewijskracht beperkt.

gevolg	ernst [1]	betrokkenen [2]	waarnemingsdrempel
hypertensie	**	**	eq. geluidniveau buiten (06-22 uur) van 70 dB(A)
ischemische hartziekte	***	*	eq. geluidniveau buiten (06-22 uur) van 70 dB(A)
hinder	*	***	dag-nachtniveau buiten van 42 dB(A) [3]
slaapverstoring	**	***	afhankelijk van het effect een SEL-waarde binnen van 35-50 dB(A) [4]
leerprestaties	**	**	eq. geluidniveau buiten (schooluren) van 70 dB(A)

1 * = licht, ** = matig, *** = ernstig

2 * = gevoelige personen, ** = speciale groepen, *** = aanzienlijk deel van de blootgestelden

3 waarnemingsdrempel voor 'ernstige hinder'; het dag-nachtniveau is het equivalente geluidniveau gedurende een etmaal, waarbij bij de niveaus gedurende de nacht (periode van 23-07 uur) 10 dB(A) is opgeteld.

4 SEL is het equivalente geluidniveau gedurende een geluidgebeurtenis, genormaliseerd op een periode van 1 seconde

Verschillende andere effecten zijn in verband gebracht met blootstelling aan geluid: verminderde prestaties, biochemische effecten, achteruitgang van het immuunsysteem, een lager geboortegewicht, psychische klachten en aantasting van welzijn. Het bewijs voor die verbanden is echter beperkt. Alle zojuist genoemde effecten beoordeelt de commissie als licht, met uitzondering van psychische klachten (ernstig) en invloed op geboortegewicht en welzijn (matig). Er zijn geen aanwijzingen dat blootstelling van zwangeren kan leiden tot aangeboren afwijkingen.

Met uitzondering van gehoorbeschadiging, hangen de gezondheidseffecten van geluid af van de beoordeling van het geluid door de blootgestelde en van de vegetatieve reacties die het geluid oproept. Sommige effecten, zoals hoge bloeddruk en hart- en vaatziekten, kunnen een direct gevolg zijn van de wijze waarop het organisme de blootstelling verwerkt, andere zijn mogelijk een gevolg van het optreden van aan de blootstelling gerelateerde hinder. Hinder is een gevoel van afkeer, boosheid, onbehagen, onvoldaanheid of gekwetstheid, dat optreedt wanneer een milieufactor iemands gedachten, gevoelens of activiteiten negatief beïnvloedt.

Blootstelling aan geluid is slechts een van de factoren die de hinder bepaalt. Uit onderzoek blijkt dat vliegtuiggeluid als hinderlijker wordt ervaren dan geluid van weg- en treinverkeer bij de zelfde dag-nachtniveaus. Ook de mate van verontrusting over vliegtuigongevallen is van invloed. Andere zogeheten niet-akoestische factoren die een rol spelen, zijn de mate van openheid van het luchthavenbedrijf of van de overheid en de wijze waarop de overheid de milieunormen handhaaft. Deze factoren kunnen zowel de hinder verminderen (meer openheid, strenge handhaving) als doen toenemen.

Nieuw onderzoek heeft eerdere bevindingen van een negatieve invloed van vliegtuiggeluid op leerprestaties van kinderen bevestigd. De commissie beveelt nader onderzoek aan om het verband tussen blootstelling en effect op te helderen en na te gaan wat de gevolgen zijn op lange termijn.

Veiligheid

Bij het onderwerp veiligheid in relatie tot luchthavens denkt men meestal in de eerste plaats aan neerstortende vliegtuigen. Maar ook andersoortige ongevallen kunnen plaatsvinden (en hebben plaatsgevonden), zoals ongevallen bij het innemen van brandstof en bij vliegtuigonderhoud, ernstige branden in aankomst- en vertrekhallen of in terminals voor vliegtuig-, trein- en buspassagiers. Ook terroristische acties bij luchthavens vormen een veiligheidsrisico. Ongevallen kunnen ook elders in een groot-vliegveldsysteem optreden: verkeersongevallen, ernstige bedrijfsstoringen en brand, etc.

De commissie gaat alleen nader in op vliegtuigongevallen. De kans op een ongeval is het grootst tijdens de start- en landingsfase. Ze hangt verder af van het soort vliegtuig, het gewicht, de staat van onderhoud en van het weer. Het beheersen van de kwaliteit van bedrijfssystemen en -organisaties die zijn betrokken bij de luchtvaart en de luchtvaartveiligheid, is bepalend voor het ongevalsrisico. Dat geldt in gelijke mate voor vliegtuigbemanning, luchtverkeersleiding, vliegmaatschappijen en de diverse veiligheids- en hulpdiensten.

In de afgelopen decennia verongelukten wereldwijd elk jaar gemiddeld ongeveer 50 vliegtuigen, hetgeen leidde tot ongeveer 1500 dodelijke slachtoffers per jaar, waaronder 35 personen uit de bevolking ter plaatse van het ongeval. Deze getallen geven duidelijk aan dat de slachtoffers in de eerste plaats vallen onder de bemanning en de passagiers. Becijferd per vlieguur, is vliegen met grote luchtvaartmaatschappijen veiliger dan de algemene (niet commerciële) luchtvaart.

Vliegtuigongevallen zijn zeldzame gebeurtenissen, bezien tegen de achtergrond van het grote aantal vluchten. Thans bedraagt de kans op een *crash* in de nabijheid van een grote luchthaven ongeveer één tot twee per miljoen vliegbewegingen (starts en landingen). Naar berekening zullen in de nabijheid van een grote luchthaven gemiddeld grofweg 1 à 2 vliegtuigen per tien jaar verongelukken.

Toepassing van het classificatiesysteem van de commissie leidt tot de uitspraak dat vliegtuigongevallen vóórkomen (voldoende bewijskracht), dat de gevolgen ernstig zijn en dat de hele bevolking in een groot-vliegveldsysteem een zeker risico loopt, zij het dat het aantal daadwerkelijke slachtoffers zeer klein is.

Het zogeheten individueel risiconiveau voor mensen die rond een vliegveld wonen, werken of reizen is gering (de kans om door een vliegtuigongeval te worden getroffen is extreem klein) en hangt in samenhang met de aan- en afvliegroutes sterk af van de locatie. Het gebied waar de berekende kans om bij voortdurend verblijf op een bepaalde locatie door een vliegtuigongeval te overlijden meer is dan 1 op de 10 000 per jaar blijft beperkt tot het luchthaventerrein, in de directe omgeving van de start- en landingsbanen. Woonlocaties waar het individuele risico ligt tussen 1 op de 100 000 en 1 op de miljoen per jaar blijken voor te komen rond luchthavens. In Nederland mogen rond industriële installaties nieuwe huizen alleen worden gebouwd indien het berekende individuele risico een waarde van 1 op de miljoen per jaar niet te boven gaat.

Bodem- en waterverontreiniging

Lekkende ondergrondse opslagtanks en pijpleidingen, morsen van brandstof of lekkage tijdens het bijtanken van vliegtuigen, het wassen van toestellen en andere voertuigen, en brandweertraining waarbij brandvertragers worden toegepast zijn voorbeelden van bronnen van water- en bodemverontreining. Als preventieve maatregelen zijn genomen, zijn de gevolgen voor de gezondheid gering. Een luchthaven-specifieke bron van verontreiniging is het bestrijden van ijsvorming op vliegtuigdelen en start- en landingsbanen. In de praktijk blijkt de kans op gezondheidseffecten door blootstelling aan de hierbij gebruikte stoffen gering.

Import van infectieziekten door luchtverkeer

Het wereldwijde luchtvervoer vergroot de mogelijkheid dat infectieziekten van het ene land naar het andere worden overgebracht. Een voorbeeld is ‘vliegveldmalaria’, besmetting van mensen door met *Plasmodium falciparum* geïnfecteerde muggen die meegevoerd zijn vanaf vliegvelden elders. Het aantal tot op heden geregistreerde gevallen is gering, maar de commissie raadt, gegeven de wereldwijde toename van het vliegverkeer, luchthavenbedrijven en vliegmaatschappijen aan alert te zijn op dit fenomeen.

Arbeidsomstandigheden

Werkzaamheden in de omgeving van een luchthaven verschillen niet wezenlijk van werk elders. Voor het luchtvaartbedrijf kan dat anders liggen. Zo blijken onder grondpersoneel meer klachten over het bewegingsapparaat voor te komen dan in het algemeen onder de beroepsbevolking. Onder piloten is de sterfte ten gevolge van vliegtuigongevallen verhoogd, maar dat is niet het geval voor andere doodsoorzaken. Men zou verwachten dat luchtverkeersleiders en vliegtuigbemanningen meer klagen over vermoeidheid en werkdruk, maar dat wordt niet gestaafd door onderzoeksgegevens. Hoewel de bedrijvigheid in een groot-vliegveldsysteem de gezondheid van de werknemers beïnvloedt, verschilt het beroepsrisico hier niet wezenlijk van dat in andere bedrijfstakken.

Geïntegreerde beoordeling van effecten op de gezondheid

Mensen in een groot-vliegveldsysteem staan bloot aan diverse milieufactoren tegelijk: bijvoorbeeld aan luchtverontreiniging en aan geluid en aan ongevalsrisico. Zij kunnen die blootstelling in het dagelijks leven — werken, boodschappen doen, naar school gaan — niet ontlopen. Daar komt ook nog een wisselwerking tussen de milieufactoren bij: zo kan bezorgdheid over vliegtuigongevallen de geluidhinder versterken en omgekeerd. Andere factoren zullen ook hun invloed uitoefenen op de uiteindelijke gevolgen. Het aanzicht van de omgeving kan zowel in positieve als negatieve zin werken, afhankelijk van, bijvoorbeeld, de wijze waarop de verkeersinfrastructuur in het landschap is ingepast. Ook de beschikbaarheid van voorzieningen, zoals winkels, openbaar vervoer, parken en scholen, is van invloed op het oordeel van mensen over hun leefomgeving en zal de gezondheidseffecten van factoren als geluid en geur, die vooral via psycho-sociale mechanismen werkzaam zijn, mede bepalen. Maatregelen die bij mensen het gevoel versterkt baas te zijn over de eigen leefomgeving, kunnen in dit verband een gunstige uitwerking hebben.

Er zijn geen publicaties met resultaten van geïntegreerde beoordelingen van de invloed van grote luchthavens op de gezondheid. Daardoor is het de commissie niet mogelijk om een direct antwoord op de vraag van de bewindslieden te geven. De lopende Gezondheidskundige Evaluatie Schiphol is in feite een uitzondering op wat volgens de commissie regel zou moeten zijn. Op grond van dergelijk onderzoek kunnen immers effectieve en doelmatige maatregelen ter bescherming van de gezondheid worden genomen. De commissie bepleit het als regel uitvoeren van gezondheidseffectbeoordelingen om mede richting te geven aan de verdere ontwikkeling van de burgerluchtvaart.

Toekomst

De ontwikkeling van luchthavens en de luchtvaart beïnvloedt het leven van velen. De beslissingen die als onderdeel van die ontwikkelingen moeten worden genomen, hebben een strategisch karakter en vereisen daarom zorgvuldig overleg en toegesneden besluitvormingsprocedures, waarbij alle partijen, met inbegrip van de mensen die rondom een luchthaven wonen, zijn betrokken. Het zal vaak lastig zijn om de uiteenlopende visies op gezondheid en gezondheidseffecten te verenigen en mede zo consensus te bereiken over de noodzaak en wenselijkheid van de voorgestelde ontwikkeling. Toch prefereert de commissie een structuur waarin de uiteenlopende visies kunnen worden besproken, boven een autocratische wijze van besluitvorming. Het is onvermijdelijk dat bij de uiteindelijke besluitvorming ook het mobiliteitsbeleid wordt betrokken, met als doel het luchtvervoer in te passen in een strategie voor duurzaam vervoer.

Bij het beheersen van gezondheidsrisico's zijn twee benaderingen te onderscheiden. Eén strategie omvat het vaststellen van plaatsgebonden milieukwaliteitsnormen (zonering), die door de overheid worden gehandhaafd. De andere benadering houdt in dat alle betrokkenen 'onderhandelen' over een samenhangend pakket van maatregelen waarbij de negatieve invloed van een factor als geluid, niet alleen wordt beperkt door geluidreducerende maatregelen, maar ook wordt gecompenseerd door verbeteringen in de landschappelijke kwaliteit, door de kwaliteit van voorzieningen in woonwijken, door een open communicatie tussen de betrokken partijen over de ontwikkeling en andere bedrijvigheden in het groot-vliegveldsysteem en de gevolgen van die ontwikkeling en over maatregelen om de blootstelling aan geluid en luchtverontreiniging te verminderen. In de praktijk zullen beide strategieën vermoedelijk een plaats krijgen, waarbij de 'mix' afhankelijk is van de heersende politieke cultuur.

Op het gebied van de luchtvaarttechnologie zijn vernieuwingen noodzakelijk teneinde de groei van het luchtvervoer te kunnen accommoderen. Op dit ogenblik raakt het luchtruim rond verscheidene grote luchthavens reeds 'vol', hetgeen de kans op ongevallen en bijna-ongevallen vergroot. Ook is vernieuwing nodig om de gezondheidseffecten van de zich uitbreidende luchthavenactiviteiten te verminderen of in elk geval niet te laten groeien. De commissie beveelt aan de technologische ontwikkeling vergezeld te laten gaan van technologisch-aspectenonderzoek waarin expliciet de milieu- en gezondheidseffecten op korte en lange termijn aan bod komen.

Gegeven de vele partijen die bij het in stand houden van een groot-vliegveldsysteem zijn betrokken en gegeven de wisselwerking tussen de diverse maatregelen ter inperking van ongewenste gezondheidseffecten, beveelt de commissie aan dat de consequenties van alle ontwikkelingen op een geïntegreerde manier worden gevolgd en beoordeeld.

Over de structuur van zo'n geïntegreerd risicobeheersingssysteem moet de politiek beslissen. Wil het effectief zijn, dan is een draagvlak bij de betrokken partijen noodzakelijk, evenals de bereidheid om op tijd de benodigde gegevens aan te leveren.

Chapter 1

Introduction

1.1 The two sides of the aviation coin

In 1903 the Wright brothers made the world's first successful flight in a heavier-than-air craft under power and control and as early as May 1927 Charles Lindberg was the first to make a non-stop solo flight across the Atlantic; international air travel was born. After that aviation expanded at a fast rate and at the brink of the 21st century many thousands follow the paths marked by the Wright brothers and Lindbergh. Civil aviation is a business that moves many millions of people annually across the globe. Business air travel and air freight are cornerstones of the global economy and air transport is a key factor in international tourism. Air travel is valued by many as it generates income for a considerable number of people and produces social benefits, such as providing people with useful goods otherwise unavailable to them, bringing new experiences and reinforcing old ties.

The aviation coin also has a flip side. Aviation has direct environmental impacts; the possible health effects of these impacts are the subject of the present report. Taking a more long term and global perspective flying is the only activity that emits gases in the form of jet fuel combustion products directly in the upper layers of the atmosphere, the long term effects of which are not known but are presumed to contribute to global climate change. [122] The aviation enabled mass tourism is primarily an activity of affluent populations in industrialised societies and may threaten the continuity of cultures. The aviation system uses resources not on the basis of sustainability criteria but taking account of relatively short term cost-benefit ratios. The costs of public health and environmental impacts at present and in the future are not fully taken into account in transport tariffs.[14),62),63),122)] These long term and global aspects are not discussed in this report. However, the committee stresses that questions about the impacts of global mobility are of paramount importance and that the answers determine the possibilities for measures to safeguard public health and the environment in the long run.

The nodes of the global air transport network are the major airports with an ever increasing concentration of aircraft taking off and landing and an associated increase in people moving to and from the airport. At these major airports up to 100 million passengers per year arrive and depart in aircraft takeoffs and landings approaching one million annually (Chapter 2). With an expected growth of about five per cent per year these figures will be greatly superseded in the next decades.

The local and regional environment of the airport has to cope with the impacts of all this activity. People and ecosystems are exposed to air and road traffic exhausts, noxious odours, aircraft and road traffic noise and urbanisation. Serious accidents, such as aircraft crashes and airport fires do happen, albeit infrequently, and the perceived accident risk does not leave people unaffected. So, notwithstanding the economic and social benefits of the airport activities, the health and quality of life of people living and working at or in the vicinity of a major airport is also negatively affected.

1.2 Request for advice

The physical planning of large infrastructure projects with sizeable environmental impacts, increasingly provokes public and political controversy. Concern about unfavourable impacts on health and quality of life associated with the new environmental conditions often dominate the social and political debate. The establishment of a new airport or the expansion of an existing one provide examples.

To facilitate the decision process on the future of the Dutch aviation infrastructure, and specifically the development of the Amsterdam Schiphol airport, the Netherlands Cabinet Ministers responsible for health, for the environment and for transportation requested the Health Council of the Netherlands to evaluate the state of knowledge with respect to the health impacts associated with large airports. The President of the Health Council received the following request, dated 14 February 1998, from the Minister of Health, Welfare and Sport:

> As you will be aware, the future of aviation in the Netherlands and the scale upon which developments in this area should take place continues to be the subject of intense debate at all levels of Dutch society and of course within the government itself. On my own behalf and that of the Minister of Housing, Spatial Planning and the Environment and the Minister of Transport, Public Works and Water Management, I

would therefore be most grateful if you would provide a short report detailing the current state of knowledge regarding the health effects of major airports.

I am fully aware that the time available for producing such a report is extremely limited and I therefore suggest that you consider alternative channels by which this knowledge might be obtained. Organising a seminar with an international panel of experts, that try to reach the greatest possible consensus on the subject, could serve as an effective instrument for knowledge collection.

Subsequently the minister and the Health Council President agreed to aim for a report in spring 1999.

1.3 Committee and method of work

Committee

The debate on the future of the Dutch aviation infrastructure focuses on the expansion of Amsterdam Schiphol, but the Minister's letter asks for information on health effects of large airports in general. This led the Health Council President to follow the Minister's suggestion to prepare the requested advisory report with an international group of experts that met in a three-day workshop in March 1999, in Rolduc Abbey, Kerkrade, the Netherlands. The members of the committee that is responsible for the present report, and the other workshop participants are listed in Annex A.

The Health Council staff started work on this project at the end of summer 1998. Its first tasks were compiling the relevant scientific literature and initiating a selection process for committee members.

Literature

The staff collected recent review papers and reports on the public health effects of environmental factors associated with airport operations. Also a literature search was performed in a variety of databases, that are listed in Annex B together with the keywords used in the search. References were selected by staff based on their relevance to the project. It is noticeable that relatively few useful publications are categorised under 'health & airports'. Also literature was provided by members of the preparatory committee (see below) and by committee members. Additional literature was retrieved on specific subjects using recent review papers.

The staff used the literature retrieved to prepare the working papers for the Rolduc workshop and for the subsequent drafting of the committee's report.

Involvement of committee members and other experts

The Health Council Presidency asked scientists from Dutch universities and research institutes and a few others to take part in a preparatory committee. This committee provided guidance for the work of the staff in preparing the Rolduc workshop and identified committee members from outside the Netherlands. The committee that is responsible for the present report, consists of the members of the preparatory committee and international experts. The international committee members were interviewed by the staff and their comments were used in drafting the working papers for the Rolduc workshop. Furthermore, other scientists were invited to take part in the workshop to provide additional views and insights. After the workshop the committee finalised the report by commenting on draft texts posted to them.

Case studies

The staff performed three case studies in order to gain some perspective on how health concerns play a role in the development of large airports. The cases chosen were:

- London Heathrow - development of a new passenger terminal (Terminal 5)
- Munich International Airport Franz Jozef Strauss - a new airport that opened in 1992
- Berlin Brandenburg International - a planned reconstruction of Berlin Schönefeld to become the main Berlin airport in the beginning of the next century.

The report of the case studies is included in Annex C.

Public involvement

On 23 October 1998 the Health Council put an announcement in the Dutch Official Gazette (Staatscourant), outlining the design of the project and calling upon interested parties to provide data and views that might be helpful in preparing a scientific assessment of the public health impact of large airports. Several organisations, such as Amsterdam Airport Schiphol, KLM Royal Dutch Airlines, environmental organisations, citizen groups, municipalities in the vicinity of Amsterdam Schiphol and municipal health services were approached directly with the same request. The reactions received were reviewed by the Dutch members of the committee and taken into account in preparing the present report. In July 1999 all the individuals and organisations that had responded were approached again with a draft version of the first three chapters of the report and an outline of the contents of the other chapters. All parties were given the opportunity to present additional information to the committee. The comments received were used to clarify the views put forward in the first three chapters and were considered in the final editing of the full report.

1.4 Report

The present report approaches the subject of health impacts of large airports in an integral manner, in so far as this is possible given the present state of knowledge and the available data. Chapters 2 and 3 provide the framework for discussing public health impacts of large airports. The effect of single environmental factors is considered in Chapters 4 to 7. Chapter 7 also discusses occupational health at the airport and risk perception. Chapter 8 endeavours to integrate the findings whereas the final chapter (9) presents recommendations for controlling environmental and public health risk associated with major airports as part of a growing aviation industry.

Chapter 2

Airport operations system

2.1 Civil aviation system

Airports and airport operations are part of the civil aviation system*. That system provides for the transport of people and cargo to different places of the world; transport legs are usually 300 kilometres or more, but shorter distances may be accommodated depending on the geography and the availability of other modes of transport.

In the last decade civil aviation has grown continuously by nearly 5 percent annually in terms of both the number of passengers and flight-kilometres. Figures of the International Civil Aviation Organisation (ICAO) show that the world's scheduled airlines, as a whole, made an operating profit of about 6 percent of operating revenues, or US$ 17 billion in 1997. In Table *1* transportation figures for the global civil aviation system are presented.

* Military aviation and military airports are not considered here.

Table *1* Transportation figures of the global civil aviation system for 1988 and 1997 (source: ICAO, Press Release PIO 04/98).

all scheduled services	1988	1997	% incr.[a]
passengers (billion)	1,1	1,5	3,3
freight tonnes (million)	17	26	4,8
passenger-km flown (1000 billion)	1,7	2,6	4,7
seat-kms available (1000 billion)	2,5	3,7	4,4
load factor (percentage seats occupied)	68	69	0,2
freight tonne-km (billion)	53	100	7,2
mail tonne-km (billion)	4,8	6	2,4
total tonne-km (passengers, freight & mail) (billion)	212	341	3,9

a average percentage increase per year

The growth of the aviation system is expected to continue in the next century given the increasing globalisation of the economy and the increasing tendency in western affluent societies to travel far away from home. Parallel with this development and given deregulation tendencies, a restructuring process in the aviation industry is taking place. The production of large civil aircraft is in the hands of two companies, the airlines are joining forces and a handful of global alliances is emerging, whereas the airline route structure has been developing — with exceptions — in the direction of a global network connecting major airports ('hubs'). A characteristic of the hub-airports is the large fraction of transfer passengers, arriving from or departing to secondary airports via the 'spokes' of the aviation network. This development has been stimulated by government policies. The Netherlands Government, for example, has attributed a so-called 'mainport' function to Amsterdam Schiphol. This implies that Amsterdam Schiphol, in the view of the government, should fulfil the role of a node in the global aviation network with the implied large number of passengers arriving at and departing from the airport and the large fraction of transfer-passengers and -freight. The stimulus behind such a policy are the economic benefits that a 'mainport'-type of airport is expected to generate.

2.2 Large airports

In this report 'large airports' are considered to be the nodes ('hubs') of the global aviation network. Such airports have several hundred thousand aircraft movements (landings and takeoffs) and at least a few tens of millions of passengers (arriving, departing or transferring) per year. Most of the larger airports of the world are located in the United States as can be seen from Table *2* and Table *3*. The ranking according to the number of movements differs from that according to the number of passengers; in the US the fraction of smaller aircraft (general aviation, air taxis) is larger than in Europe.

An airport and its operations form a complicated system. Figure 1 lists the various stakeholders and participators involved in the airport operations system. In the lower right-hand corner the affected population groups are depicted.

Table *2* Airports ranked according to the number of total aircraft movements in 1998 (landings and takeoffs); 20 largest airports and 4 largest European airports in bold. [6)]

	airport	movements		airport	movements
1	Chicago, IL, USA	897 354	11	Long Beach, CA, USA	471 583
2	Atlanta, GA, USA	846 881	12	Las Vegas, NV, USA	470 707
3	Dallas/Ft Worth, TX, USA	836 079	13	Philadelphia, PA, USA	469 655
4	Los Angeles, CA, USA	773 569	14	Denver, CO, USA	464 429
5	Detroit, MI, USA	542 440	15	Newark, NJ, USA (estimated)	451 600
6	Phoenix, AZ, USA	537 822	**16**	**London Heathrow, GB**	**451 371**
7	Miami, FL, USA	536 262	17	Pittsburgh, PA, USA	451 060
8	Boston, MA, USA	507 449	18	Houston, TX, USA	447 701
9	Oakland, CA, USA	506 628	19	Cincinnati, OH, USA	445 130
10	Minneap./St Paul, MN, USA	482 776	20	Charlotte, NC, USA	441 635
			22	**Paris Charles de Gaulle, F**	**427 691**
			25	**Frankfurt, D**	**416 227**
			27	**Amsterdam Schiphol, NL**	**392 715**

Table *3* Airports ranked according to the number of total passengers in 1998 (arriving + departing passengers + direct transit passengers counted once); 20 largest airports; European airports in bold. [7)]

	airport	passengers		airport	passengers
1	Atlanta, GA, USA	73 474 298	11	**Amsterdam Schiphol, NL**	**34 420 143**
2	Chicago, IL, USA	72 369 951	12	Miami, FL, USA	33 935 491
3	Los Angeles, CA, USA	61 216 072	13	Newark, NJ, USA (estimated)	32 445 000
4	**London Heathrow, GB**	**60 659 500**	14	Phoenix, AZ, USA	31 771 762
5	Dallas/Ft Worth, TX, USA	60 482 700	15	Detroit, MI, USA	31 544 426
6	Tokyo, Jp	51 240 704	**16**	N.York JFK, NY, USA (est.)	31 295 000
7	**Frankfurt, D**	**42 734 178**	17	Houston, TX, USA	31 025 726
8	San Francisco, CA, USA	40 059 975	18	Las Vegas, NV, USA	30 217 665
9	**Paris Charles de Gaulle, F**	**38 628 916**	19	Seoul, Korea	29 429 044
10	Denver, CO, USA	36 817 520	20	**London Gatwick, GB**	**29 173 257**

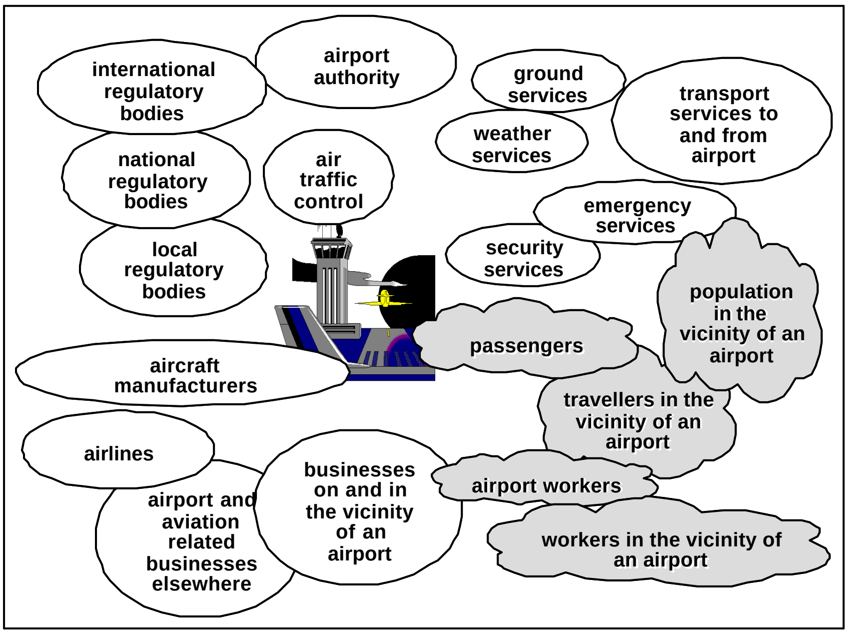


Figure 1 Participators and stakeholders in the airport operations system.

The stakeholders and participators can be categorised as:

- regulatory bodies and government inspectorates
- airport authority and airport services
- air traffic control
- airlines

- aircraft manufacturers
- local transport operators
- operators of activities in the vicinity of the airport*
- operators of airport and aviation related industries elsewhere
- airport, airlines and other personnel and their representatives
- airline passengers
- other affected population groups.

Bodies regulating the aviation system are, *inter alia*, the International Civil Aviation Organisation (ICAO), the European Joint Aviation Authority (JAA), the Federal Aviation Administration (FAA) in the USA and the Directorate General of Civil Aviation (RLD) in the Netherlands. National and local governments often provide the infrastructure (e.g. airport access), license airport operations, levy taxes on operations, and maintain national border security and import and export control. The airport authority is responsible for operating the airport within the international and national regulations. It governs to a large extent the activities of various operators, like ground services (including maintenance and aircraft fuelling), airport-related businesses such as cargo-handlers, weather services, security services and emergency services. Part of the emergency services will be the responsibility of the local government (e.g. the provision of enough hospital beds). The airlines and aircraft manufacturers play a key role in the environmental and public health impacts of airport operations. A separate role in this respect is fulfilled by the air traffic control services.

All of these parties do not act independently from each other. On the contrary, the reliability of the airport operations system (as further defined below) and its environmental and public health impacts depend on the quality of the interaction between the various participators and stakeholders. This interaction also includes the population living and working in the vicinity of the airport. As several of the parties involved are supranational organisations, measures to control the public health impacts of large airport have an international dimension.

2.3 Normal operations and accidents

Public health impacts of airport and airport-related operations and of other activities in the vicinity of a large airport can be analysed in terms of risks associated with normal operations and those associated with accidents (Figure 2).

* Some of the businesses in the vicinity of the airport are directly concerned with air transport — e.g. catering or cargo handling — whereas others are situated near the airport because of the convenient location for transport of products or business travel.

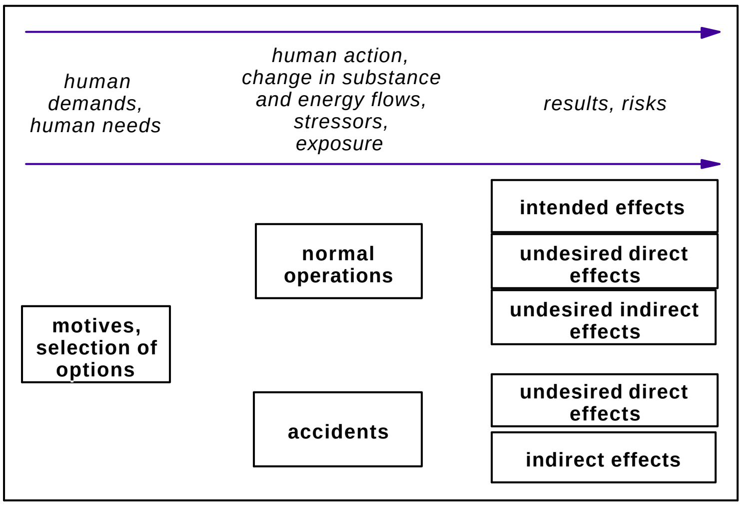


Figure 2 Cause-effect sequence for the generation of risk. [95)]

Ideally, selecting the appropriate options for carrying out an activity, the intended effects are obtained and no harm or loss results. Such an ideal situation would be represented by an airport where all takeoffs and landings occur according to schedule, passenger safety is 100 percent assured and the people living near the airport only reap the economic fruits from the operations without any negative impact on the quality of their lives. However, this ideal situation does not correspond to real life. Planes depart or arrive late, workers may be injured in loading baggage and the quality of life of the population in the airport vicinity is affected, *inter alia*, by exhaust emissions and aircraft noise. The time pattern of these occurrences may vary but some harm, although in principle preventable, is inevitably incurred and tolerated, albeit not necessarily tolerated by all parties affected.

The normal course of events may also be seriously disturbed; accidents may occur. The accident risk is usually characterised by a low probability and a relatively high impact. Cases in point are aircraft crashes and fires in airport terminals. Although the boundary between intended and disturbed human activities is not sharp, in practice and in the context of the present report, the distinction is useful. Accidents are not unavoidable 'acts of God'. In principle they are preventable, but in practice the probability of an accident occurring will never be zero. Given sufficient resources and efforts both the probability and the effect can be reduced considerably.

Table 4 lists the different effects of airport operations classified according to effects of normal operations and of accidents. Not all effects will be discussed in the present report. The focus is on 'local' public health effects. Table 5 presents some examples of accidens at or in the vicinity of large airports. Terrorist actions have also been listed in the table; even though from the point of view of the terrorists the harmful effects are no accident. From the point a view of, e.g., the airport authorities, they have the characteristics of accidents; occurrence of severe direct and indirect effects, and time, frequency and nature not being well known.

2.4 Airport operations system and environmental factors

This report deals with *public health** impacts at and in the vicinity of airports. The term 'the vicinity of an airport' pertains to the region in which the airport and its operations have an impact, *i.e.* are perceived more or less regularly in daily life. Roughly speaking, we are talking about an area within a few tens of kilometres distance of the airport: *the airport operations system.*

Table 4 Effects of airport and airport-related operations, classified according to Figure 2.

normal operation, intended effects	safe air transport (satisfying transportation needs) economic growth financial gain for airport stockholders employment stimulating improvements in, e.g., airport operations and passenger services (indirect effect)
normal operation, undesired direct effects	occupational injuries and disease damage to aircraft and airport facilities environmental impacts impacts on health and quality of life of population groups
normal operation, undesired indirect effects	depletion of environmental resources local environmental degradation global environmental effects
disturbed operation (serious accidents), undesired direct effects	injury and death among affected population groups long term and late health effects (including psychological effects) material damage
disturbed operation (serious accidents), indirect effects	negative impact on economic viability of airport operations stimulating improvements in, e.g., aircraft and airport construction and operation

* See Section 3.1

Table 5 Examples of accidents (and near-accidents) occurring in the airport operations system.

aircraft crashes during takeoff, climb, descent and landing
aircraft accidents during taxiing and 'at the gate' during refuelling and reprovisioning
accidents during aircraft maintenance
ground traffic accidents at the airport
fire (or other type of serious accidents) in passenger areas
accidents in the vicinity of the airport
terrorist actions

An airport operations system has economic, ecological and human welfare aspects. Economic forces determine the viability of the airport operations and the resources available to reduce human health risks (cf. Annex F). Profitable airport operations enable satisfying transportation needs and generate work and contribute to prosperity of the population in the airport vicinity and the population at large. The operations of an airport also affect the environment, *i.e.* the ecological part of the airport operations system, generally in a negative sense; the airport operations entail noise and chemical emissions, the natural environment is replaced by an industrial environment and waste is being generated. All these impacts directly or indirectly influence human health and the quality of life. On the other hand, affected populations will respond by exerting pressure to reduce the negative impacts whilst maximising the benefits. One might view these dynamics of the system as a learning process, that might improve the functioning of the system as a whole. Likewise, possible accidents, like aircraft crashes, fires, explosions, etc. at or near airports impact on the airport operations systems in a negative manner, but will also stimulate social and technological learning processes.

The complexity of the airport operations system, also given the differing goals of the participators in the system, is such that public health will not automatically be safeguarded. Political factors and short term gains may be counterproductive to optimising public health in the long term. Economic, institutional and regulatory factors are driving forces in the system, also with respect to public health. Apart from directly influencing public health and the health care system, these forces shape the physical environment, and determine the level of safety and security.

As outlined above, the committee includes in its considerations the activities in the vicinity of the airport, like traffic and businesses and industries, which may be only partly air transport related, but that are a characteristic of the 'landscape' around all major airports and therefore actually belong to the airport operations system.

To answer risk management questions — *i.e.* how to reduce health (and ecological) risks while keeping the airport operations going — it is relevant to analyse to what extent each part of the system contributes to the public health risk. The committee will not give such analyses in depth. Depending on the policy questions to be answered they can be performed for specific airports. To provide some insight into the variety of sources of physical factors — such as noise, air pollutants — the committee lists in Table 6 locations and activities together with the emissions that are associated with them.[32)]

Table 6 contains clues to the factors that have a direct impact on public health. As will be discussed in the following chapters, the more prominent ones appear to be air pollution, odour, noise and lack of safety. Other factors (sources) are of a more indirect nature. In Chapter 7 the committee will deal with some of these other aspects, such as water and soil pollution, particularly in relation to de-icing, the spread of infectious diseases through air travel and the relationship between health and visual aspects of the environment.

Table 6 Environmental factors from ‘normal’ airport operations classified according to type of activity and area. Adapted from [32)].

	emissions of substances in air	water discharges	waste	surface, soil and water contamination	noise, odour, vibrations, visual
general activities					
pax* terminal [a]		■	■		■
apron** and runways	■			■	■
cargo terminal	■		■		
roads and parkings	■		■	■	■
offices		■			
cantines		■	■		
energy plants	■				
incinerator	■		■		■
water plants			■		■
ramp area					
fuelling	■	■		■	■
catering			■		■
de-icing		■		■	
toilet services			■		■
cabin cleaning			■		■

* pax: passengers
** apron: the extensive paved part of an airport immediately adjacent to the terminal area or hangars

	emissions of substances in air	water discharges	waste	surface, soil and water contamination	noise, odour, vibrations, visual
technical services					
cargo area					
import					
storage					
export					
air space					
takeoff, landing, flight					
local road traffic					
to/from airport					
other transport					
businesses					
various					

[a] passengers and crew may transmit infectious diseases ('airport malaria')

Chapter 3

Environmental quality and public health

3.1 Public health effects

The committee uses the term *public health* for the purpose of the present report to denote health and quality of life of individuals and population groups. Public health thus encompasses the concepts of health and quality of life. A further distinction between these concepts is not easy, as they differ from era to era and from region to region, since they reflect changes or differences in social and cultural beliefs, in medical technology, and economic conditions. In Annex E the committee discusses several concepts of health. In describing the public health impact of large airports the committee does not advocate a specific, more restrictive or more encompassing definition of 'health'. The report will outline the impacts on health and quality of life. The desirable degree of protection against these 'public health' effects, whether classified as health effects or impacts on quality of life, is ultimately a political and ethical choice.

Major airports are situated in countries with a relatively high standard of living. In these countries the impacts of environmental degradation on public health do not primarily involve mortality risks or serious loss of life expectancy, but also, and predominantly so, aspects of the quality of life in a broader sense.[117] Examples are:

- aggravation of pre-existing disease symptoms, e.g. asthma, chronic bronchitis, cardiovascular or psychological disorders[176]
- severe annoyance, sleep disturbance, as well as a reduced ability to concentrate, communicate or perform normal daily tasks[239]

- feelings of insecurity or alienation, unfavourable health perception and stress in relation to poor quality of the local environment and perceived danger of large fatal accidents. [176]

In evaluating these impacts one has to take account of a number of dilemmas.

- 'Health' has become one of the most treasured goods in Western societies. Several authors have pointed towards the tendency to put social problems into a health context ('medicalisation'). [58, 89, 252, 281]
- There are indications that people with higher education and income are inclined to display more readiness to complain about environmental quality and its effect on their own health than people with a lower socio-economic status. [174] This necessitates caution in interpreting data involving indicators based on self rated health surveys, in view of decision making.
- Finally, 'medicalisation' of everyday life problems by itself might just as well erode people's basic trust in their own health and health maintenance, which in turn may affect their well-being. [252]

The committee will refrain from making judgements on how to deal with these dilemmas. It will describe outcomes that are significant to mortality, morbidity and quality of life (in a broad sense). Obviously this includes intermediate morbidity and mortality risk indicators, such as impaired lung function, hypertension, cardiac arrhythmia, aggravation of asthma, or severe sleeping problems, as well as indirect indicators such as use of medical services or self-medication. Several authors have suggested that 'physical' health responses may be mediated through social-psychological responses, such as stress* or severe annoyance (which is also stressful). Indirect behavioural response may comprise social isolation, aggression as well as excessive use of alcohol, tobacco, drugs or food. Stress-related physiological responses may include hypertension, unfavourable blood lipoprotein composition, and cardiac arrhythmia. A clear distinction between psychological disorders, such as clinical depression and anxiety on the one hand and anger, annoyance, irritation, or loss of morale on the other will not always be easily made. [172]

There are indications that social responses to environmental interventions, such as the expansion of an airport, may lead to an increase in medical consumption, such as (self-)medication, GP-visits or hospital admissions. [190, 223, 239] Furthermore, several authors have pointed out the important role of socio-economic inequalities within societies with regard to public health status. Independent of the absolute level of income, material insecurity, social exclusion, lack of self-esteem and loss of social cohesion may

* Defined here as an imbalance between the individual capabilities and environmental demands.

lead to a higher prevalence of health problems among the more deprived. [161), 192), 235), 269)] These observations will not be discussed in detail in the following chapters, but will be taken into account in the conceptual model of the relation between environment and health and quality of life described in the next section.

3.2 Determinants of public health effects

To evaluate the manner in which environmental exposure influences public health the committee considers a conceptual model derived from propositions made by others, most particularly by the Canadian Minister of Health Lalonde in 1974 and the National Institute of Public Health and the Environment (RIVM) [207)] (Figure 3). The model considers effects on health and quality of life as the outcome of the way in which the human organism processes exogenous determinants, *i.e.* determinants of the physical and social environment and life style. This process is influenced by genetic and acquired characteristics of the organism. The public health and health care system will modify the actions and outcomes at all three stages depicted in Figure 3, e.g. by preventing noise exposure by insulating houses, by preventing the transmission of genetic defects by genetic counselling and by lessening the burden of disease by providing medical care. Environmental exposures and processing of such exposures by the human organism does not take place in isolation, but within societal systems with their social, cultural, economical and technological characteristics. The variety of factors that play a role in the pathway from exposure to effect may explain why the response to environmental exposures varies substantially from one individual to the other and from one population group to the other. [67)]

Characteristics of the organism (Figure 3) may be genetic or acquired in the course of life. *Genetic* predisposition may involve clear abnormalities such as haemophilia or colour blindness. However, often a particular feature in a population may show a more complex genetically determined distribution, reflecting differences in susceptibility to pathogenic factors. An example is the variation in the ability to detoxify harmful substances. *Acquired attributes* are built up in the course of life, for instance immunity acquired through vaccination or prior infection, reduced lung function as a result of an earlier respiratory infection, many years of smoking or adverse occupational exposures, and earlier experiences with perilous environmental accidents that may increase one’s susceptibility to anxiety or annoyance. [201)]

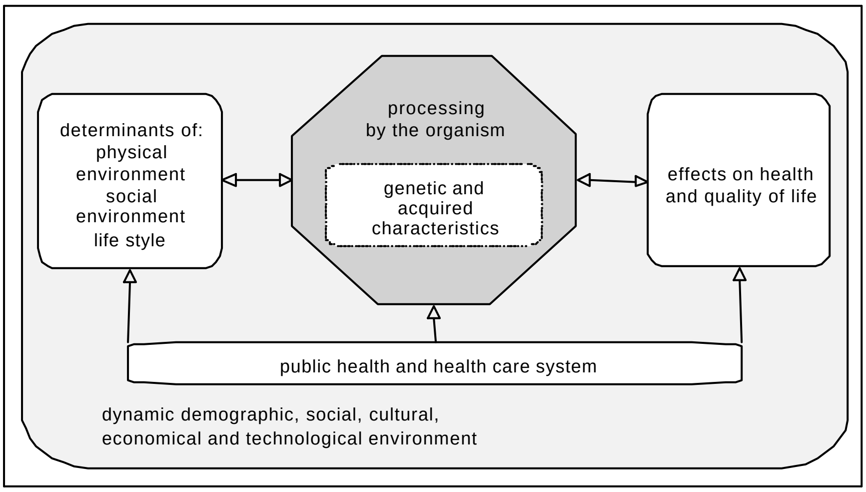


Figure 3 Model describing the relationship between the environment and health and quality of life.

Probably most endogenous characteristics develop through interactions between genes and environmental factors and thus have both a genetic and an acquired component. Of course age (and the ageing processes associated with it) is an important attribute that determines health and environment-induced public health effects. Inevitably our chances of suffering from chronic diseases and associated functional limitations increase as we grow older. Some theories assume that we are accumulating adverse physiological events during our life, such as DNA-deficiencies or tissue damage, others claim our physical and mental decline is programmed, for instance as a result of an evolutionary process.[232] A person's 'resilience' with regard to the effect of exogenous determinants generally decreases with age.

With respect to exogenous determinants of health a distinction is made in Figure 3 between the physical environment, lifestyle factors and the social environment. The *physical environment* includes energy, radiation, noise and heat; oxygen supply, nutrients, hazardous substances in the outdoor and indoor environment (including the working environment); bacteria, viruses and other micro-organisms which may have both positive as well as negative effects on health status. *Lifestyle* factors include diet, smoking, drug and alcohol abuse, sexual habits, physical (in)activity etc. The *social environment* includes the pattern of social networks and socio-economic status (see Annex E and F). In the context of the present report one might consider the degree to which one's everyday life is affected by side effects of large infrastructure projects, such as the expansion of an airport.[258]

Exogenous determinants mutually interact and act on the genetic and acquired characteristics of the organism. Lifestyle, for instance, is to a considerable extent determined by the social environment (e.g. family situation). Aspects of lifestyle or behaviour may largely determine exposure to factors from the physical environment such as noise and air pollutants. The possibility to abide in a natural, peaceful or aesthetic environment may help restore the accumulated physiological or psychological damage associated with negative stress. [249]

The model underlines the processing of environmental exposures by the organism. This processing may be of a physiological nature, e.g. detoxification processes that operate after inhalation or ingestion of toxic substances, or psychologically determined as in the case of noise leading tot annoyance, or may encompass both mechanisms. These control mechanisms lead to coping behaviour, with the aim of reducing or avoiding the exposure or adapting to a certain extent to the environmental stressors.

3.3 Observing public health effects

Due to the strong and consistent influences of social-economic factors on public health (discussed in Annex F) one will often search in vain for an independent effect of environmental exposures in available health statistics, such as mortality and morbidity rates or medical consumption. [67] The strong association between socio-economic and environmental conditions, such as the geographic association between socio-economic status and residential environmental quality in the vicinity of airports, freeways, and industrial areas, makes detection of environmental health effects by epidemiological methods quite difficult and often impossible. [83, 146, 172, 176, 212, 233, 239, 262] Only when health outcomes or effects on quality of life effects are more or less specific for a certain environmental exposure, quantitative associations between exposure and effect may be observable.

The impact of hazardous environmental exposures on human health can take numerous shapes of varying severity. Among the many responses that have been attributed to environmental exposures, are disturbed cognitive development in children, several types of cancer, reduced fertility, immune-suppression, severe noise annoyance and sleep disturbance. [113, 215, 277] During air pollution episodes well-studied human responses range from temporary lung function deficits, to aggravation of symptoms among asthmatics, and from hospital admission of patients with cardiopulmonary disease to the premature death of some of the very frail. [38, 143, 143] These effects are situated at different ‘heights’ of the ‘iceberg’ of Figure 4, depending on the nature of the endogenous and exogenous factors (Figure 3) that act on the individual or population level.

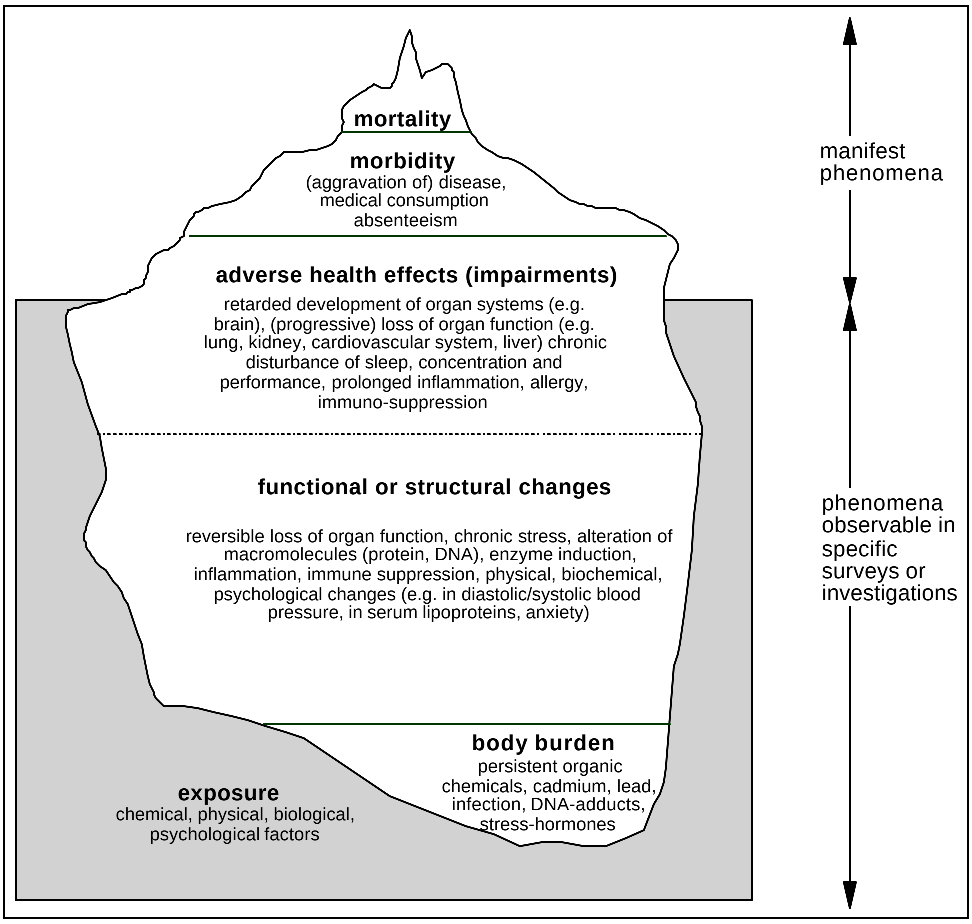


Figure 4 Diagram ('iceberg') representing the public health relevance of endpoints. Only the severe responses require medical treatment and show up in official health statistics ('part of the iceberg above the surface'). Responses 'beneath the surface' are only seen in specific population surveys or investigations.

Some effects occur soon after the onset of exposure; others emerge after long term cumulative exposure, including a latency period. The public health significance of any biochemical, physiological or psychological response to an environmental insult depends, as mentioned above, on endogenous and exogenous factors. Whether or not an environmentally induced change affects individual health or quality of life depends on the possibilities for recovery or compensation.

Figure 4 also clarifies the significance of apparently harmless effects such as a slight reduction in pulmonary function. Environmental exposures may cause transient functional changes in a relatively large proportion of the population exposed. In a smaller susceptible proportion of the population these changes may lead to physical or mental symptoms and in the end promote the initiation of disease or the aggravation of its symptoms. At the top of the iceberg environmental exposure may precipitate mortality, especially among the most susceptible subjects. In some cases the loss may amount to many years of healthy life.

It is generally accepted that the individual and population health effects of exposure to an attribute of the physical environment depends on the exposure dose. In many exposure situations, effects are only observed after a certain threshold dose is exceeded. However, dose-effect relationships, and the threshold doses, may vary from one individual to another and from one exposure situation to another.

In research as well as in policy public health status and public health effects have to be expressed in metrics that provide insight in the frequency and distribution of impacts on health and quality of life. Given the multitude of possible effects one can either choose one or a few metrics, such as mortality or prevalence of a group of diseases, or resort to aggregate metrics, *i.e.* quantities that rate the different effects on a common scale such as years of life lost. In Annex E some examples of aggregated metrics are presented. In the context of aggregation, subjective choices have to be made with regard to the relative importance of the impacts considered and therefore inevitably some aspects of the problem at hand are lost.[95] However, there are advantages from a policy or public health management point of view in using aggregate metrics, such as the possibility of comparative risk evaluation (e.g. setting priorities), evaluation of the efficiency of environmental policies in terms of public health gains, and characterising public health risks associated with the geographical accumulation of multiple environmental exposures. Promising concepts in this respect are metrics that aggregate effects of environmental exposures in terms of quality or disability adjusted years of life lost or gained.[89, 174]

3.4 Public health in an airport operations system

Empirical data on the various aspects of the relationship between environment and health in an airport operations system are far from complete. Figure 4 provides a framework to put incomplete data sets on public health effects of environmental exposures into a perspective. The framework implies that, as a starting point, in principle any factor in the physical environment may have a certain impact on public health. As far as possible the committee will try to determine the likelihood of the possible effects, their distribution within the exposed population and the factors that influence the distribution and the severity of the effects. To assess the causality of a relationship between environment and public health in an airport operations system the committee uses the rating system of the International Agency for Research on Cancer (IARC). IARC uses this system in its assessment of carcinogenic agents. The qualifications are described as:[123)]

- *Sufficient evidence* of causal relationship: an association between exposure and a specific health response has been observed in studies in which chance, bias and confounding could be ruled out with reasonable confidence.
- *Limited evidence* of causal relationship: the causality of an association between exposure and a specific health response is considered to be plausible; however, it cannot be ruled out (with reasonable confidence) that the associations are due to chance, bias, and/or confounding.
- *Inadequate or inconsistent evidence* of causal relationship: the available studies are of insufficient quality, or lack consistency or statistical power to permit conclusions regarding causality.
- *Evidence suggesting lack of causality*; several adequate studies covering the full range of exposure are mutually consistent in not showing a positive association between exposure and response at any observed level of exposure.

The committee has rated the severity of an effect as being *slight*, *moderate* or *severe*. The determining factor is the degree of impairment an individual experiences in his or her daily life. This type of rating is to a certain extent similar to the rating of diseases in constructing quality or disability adjusted life years metrics.[89), 174)] A health effect is rated as 'slight' if it does not have a very significant impact on daily functioning, may be reversible or has a small effect in the long run. Effects that, at least after short-term exposure, in a large fraction of the exposed would be within normal biological variation, would fall in this category. Severe effects on the other hand seriously impair day-to-day functioning and usually require professional medical care. Moderate effects are in between these two extremes.

Finally the number of affected people within an exposed population is relevant. To make a general categorisation in this case is not easy, as here, the magnitude of the exposure as well as the susceptibility of the exposed also play a role. The committee distinguishes three categories:

- *susceptible individuals*
- *specific subgroups*, such as children, persons with specific occupations, etc.
- *a substantial part* of the total exposed population.

The committee will only present the rating for 'number affected' for effects that are causally related to an environmental factor with sufficient evidence. All ratings are to be considered as judgements of the committee.

Chapter 4

Air quality

4.1 Overview

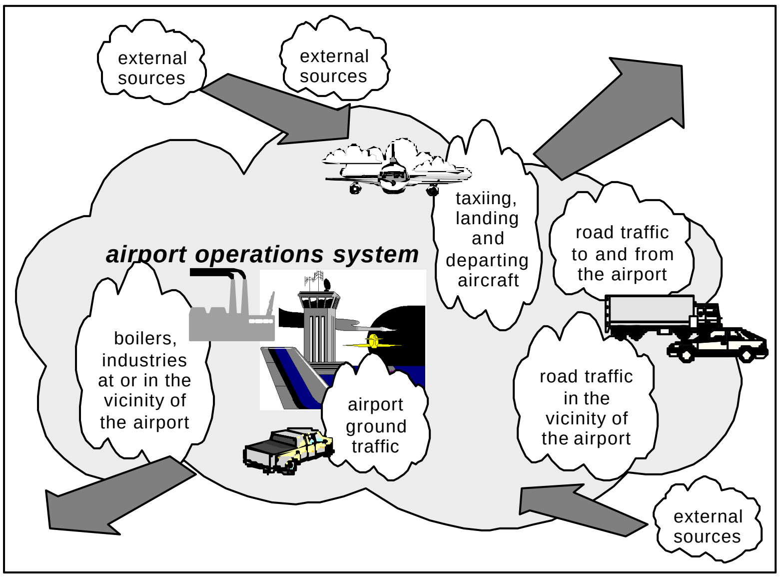


Figure 5 Overview of air pollution sources affecting an airport operations system.

Air pollution is one of the exogenous factors in an airport operations system that may have an impact on public health. Pollutant sources stem primarily from fossil fuel combustion and can be categorised as operations at the airport, road traffic in the vicinity of he airports and nearby industry and households, apart from sources external to the system (Figure 5). Airport operations entail taxiing, landing and departing of aircraft and all sorts of ground activities, such as engine testing, heating plants, power generating systems and airport ground traffic. Pollutants are emitted at surface level, in the atmospheric boundary layer and at higher levels in the troposphere. Emissions in the higher regions of the troposphere are of relevance for public health via climate change mechanisms, such as destruction of the ozone layer and global warming. As stated before, these effects — though of major importance — are outside the scope of the present report.*

Air pollution is a large-scale phenomenon. Levels of air pollutants in, e.g., the Netherlands are the result of contributions of a number of diffuse sources in various regions of the European continent. This means that the pollution levels within the boundaries of an airport operations system are also determined by sources external to the system. Sources within the airport operations system may cause localised, increased pollutants levels; e.g. black smoke and nitrogen dioxide (NO_2) are observed in relatively high levels near highways and roads.

Few epidemiological studies have focused on the impact of air pollution at or near airports. Therefore, the committee has also reviewed the scientific literature on public health effects of air pollution in urban areas in general. It is plausible that these data are relevant with respect to the airport operations system as in several monitoring studies near large airports air pollution levels similar to those in urban areas were observed.[45), 154), 181)]

In this chapter the committee will try to answer the following questions:

- Which pollutants are emitted by which sources and which of these pollutants are of concern in terms of public health impact?
- What are the concentration levels of these pollutants near airports and what levels are expected in the future?
- Which public health impacts can be expected among people exposed to such air pollution exposure levels?

* Aircraft that have to return to ground shortly after takeoff dump most of their fuel load in order not to exceed the maximum landing weight. The kerosene evaporates in the higher troposphere, but hardly affects the air quality in the airports operations system. KLM Royal Dutch Airlines reports in its most recent annual environment report that 1060 ton kerosene was dumped in this way, equivalent to 0,04 per cent of the total fuel used by the airline's fleet.[140)]

4.2 Air pollutants

Numerous pollutants are emitted as a result of fossil fuel combustion in activities within an airport operations system. The dominant substances emitted are nitrogen oxides (NO_2 and NO, also denoted together as NO_x), carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOC), sulphur dioxide (SO_2) and particulate matter (PM). PM is not a well-defined entity, but denotes a collection of aerosols with widely differing chemical and physical characteristics. Fine particles with an aerodynamic diameter of less than 2.5 μm and of less than 10 μm are denoted by, respectively, $PM_{2.5}$ and PM_{10}. Ultra-fine particles have an aerodynamic diameter of less than 100 nm*. Ozone is a secondary air pollutant formed by a sunlight-induced photochemical reaction of the precursors NO_x and VOC. Nitrogen dioxide is formed in the atmosphere through the oxidation of NO by ozone and other compounds. Carbon dioxide is an important greenhouse gas, but poses no direct threat to human health in concentrations observed in the atmosphere. VOC is a mixture of a large number of hydrocarbons mostly released through evaporation of fuel and a variety of solvents. Also polycyclic aromatic hydrocarbons (PAH) are part of the emissions from activities of an airport operations system.

WHO guidelines for major air pollutants are presented in Table 16, Annex G together with limit values and guide values established in European Union regulations.[155), 156), 278)] Associations between pollutant exposure and public health responses have been observed below these limits.[8), 57)]

Aircraft emissions depend on the power output of the engine but also on the type of engine and type of fuel used.[236),278)] In Table 7 the rates of emission for different operations are given for so-called Chapter 2** aircraft. During the taxiing phase, emissions of CO and VOC dominate, while during takeoff the engine temperature and pressure increase and the aircraft emission changes from a dominant CO/VOC mix to one in which NO_x is more important.[143)]

In contrast to road traffic, that emits hydrocarbons in the range of C6-C9***, aircraft petrol or kerosene consists of hydrocarbons in the range of C10-C16. Important components are n-dodecane, trialkylbenzenes and naftalene.[16)] Although n-dodecane was detected in the air around Amsterdam Schiphol[16)], the committee expects the levels of these compounds to be relatively low in general. A monitoring study, in which

* μm - micrometer (10^{-6} m), nm - nanometer (10^{-9} m)
** refers to Chapter 2 of Annex 16, Volume I of the ICAO-convention
*** compounds with 6 to 9 carbon atoms

components of aircraft emissions were measured, concluded that no specific toxic VOC or PAH could be detected from aircraft emissions.[220), 236)]

Table 7 Typical mean emissions from gas turbine aircraft engines at various stages of the landing and takeoff cycle.[155)]

landing and takeoff stage	engine power (%)	CO emitted (g/kg fuel)	hydrocarbons (g/kg fuel)	NO_x (g/kg fuel)
idle	5	5	20	5
approach	30	5	2	10
cruise	60	0	0	20
takeoff	100	0	0	40

4.3 Relative contribution of air pollution sources

Concentrations of air pollutants appear to increase with decreasing distance to an airport (see Figure 6). However, it is complicated to estimate the relative contributions of the separate sources to local air pollution levels. Road traffic is usually considered to be the most dominant one.[52), 142), 177)] Several studies around airports in the UK[154)] and in Germany[181)] confirmed that road traffic is in general the most important contributor to air pollution in the vicinity of airports.

Den Boeft and colleagues estimated the relative contribution of airport operations at Amsterdam Schiphol (including ground traffic at the airport) to the emission levels of NO_x, CO, VOC, SO_2 and black smoke in the 20x20 km^2 region surrounding the airport in 1990 to be 3-9%, depending on the component.[29)] The relative contribution of road traffic in the vicinity of the airport was estimated at 32% for VOC to 84% for black smoke. In a follow-up study it was demonstrated that the relative contribution of emissions at Amsterdam Schiphol airport compared to motor transport on nearby roads in 1995 and 1996 had increased since 1990.[52)] Despite decreased emissions of VOC, CO, SO_2 and black smoke per landing and takeoff cycle (NO_x remaining at the same level) the total emission of Amsterdam Schiphol operations increased due to the increase in aeroplane movements. However, air quality was similar in 1990, 1995 and 1996 due to decreased emissions by road traffic.[52)]

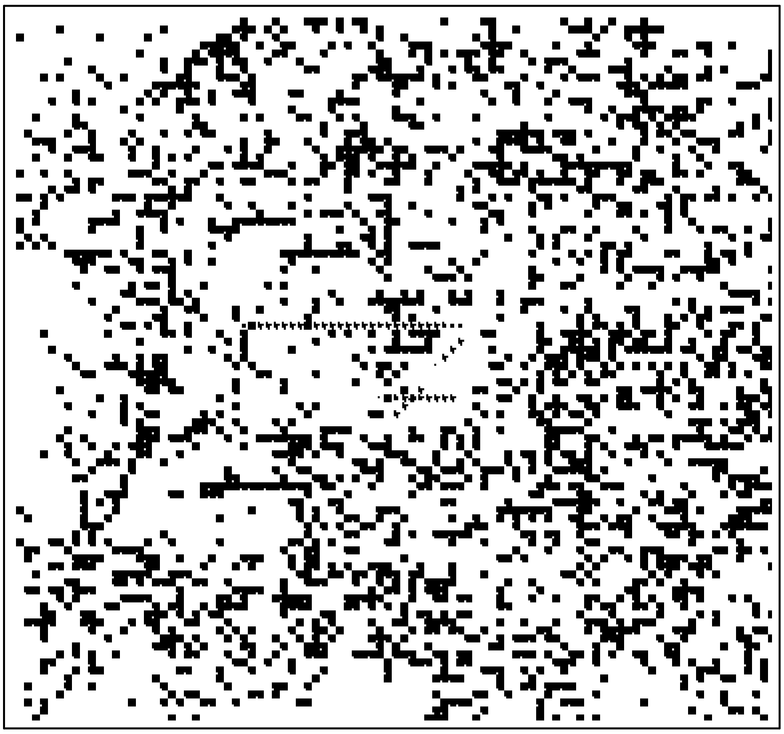


Figure 6 Calculated contours of NO_x ground level concentrations in µg m^{-3} at Heathrow for 1993.[37)]

4.4 Current and future levels of air pollution near airports

The results of air quality monitoring studies in airport operations systems in Europe and the US show levels for SO_2, CO and black smoke below guideline values at all airports studied.[10), 78), 80), 180), 181), 213)] Guideline values for NO_2 have been exceeded from time to time.[10), 45), 78), 181)]

Several scenario studies assessed future levels of air pollution near airports. Nitsche and Walker expect the following changes in the emission pattern by airport activities: NO_x emissions will increase and CO and VOC emissions will decrease in the next 10-12 years due to the continuing introduction of more fuel-efficient aircraft (that are also less noisy).[78), 181)] The impact of such a more NO_x-dominant emission by aircraft on ozone levels is not clear, since both NO_x and VOC are precursors of ozone. The Dutch National Institute of Public Health and the Environment predicted the increase of aircraft emissions due to the increased number of aeroplane movements at Amsterdam Schiphol to be lower than the decrease of road traffic emissions in the vicinity of the airport.[177)] However, the committee considers this result overly optimistic: it is difficult to predict at what pace combustion technology will progress to reduce emissions of car engines and to what extent this can compensate for the expected increase in road traffic. A recent EU report shows that, although considerable improvements have been made, the expanding economy makes the pace at which further reductions in polluting emissions can be made rather uncertain.[73]

4.5 Air pollutants and public health

4.5.1 Data

Monitoring studies show that, in general, levels of air pollutants in the vicinity of airports are similar to those observed in urban areas elsewhere. This finding is not surprising as road traffic and external sources are major contributors to air pollution in an airport operations system (see Section 4.3). The committee bases its conclusions on the health effects of air pollution primarily on COMEAP's* recent review publication 'The quantification of effects of air pollution on health in the United Kingdom'.[57] Two other, more brief, review reports were also consulted.[40,162] Furthermore, recent original scientific publications were taken into account.

4.5.2 Airport studies

Several studies in the Amsterdam Schiphol region showed a negative relationship of the distance of the residents' homes from the airport with respiratory complaints[168,239,267] and use of medicines for allergy or asthma.[267] In a recent, survey-type study these associations were observed after correction for determinants such as smoking, damp houses and distance from the nearest traffic road.[239] These findings cannot simply be attributed to air pollution from aircraft, because of the lack of data on ambient air pollution exposure of the study subjects.

Other studies observed no difference between the incidence of respiratory or cardiovascular disease in the region around an airport and in other urban areas.[36,224,225] However, in these studies no correction could be made for other factors besides exposure to air pollution, e.g. social-economic status and life style factors, that may contribute to non-uniform spatial patterns of diseases.

In another study no differences in incidence of cancer within the Amsterdam Schiphol region was observed compared to a part of the city of Amsterdam.[255] Besides, observed levels of VOC and PAH concentrations and PM mutagenic activity were similar to city levels.[28] Whether specific compounds in the vicinity of airport

* COMEAP: Committee on the Medical Effects of Air Pollutants (UK)

operation systems, such as jet fuel additives, contribute to the cancer incidence is difficult to predict, since very few data exist on the toxicology of jet engine emissions.

From the literature reviewed, the committee concludes that there are no convincing indications that air pollution in the vicinity of an airport causes extra health risks as compared to other urban areas.

4.5.3 Exposure to air pollutant mixtures

Effects on public health parameters have been observed in populations exposed to mixtures of ambient air pollutants. From such studies, it is not easy to assess which particular compound or compounds are responsible for a given effect and whether synergistic or antagonistic effects occur.[138), 242)] In recent epidemiological literature this topic has been extensively discussed.[91), 153), 196)] Reviews compiled some years ago concluded that associations between air pollutant mixtures and morbidity and mortality were largely driven by (ultra-fine) particulate matter, as such relationships were also observed in areas with low concentrations of other, gaseous pollutants.[278)] The only exception seemed to be ozone, which was shown to be directly related to public health effects.[40)] However, several more recent studies suggest that the role of gaseous pollutants, such as CO and SO_2, may be more important than was previously thought.[9), 136), 222), 231)]

Another important question is the extent to which exposure to one pollutant makes people more sensitive to the effects of other compounds. A study at Birmingham International Airport demonstrated a statistically significant association between high exposure to aviation fuel or jet stream and a cough with phlegm and a running nose amongst male airport workers.[243)] This observation appears to confirm the hypothesis that VOC may be an irritant to the upper airways inducing sensibility to other components like NO_x and fine particles.

4.5.4 Short-term health effects

Acute morbidity and mortality

Several recent epidemiological studies demonstrated statistically significant associations between day-to-day variations in air pollutant levels and day-to-day variations in mortality and in hospital admissions for respiratory and cardiovascular events.[57)] These associations are observed for NO_2, SO_2, CO, O_3, PM_{10} and $PM_{2.5}$ at average 24 h levels as low as, respectively, 60 µg/m³, 30 µg/m³, 2 mg/m³, 40 µg/m³ [43)], 30 µg/m³ and 20 µg/m³ [61)]. Some of these results suggest that there are no clearly discernible threshold exposure levels below which none of the exposed would be affected. COMEAP identified dose-response functions for effects on acute mortality and hospital admissions of PM_{10}, SO_2 and O_3. Evidence for similar effects of NO_2 and CO on health was also presented, but was considered to be insufficient for quantification of an exposure-response relationship.[57)]

Associations between episodes of air pollution and increased mortality are mostly observed in the elderly and in the sick. The main question is whether the increased mortality associated with higher pollution levels is restricted to these frail persons for whom life expectancy is short in the absence of pollution; this possibility has been termed the 'harvesting hypothesis'. Recent research shows that the relationship between acute mortality and particulate levels cannot be explained fully by this hypothesis.[279)]

Demonstrated effects of exposure to air pollution episodes on respiratory health are a decrease in pulmonary function, increased prevalence of respiratory symptoms (such as wheezing, coughing and shortness of breath) and aggravation of asthma (attacks, use of bronchodilators). In many people these effects are reversible.

4.5.5 Long-term health effects

Responses to long-term air pollution exposure are potentially more significant from a public health perspective than short-term effects. Such responses imply a role of air pollution in the onset and development of disease and the committee points out that long-term health effects may lead to a substantial loss of healthy life expectancy. Chronic effects have been observed in a limited number of prospective studies. However, the findings are supported by the results of various study projects of cross-sectional design.

Respiratory morbidity

Evidence for long-term effects on the respiratory system is increasing. Two prospective studies, one in the Netherlands and one in California, suggest that living in an urban, polluted area is associated with a faster decline in pulmonary function than living in a rural, less polluted area.[150), 234)] These results indicate that exposure to air pollution contributes to chronic obstructive pulmonary disease (COPD). Chronic respiratory symptoms and morbidity were observed in several other prospective studies. Long-term exposure to ambient levels of PM_{10} and NO_x was associated with increased airway obstruction and higher prevalence of bronchial hyperresponsiveness in a population of asthma and COPD patients.[129)] Both long-term ambient PM_{10} and $PM_{2.5}$ exposure were found to be associated with development of definite symptoms of chronic bronchitis in a longitudinal study with 10 years of follow-up.[2), 3)] In the same study population an association was demonstrated between 20 years of exposure to PM_{10}, SO_2 and O_3 and pulmonary function in persons whose parents were asthma or COPD patients or suffered from hay fever.[4] For O_3, however, chronic lung injury is not supported by a recent cohort study among non-smoking residents of an ozone-polluted community.[90] One cross-sectional study in Switzerland, with a large study population of adults, showed a positive association between long-term exposure to PM_{10} and NO_2 and respiratory symptoms.[280] Also among the children participating in a cross-sectional study in 24 cities in Canada and the US a relationship between long-term exposure to particulate matter and an increase in prevalence of bronchitis[66] and a decrease in pulmonary function[199] was observed. There is to date only inadequate evidence to link long term exposure to community air pollution to the prevalence of allergy ands asthma.

Respiratory mortality and lung cancer

The evidence for effects on survival of chronic exposure to particulate matter comes largely from two cohort studies showing a positive association between exposure to ambient particulate matter and death from cardiopulmonary disease and lung cancer.[65),196] A recent prospective study confirmed these results through observing a strong association of ambient levels of PM_{10} with non-malignant respiratory mortality and lung cancer mortality. However, in this study no association between particulate matter exposure and cardiopulmonary mortality was found.[5] Long-term exposure to O_3 and SO_2 in the same cohort study also showed a relationship with lung cancer mortality[5),23)], which confirmed earlier findings of an association between long-term cumulative exposure to ambient O_3 levels and lung cancer mortality.[171]

4.5.6 Road traffic-related studies

Several cross-sectional studies indicate an association between road traffic emissions and respiratory symptoms and disease.[40),162] Both in adults[175),182] and in children[39),185),259] a relationship was found between living near busy roads and prevalence of a number of respiratory symptoms. Also an association was observed between density of heavy traffic on roads near residences and respiratory symptoms[39),50),70),259),263),271] or pulmonary function[39),259),271] in school children. In one of these studies, decreased lung function was related to measured black smoke concentrations at the schools; the black smoke concentrations can be seen as a proxy for concentrations of diesel exhaust particles.[39),259]

These results indicate that exposure of children to air pollution in the direct vicinity of major roads, in particular exposure to diesel exhaust particles (black smoke), may lead to reduced lung function. However, this finding is not confirmed by all studies and it is not clear to what extent the results of the studies mentioned above are biased by the self-reporting method. [40]

In recent work in Germany evidence was obtained for allergic sensitisation and allergic symptoms in school children in relation to road-traffic intensity. [147] In this study the effects were determined both by objective methods and by data based on standardised questionnaires as well as symptom-diaries.

4.5.7 Odour

The distinctive smell of unburned and partially burned kerosene is frequently reported in the vicinity of airports. [155] In the recent questionnaire study around Amsterdam Schiphol, 5 per cent of those living in the vicinity of the airport reported to be severely annoyed by odour. [239] It appears that exposure to odour is less accepted than exposure to noise. [270] The committee concludes that there is sufficient evidence for odour-induced annoyance and that a large number of the population in the vicinity of the airport is affected.

Studies around industrial plants showed an association between self-rated odour-induced nuisance and psychological and psychosomatic symptoms [151] and an increase in somatic symptoms, especially gastric symptoms such as nausea, loss of appetite, disgust and vomiting [228]. However, the conclusion of the authors was that the relationship between odour annoyance and clinical health effects is uncertain. The committee rates the evidence as limited. Due to the lack of similar studies in the vicinity of airports, the committee is unable to provide additional information on the effects of airport-related odour exposure. Observation thresholds for the effects related to odour exposure are difficult to define.*

In addition to effects of odour exposure on public health through annoyance, the committee mentions the possibility that odour exposure, through its 'signal function', may lead to increased concern about possible health effects caused by air pollution.

4.5.8 Indoor air pollution

Indoor air quality in buildings within an airport operation system, in offices as well as in residents' homes, may be negatively affected by interventions to reduce noise exposure, such as insulation. Although no specific information on such an effect is available, general data on the relationship between building construction and indoor air quality make it quite plausible. The indoor levels of dampness-related allergens, pollutants emitted by building materials and furniture and environmental tobacco smoke may

* In some countries regulations have been proposed or are in force based on so-called odour units (The Netherlands) and odour-events per year (Germany).

increase due to insulation. The increased exposure to these pollutants may be aggravated by staying indoors longer in order to avoid exposure to outdoor noise. The committee advocates further research into this subject.

4.6 Evaluation

Summary of the health effects of air pollution in general

The committee concludes that there is sufficient evidence that episodes of air pollution with levels observed within an airport operations system cause short-term effects like an increased mortality rate and an increased frequency of hospital admissions due to acute respiratory and cardiovascular morbidity. A decrease in pulmonary function is also one of the acute effects for which the committee considers there to be sufficient evidence. For increase of respiratory symptoms and aggravation of asthma attacks the evidence appears to be limited. In Table 8 the committee summarises its evaluation of the causal association of health effects with episodes of air pollution.

Table 8 Overview of reported acute health effects related to exposure to air pollutants.

response	evidence [1]	severity [2]	number affected [3]
premature death	***	***	*
aggravation of respiratory and cardiovascular disorders (resulting in hospital admissions)	***	***	*
decreased lung function	***	*	[4]
increase in chronic respiratory conditions	**	**	
aggravation of asthma	**	***	

1 * = inadequate, inconsistent evidence, ** = limited evidence, *** = sufficient evidence

2 * = slight, ** = moderate, *** = severe

3 * = susceptible individuals, ** = specific subgroups, ***= substantial part of exposed population; only rated in case of sufficient evidence

4 A mean fall in lung function has been observed, but it is difficult to classify the number affected on the basis of the available data.

Epidemiological research has also produced evidence for effects of long-term exposure to air pollutants. The committee qualifies the evidence for several health effects of long-term exposure to ambient air pollution as sufficient. More prospective studies could give further insights in the relationship of chronic exposure to air pollutants with chronic morbidity and mortality. One of the questions to be answered is to what extent the increase in respiratory conditions is due to exacerbation of existing disorders. Although it is plausible that air pollutants contribute in a modest way to cancer incidence, there is no evidence for specific contributions from local sources (e.g. PAH emissions by aircraft) in an airport operations system.

Sufficient evidence exists for odour-induced annoyance. Psychosomatic and somatic effects of odour (Section 4.5.7) for which there is limited evidence, may be mediated by annoyance or be a direct effect of odour exposure.

Table 9 provides the evaluation of chronic health effects, including effects related to odour.

Table 9 Overview of reported health effects related to chronic exposure to air pollutants.

response	evidence [1]	severity [2]	number affected [3]
premature death (decrease in life expectancy), including lung cancer mortality and cardiopulmonary mortality	***	***	*
reduced lung function due to chronic exposure	***	**	**
chronic respiratory symptoms in children	**	***	
increase in chronic respiratory conditions (bronchitis) in adults	***	**	**
prevalence of asthma and allergic symptoms	*	**	
odour annoyance	***	*	***
odour-related somatic and psychosomatic symptoms	**	**	

1 * = inadequate, inconsistent evidence, ** = limited evidence, *** = sufficient evidence

2 * = slight, ** = moderate, *** = severe

3 * = susceptible individuals, ** = specific subgroups, *** = substantial part of exposed population; only rated in case of sufficient evidence

The committee points out that within the airport setting people are always exposed to mixtures of air pollutants. Therefore, given the available data, it is not possible to separate effects due to individual ambient pollutants from interaction effects. However, the committee concurs with COMEAP in the UK that there is no doubt that major pollutants, such as PM_{10}*, O_3 and SO_2, are damaging to public health, without clear-cut evidence for a threshold below which the response is nil. Apart from these fossil fuel combustion products, emissions might contain other products, partly unknown. Data on the possible public health effects of these compounds are lacking and further risk assessment is at present not possible. Concurrent exposure to odour may induce concern for effects of air pollution on health and in this way aggravate public health complaints.

* Using only PM_{10} as a measure to describe exposure to particulate matter is probably insufficient. A recent review of the epidemiological data has led the United States Environmental Protection Agency to establish a $PM_{2.5}$-standard. [72)]

Specific subgroups of the exposed population are possibly susceptible to long-term effects and to short-term effects such as decreased lung function and increased respiratory symptoms. These vulnerable groups are mostly elderly people with pre-existing respiratory and cardiovascular problems. The committee points out that although associations between days of increased levels of air pollution and increased daily mortality are mostly observed in susceptible individuals there is a possibility that this association is not only based on the so-called 'harvesting principle'.[279] Several studies suggest factors that identify persons who are susceptible to air pollution; e.g. peak expiratory flow variability[30], bronchial hyperresponsiveness[30),31] and relatively high concentrations of total IgE* in serum [31]. Another factor that might increase the susceptibility to air pollution is a low intake of dietary antioxidants.[5),99),205] More research is necessary to further identify individual determinants of susceptibility to air pollution, since the above mentioned factors apply to large numbers of people. If indeed the susceptible people in the population are not confined to frail individuals, then the impact of air pollution on public health would be greater then is presently thought.

Controlling air pollution in the future

Future levels of air pollutants in the vicinity of airports are difficult to predict. If the world-wide growth of the aviation industry continues, the relative contribution of airport operations to local air pollution levels might increase. The tendency to transport air passengers by rail instead of by road will decrease road traffic flow to and from the airport, but other road traffic is more likely to increase.[73] Unless present-day behaviour in affluent societies drastically changes, the committee expects road traffic to remain the major emitter in an airport operations system.

The primary source of airport operations related odour annoyance appears to be VOC emissions by aircraft. Adjusting idling and taxiing procedures can already lead to some improvement.[178]

With respect to controlling air pollution the committee notes that in most industrialised nations industrial and road traffic sources of air pollution are subject to regulatory control, contrary to aircraft emissions.[11] An integrated approach to combat air pollution is at odds with a system in which one important source, *i.e.* aircraft emissions, is exempt from such control. Given the transboundary nature of the aviation industry such regulations require international agreement.

* IgE - immunoglobulin E

Chapter 5

Noise

5.1 Overview

In this chapter the committee discusses the public health impact from noise emitted by sources in an airport operations system. The focus is on aircraft noise exposure in the vicinity of the airport. For people living, working or travelling near the flight paths aircraft noise will distract them from their pursuits, presumably more so than other environmental noises at the same location. At the airport itself noise is primarily an occupational health problem. As far as the passengers are concerned they appear to accept the prevailing noise levels, as belonging to their preferred mode of transport.

Much of the scientific evidence for the public health impact of noise concerns noise in general rather than aircraft noise in particular. However, the committee deems these data also relevant for its assessment. The reported non-auditory effects in individuals and populations exposed to aircraft noise and other forms of environmental noise range from social-psychological effects such as annoyance, effects on mental health, effects on sleep, effects on performance to stress-related health effects such as hypertension and ischaemic heart disease. Hearing loss is an auditory effect that is relevant for the exposure of airport and airline workers, but generally will not affect the hearing of the population in the vicinity of the airport giving the prevailing exposure levels.

The committee has primarily based its conclusions on recent reviews, that are considered to represent the state of present knowledge. The Health Council reports on aircraft noise and sleep[92)], on noise and health[93)] and on metrics for assessing noise induced annoyance and sleep disturbance[96)], and a recent UK National Physical

Laboratory report on health effect-based noise assessment methods[197] that evaluated data published since the 1994 Health Council report, have been taken into account. On subjects where scientific controversy exists the committee also studied recent reports of original research.

5.2 Characterisation of noise exposure

Sound is a physical phenomenon with alternating compression and expansion of air which propagates from a source in all directions. The frequency of the alternations determines the pitch of a sound. Sounds are sometimes perceived as noise; noise usually has unpleasant connotations (‘unwanted sound’).

To assess noise for public health purposes various so-called biophysical metrics have been proposed. These metrics are generally based on a physical quantity and ‘corrected’ for human sensitivity; the correction factors depend on the frequency, characteristics (continuous or intermittent, impulse character, tonality, etc.) and on the source of the noise. Within the framework of this report the following metrics are relevant:[96]

- *Sound pressure level* In practice, sound pressures range from less than 20 micropascal up to more than 200 pascal, a range of more than 10 million. Therefore, in acoustics, the logarithm of the sound pressure relative to a reference sound pressure is usually taken as a basis for the noise measure: the sound pressure level expressed in decibel (dB).
- *Sound level* The human hearing organ is not equally sensitive to sounds at different frequencies. Therefore, to take account of the loudness of a sound, a spectral sensitivity factor is used which weighs the sound pressure levels at the different frequencies in accordance with the frequency dependent sensitivity of the human hearing organ does: the so-called A-weighting. A-weighted sound pressure levels are expressed in dB(A).
- *Equivalent sound level* When the sound level fluctuates with time, as is usually the case with environmental noise, the equivalent sound level over a period of time is determined. For this purpose the A-weighted sound pressure squared is averaged, using a prescribed procedure, over the exposure period T considered (symbol $L_{Aeq,T}$). Common exposure periods are 24 hours (full day) or 8 hours (working day). for regulatory purposes often he annual average of he 24 hours of 8 hours equivalent sound level is used.
- *Day-night level* (L_{dn})* For environmental health assessments, especially related to annoyance, the so-called day-night level is used; this metric is the equivalent sound level over 24 hours, with the sound levels during the night (period of 23-07 hours)

* Day-night level and day-evening-night level better correlate with annoyance than the equivalent sound level.

increased by 10 dB(A). Also a 'day-evening-night level' (L_{den}) is used, which is constructed similarly, be it that the sound levels during the evening (19-23 hours) are increased by 5 dB(A), and those during the night (23-07 hours) by 10 dB(A). These quantities too are often averaged over periods of one year in environmental assessments or for regulatory purposes.

- *Aircraft noise exposure measure (B)* In several countries the day-night level or evening-day-night level is the preferred metric for regulating aircraft noise exposure (cf. discussion in [96]). In the Netherlands aircraft noise regulations are still based on a special quantity, denoted as *B* and expressed in Kosten-Units, in which the annual number of overflights with a maximum sound level of at least 65 dB(A), the maximum sound level during an overflight and a weighting factor for the time of the day are combined.
- *Sound exposure level of a noise event* The sound exposure level or *SEL* of a noise event, such as an over-flight of an aeroplane is the equivalent sound level during the event normalised to a period of one second.

5.3 Noise exposure in an airport operations system

Sources

The main sources of noise emission in an airport operations system are quite diverse:

- engine noise from airborne aircraft or aircraft on the ground (including engine testing and reverse thrust during braking)
- ground traffic at the airport
- movement and talking of many people at the airport
- road and rail traffic in the vicinity of the airport
- industrial noise in the vicinity of the airport.

The contribution of all these noise sources to the exposure level of people depends on the exposure location, time of the day, time of the year, etc. However, they all have in common that the exposure continues day after day, year after year, and — given that the world-wide increase of airport operations of the last decade will continue — at most airports will tend to increase. This increasing trend may, to a certain degree be offset by improved technology, especially with regard to reducing noise emission of car and aircraft engines and improved sound insulation in buildings.

Occupational exposure

The committee discusses the occupational noise exposure of workers at an airport and flight personnel in Section 7.4. For workers in the vicinity of an airport annoyance due to aircraft and road traffic noise is expected to be the dominant effect, apart from annoyance and hearing loss from industrial noise sources. Proper occupational hygiene measures can reduce this effect.

Exposure of passengers

The committee is not aware of studies on the effects of noise exposure on air travellers. The nature of the exposure levels and the exposure duration is such that long-term public health effects are not to be expected.

Environmental exposure

Outdoor aircraft noise exposure in residential areas around large airports may exceed 60 and occasionally 70 dB(A) (day-night or day-evening-night exposure level). For example, about 15 thousand people around Amsterdam Schiphol live in areas with aircraft equivalent noise levels of more than 60 dB(A).[176] Aircraft noise levels are determined by the position of the runways and the flight patterns. Figure 7 depicts noise contours for London Heathrow, based on 1997 data.

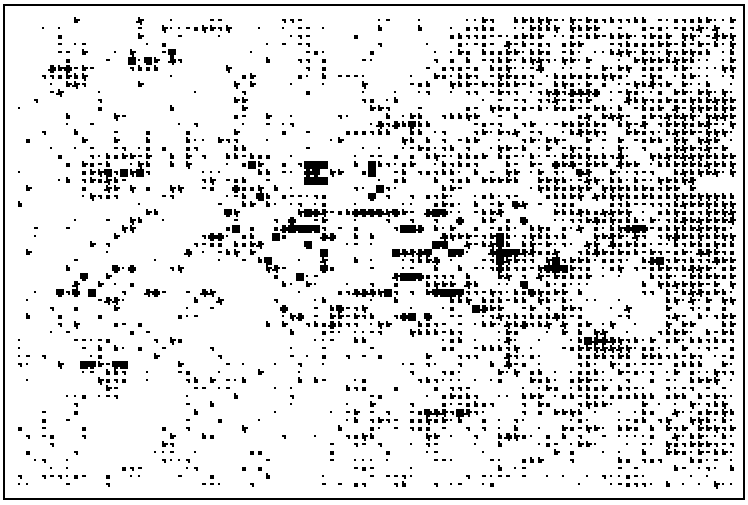


Figure 7 Noise contours for equivalent sound levels (24 h) of 57, 63 and 69 dB(A) around London Heathrow in 1997.[64]

5.4 Relationship with health and quality of life

Health Council report of 1994 [93]

The Health Council committee on Noise and Health assessed the health effects of environmental and occupational noise exposure, using the then (1994) available evidence. It rated the evidence in terms of categories used by the International Agency on the Research of Cancer [123] as sufficient, limited, inadequate and lacking and also presented observation levels, *i.e.* the lowest noise exposure levels above which generally, in well-designed epidemiological studies the effect has been observed.* A summary of the previous committee's findings is presented in Annex H. The following noise-induced effects were deemed to be supported by sufficient evidence; hearing loss, hypertension, ischaemic heart disease, annoyance, sleep disturbance and performance at school (see below and Annex H for exposure ranges at which this qualification applies). These effects are also expected to be observed in an airport operations system.

Hearing loss is an auditory effect that is relevant for the exposure of airport and airline workers, but will only affect the hearing of the population in the vicinity of the airport in exceptional situations. If people are exposed to equivalent noise levels above 70 dB(A) over 24 h for years on end, then some noise induced hearing loss would be expected in certain individuals.

The 1994 Health Council report rated the available evidence for a causal relationship with noise exposure as 'limited' for biochemical effects, immune effects, birth weight, psychiatric disorders, absentee rate, general performance and psycho-social well-being. Furthermore, the influence of noise-induced sleep disturbance on hormone levels and on performance the next day was rated as limited. Only inadequate evidence was found for sleep disturbance related changes in the immune system and no evidence was found for a relationship between noise exposure and congenital effects.

National Physical Laboratory report [197]

The UK National Physical Laboratory report took the 1994 Health Council report as a starting point and used more recent reviews and papers, in particular those of the Institute of Environment and Health of the University of Leicester [121], Berglund [26], Job [130], Shaw [214], Thompson [238] and Morrell *et al.* [172], to update the 1994 evaluation. In general

* The observation thresholds concern an average population of adults or adult workers or average populations otherwise specified, such as babies of women exposed to noise during pregnancy.

the more recent publications concur well with the conclusions of the Health Council, if we take a rating of 'inconclusive' as being equivalent to the Health Council's 'limited'.

With respect to two effects there appears to be differences of opinion. 'Leicester' and Morrell *et al.* rate noise-induced hypertension as inconclusive in contrast to the Health Council's 'sufficient'. This point will be further discussed below. Another difference exists between the evidence rating of congenital effects which according to the Health Council is lacking and according to the paper by Shaw is inadequate. The present committee concurs with the former Health Council Committee on Noise and Health.

The National Physical Laboratory report and other recent publications point to some subjects that warrant closer attention. These are discussed below on the basis of the published reviews and recent original literature.

Changes in hormone levels

In the 1994 Health Council report the evidence for biochemical effects of environmental noise exposure was rated as limited. In general, noise-induced changes, such as elevated levels of stress hormones, have been observed, which should be expected if noise acts as a stressor.[93] Recently, some reports confirm these findings and indicate that acute increases of catecholamines and cortisol have been observed at environmental noise exposure levels ($L_{Aeq,24\,h}$) above 60 dB(A), if activities are disturbed.[77),128] The committee considers these results of particular interest, but is of the opinion that further epidemiological research is necessary before more definite conclusions can be drawn with respect to the evidence for hormonal effects (see also below: 'sleep disturbance').

Annoyance

The 1997 Health Council report on noise exposure metrics focused on annoyance* and on sleep disturbance annoyance. In that report exposure-response relationships for these effects for different environmental noise sources are specified. More recently — as recommended in the 1997 report — the noise-induced annoyance data** have been reanalysed and somewhat different relationships for general annoyance have been

* The report defined general annoyance as a feeling of resentment, displeasure, discomfort, dissatisfaction or offence which occurs when noise interferes with a person's thoughts, feelings or activities. The same definition is used here.

** The analysis in the 1997 Health Council report and the reanalysis of Miedema is based on a database maintained by TNO Prevention and Health with financial support of the Netherlands Ministry of Housing, Physical Planning and the Environment. The database contains information, on an individual level, of all socio-acoustic studies for which the original data are available.

obtained.[169] The curves obtained are reproduced in Annex H; these relationships pertain to populations that have been exposed to noise at the given levels for periods of time of at least one year. The statistical variations of the relationships depicted in Annex H are such that general annoyance induced by the different modes of transport — air, road, rail — differs significantly at the higher exposure levels. Aircraft noise appears to be the most annoying and rail transport noise the least. The same holds for sleep disturbance annoyance.

Noise exposure is only one of the factors that contributes to annoyance, albeit an important one.[102),131),226] The degree of annoyance at a given noise level can in practice differ considerably from the exposure-response relationships presented in Annex H, because of the influence of non-acoustical factors. A recent study around Amsterdam Schiphol found percentages of severe annoyance from aircraft noise of 18% to 31% amongst citizens of 18+ years living within 25 km of the airport, *i.e.* 250 000 to 500 000 people.[239] This is considerably higher than the percentages derived from the pooled international data in Annex H. The committee concurs with the authors of the study, that non-acoustical factors might provide an explanation for this difference. Possible factors in the Amsterdam Schiphol case are; increased sensitivity for aircraft noise, fear of crashes*, and the heated political debate on the future of the airport. One may question whether at Amsterdam Schiphol the 'steady state' conditions under which the relationships in Annex H have been derived, did apply in the period of the study.

Non-acoustical factors may not only aggravate the degree of annoyance, but also be instrumental in lessening it. Alternate runway use has been cited as an example (see Annex C). However, empirical data on the effect of such measures on annoyance are lacking. The committee will come back to this subject in Section 8.2 and Section 9.3.

Noise on the other hand may also induce anxiety and fear, depending on the source. Aircraft noise in particular may have such an effect, by its association with aircraft crashes and possibly with feelings of helplessness due to a lack of control over one's living environment. Passchier-Vermeer in her extensive literature review on behalf of the 1994 Health Council committee summarised the then available data and found evidence that fear induces annoyance.[190] A recent pooled analysis of noise-induced annoyance studies provided evidence that fear of the noise source and general sensitivity to noise play a major role in noise-induced annoyance.[170]

Sleep disturbance

The available data allow the conclusion that there is sufficient evidence that exposure to noise can induce sleep disturbance in terms of changes in sleep patterns, in sleep stages,

* Especially in view of the 1992 accident with an El Al cargo plane crashing into a high rise residential building in the Bijlmer suburb of Amsterdam.

in subjective sleep quality and awakenings. In addition, noise exposure during sleep causes other effects such as an increase in heart rate. Moreover exposure to night time noise has also been shown to induce after effects such as decreased mood the next day.

Of particular interest are a series of recently conducted studies by Ising, Babisch, Maschke and associates, about the effects on the hormonal system of acute and chronic exposure to traffic noise during sleep. Acute and chronic changes in the excretion of stress hormones (catecholamines and cortisol) were observed in cross-sectional and longitudinal studies. [18), 163), 164)] These changes have been found in 'pseudo' field studies* at $L_{Aeq,23\text{-}06h}$ indoor values of about 42 dB(A), respectively. [128), 164)] More definitive epidemiological research data is necessary before the evidence for the causality of the relationship between night-time noise exposure and changes in stress hormone levels is to be rated as sufficient. The committee concurs with the assessment in the 1994 Health Council report and evaluates the evidence for a causal relationship as limited.

Effects among children

The committee draws attention to reports on effects on school performance**, on stress and on blood pressure in children. Evans and colleagues have shown reading deficits and long term memory impairment among schoolchildren residing near the former Munich airport; these impairments improved after the airport closed in 1992. [75), 120)] *** After that date similar effects were observed among children residing near the new Munich International Airport. Overnight resting urine catecholamines were statistically significantly elevated in children exposed to chronic aircraft noise at the former Munich airport in comparison to control groups. [75)] Longitudinal analyses showed a statistically significant increase of resting urine catecholamines after the relocation of the airport among children living in the vicinity of the new airport. In addition, systolic blood pressure was statistically significantly higher in children exposed to chronic aircraft noise than in those not so exposed. [77)] The noise levels ($L_{Aeq,24h}$) were 62 dB(A) for the experimental groups and up to 53 dB(A) for the control groups. Reading impairment has also been found in a cross-sectional study of schoolchildren living near a New York metropolitan airport chronically exposed to equivalent sound levels (24 h) of 65 dB(A). [76)] Chronic aircraft noise exposure above 66 dB(A) ($L_{Aeq,16h}$) impaired reading

* The reactions of people in their own homes exposed to 'normal' aircraft noise augmented by 'artificial' aircraft noises were observed.

** The evidence for these effects was rated in the 1994 Health Council report as 'sufficient'; see Annex H.

*** See also Annex C.

comprehension performance in schoolchildren living in the vicinity of Heathrow airport.[104] However, social-economic factors were found to play a dominant role in this case.

In general, recent studies appear to confirm the earlier findings among schoolchildren near Los Angeles airport in the beginning of the eighties[53),54] and support the evidence rating for noise-affected school performance as sufficient (Annex H). The new data do not warrant a change (lowering) of the observation threshold below 70 dB(A). As such effects may affect quality of life during the large part of a lifetime, its long-term impacts constitute a high priority study subject.

Long term effects on health

Research into long-term noise-induced health effects has focused primarily on cardiovascular disorders such as hypertension and ischaemic heart disease. In the 1994 Health Council report the evidence for both effects was rated as 'sufficient' at exposure to equivalent sound levels (6-22 h) above the observation threshold of 70 dB(A). Babisch recently evaluated ten epidemiological traffic noise studies (1977-1995) on the relationship between noise level and prevalence of hypertension.[20] Unfortunately most of these studies are of a cross-sectional design, with exposure estimates that are difficult to interpret. There appears to be considerable variation in the relative risk of hypertension for road traffic noise exposure with equivalent sound levels between 60-70 dB(A) (6-22 h). In two studies statistically significant relative risks greater than 1 for subjects who live in areas of more than 70 dB(A) daytime equivalent sound level have been found. The most recent prospective longitudinal study into effects on cardiovascular disorders due to exposure to (road) traffic noise suggests an statistically non-significant relative risk between 1.1 and 1.5 for ischaemic heart disease at noise levels above 65-70 dB(A) compared to noise levels of 51-55 dB(A) (6-22h).[20,21] Although the results are statistically insignificant, they are consistent with earlier findings about cardiovascular effects of traffic noise.[93]

These data do not contradict the evaluation of the 1994 Health Council committee. The present committee retains the earlier conclusion that above an observation threshold of 70 dB(A) there is sufficient evidence for noise-induced ischaemic heart disease and hypertension. The committee encourages further longitudinal studies into the observations thresholds and exposure-response relationships of noise-induced cardiovascular disorders.

Combinations of noise exposures

People may be exposed to various noise sources at the same location or throughout the day (and night). For instance, they may be exposed to road traffic and air traffic noise in the domestic environment or they may be exposed to various noise sources under different circumstances at different times, such as a mixture of occupational noises during working hours and air traffic noise while at home. There is a significant lack of research into effects of combined noise exposure over the 24 hours day. Only for hearing loss and annoyance are data available, which permits a conclusion on the effect of a combination of noise exposures.[93),96)] In the 1997 Health Council report on noise metrics a method is suggested (although not yet strongly recommended) to evaluate noise-induced annoyance from combined exposures.

5.5 Mechanisms

There has been an extensive discussion about the mechanism behind noise- induced public health effects. An important reason for this discussion is that, with the exception of noise-induced hearing loss, the effects are not due to a 'toxic' action of the sound wave energy, but to a reaction of the organism to a perception of sound.

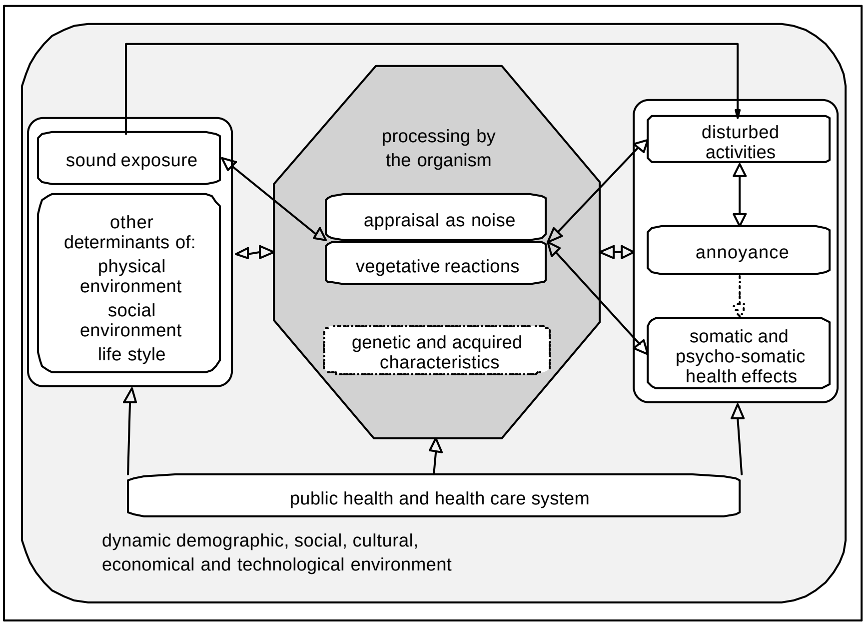


Figure 8 Conceptual model to describe the relationship between noise exposure and health and quality of life (cf. Figure 3).

In Chapter 3 the committee presented a model for the impact of environmental factors on health and quality of life. The model underlines processing of environmental exposure by the organism. Most debate on the impact of noise on health is related to the causal chain between the processing by the organism and health effects. 'Stress' has been suggested as a major mechanism by which environmental noise affects physical and mental health. The reactions to a stressor can be of a psychosomatic and somatic nature. Psychological effects concern feelings of fear, depression and frustration. Physiologically, stress manifests itself as a stimulation of the central nervous system and hormonal activity.[93] Figure 8 sets out a conceptual model in which health is more specifically related to noise.

Noise exposure may either directly or indirectly influence the vegetative, hormonal, cognitive and emotional regulation mechanisms of the organism. Indirect influences may be related to disturbed activities such as communication, recreation and sleep. The negative appraisal of noise may lead to short-term impairment of the organism both in a physiological and in psychological sense; physiologically by, *inter alia*, the production of stress hormones, psychologically by, *inter alia*, annoyance and resignation. Continuing noise exposure would result in chronic dysregulation of the organism, which in the long run might lead to an increased prevalence in the exposed population of, for instance, cardiovascular disorders and possibly of other diseases.

This picture suggests that exposure to noise in itself is a determining factor for health. However, various other factors may modify the way in which the 'noise signal' is processed by the organism and will increase or decrease the risk of noise-related diseases or impacts on well-being. Examples of such factors are the familiarity with the noise, the attitude of the individual or his community towards the noise source, the perceived control over noise, the individual's sensitivity to noise (e.g. increased by fear of an aeroplane crash), the perception of environmental exposures in general, the individual's coping potential and the presence of certain medical conditions.[102,125,130,172,197,270]

The conceptual model of Figure 8 awaits empirical confirmation. However, it is conceivable that annoyance and disturbed sleep quality (including more frequent awakening) associated with noise exposure increase the prevalence of clinically observable health effects in the exposed population. Given the many other factors that influence these effects such pathways are not easily elucidated from epidemiological studies. The committee underlines that the above discussion pertains to chronic noise exposure, *i.e.* for periods of many months to several years. However, this is the relevant situation for noise exposure within an airport operations system.

5.6 Public health impact of noise associated with an airport operations system

Table 10 summarises the relevant health impacts in relation to environmental noise exposure, including exposure to aircraft noise. The classification relates to the evidence, to the severity of an effect and to the number of people affected and is based on the relevant literature as discussed in the previous sections. Table 10 also indicates the observation thresholds based on the evidence to date.

The committee concludes that there is sufficient evidence for a causal relationship between environmental noise exposure and hypertension, ischaemic heart disease, severe annoyance, sleep disturbance and decreased performance of cognitive tasks at school. The available evidence for a causal relationship between environmental noise exposure and effects on the immune system, hormonal system, mental health and performance is limited. Noise-induced general annoyance and sleep disturbance are the most widespread effects of environmental noise.

The impact of environmental noise on human health varies in severity. Whether these changes are of significance to health depends above all on the degree to which the functioning of the organ systems (or social-psychological functioning) is affected, the reversibility and duration of the changes and the possibilities for compensation. For instance, sleeping problems and their influences on mood and performance the next day are to a certain extent part of every normal life. However, at some point, sleeping problems become severe, and normal physical, mental and social functioning is hampered.

Table 10 Overview of reported health related responses to environmental noise exposure.

response	evidence [1]	severity	number affected	observation threshold $L_{Aeq,T}$ in dB(A) [4 5]
hypertension	***	**	**	70, 06-22 h, out doors
ischaemic heart disease	***	***	*	70, 06-22 h, outdoors
annoyance	***	*	***	42[6], 24 h (dn), outdoors

response	evidence [1]	severity	number affected	observation threshold $L_{Aeq,T}$ in dB(A) [4 5]
sleep disturbance, changes in:				
sleep pattern	***	*	***	
awakening	***	**	***	50, SEL, indoors
sleep stages	***	*	***	35, SEL, indoors
subjective sleep quality	***	*	***	40, night, outdoors
heart rate	***	*	***	40, SEL, indoors
mood next day	***	**	*	<60, night, outdoors
hormones	**	*		
performance next day	**	**		
immune system	*	*		
performance at school	***	**	**	70, school, outdoors
performance	**	*		
biochemical effects	**	*		
immune effects	**	*		
birth weight	**	**		
psychiatric disorders	**	***		
psycho-social well-being	**	**		
congenital effects	-	***		

1 * = inadequate, inconclusive evidence, ** = limited evidence, *** = sufficient evidence, - = lack of evidence

2 * = slight, ** = moderate, *** = severe

3 * = susceptible individuals, ** = specific subgroups, *** = substantial part of exposed population; only rated in case of sufficient evidence

4 school = exposure of children at school, dn = day-night level, SEL = sound exposure level

5 - Observation thresholds have been derived if health effects can be linked causally to noise exposure. The values of the observation thresholds for environmental noise-induced hypertension and ischaemic heart disease in terms of the 24 h equivalent sound level are approximately equal to the values presented in the table.

6 - severe annoyance

Chapter **6**

Third party safety

6.1 Overview

In this chapter the committee further discusses accidents in an airport operations system. The focus is on aircraft crashes, in particular on third party risk, *i.e.* the risk to people in the vicinity of the airport. However, as will be discussed below, in managing accident risks, the airport operations systems — including those related to road traffic, businesses and industries in the vicinity — should be dealt with integrally.

In Chapter 2 examples of accidents were listed (Table 5). These are reproduced in Table 11. The public health impacts of accidents are possible injury, loss of life and long term or late health effects to passengers, flying personnel and people in the vicinity of the airport (inhabitants, workers, travellers).

As a primary basis for the following sections the committee has taken five publications: four about Amsterdam Schiphol, viz. two by the RAND corporation [35),114)], one by the Dutch National Aerospace Laboratory [194)] and a paper by Hale also related to Amsterdam Schiphol but of a more general content [105)], and a report about British airports [74)].

Table 11 Examples of categories of accidents due to airport operations.

aircraft crashes during takeoff, climb, descent and landing
aircraft accidents during taxiing and ‘at the gate’ during refuelling and reprovisioning
accidents during aircraft maintenance
ground traffic accidents at the airport
fire (or other type of serious accidents) in passenger areas
accidents in the vicinity of the airport
terrorist actions

6.2 Aircraft accidents

The flight paths from takeoff to cruising altitude and from cruising altitude to landing are, at least partly, above the area in the vicinity of the airport. Here takeoff and landing are supposed to include all phases before and after cruise flight, respectively, including taxiing to and from the runway.

Accident rates can be expressed in a variety of ways. Common metrics are the annual number of accidents, the annual number of accidents per million flights (departures), per million airport related movements (takeoffs and landings), per million flight-kilometres, per million of flight-hours, etc. The latter two are often used in comparing the risks of different modes of transport. All metrics can be further specified as to type of aircraft, weight of aircraft, type of airport, type of airline etc.

Often used metrics to express third party accident risk in terms of effect are: individual risk, population risk and societal risk.[74),95),114)] Individual risk is the probability per year that a person dies from an accident if he or she stays at a given location 24 hours per day, day in day out. Population risk (sometimes also called group risk) is the probability per year that a given number of people or more in a given population die due to accidents. Societal risk (called group risk in the Netherlands [244)]) is the probability per year that a group of persons of a given number or more die due to an accident.

It appears from data as presented in Figure 9 that, world-wide, the annual number of aircraft crashes and fatalities has remained more or less constant during the last 30 years. The accident frequency in terms of the number of crashes per aircraft movement per year decreases (cf. Figure 10), which can be understood in connection with Figure 9 taking into account the increase in air travel. There is some indication that this accident rate is levelling off after a large decrease associated with the introduction of jet aircraft [35),79)] although, at least on average, the crash rate of successive generations of jet planes has decreased considerably [114),194)].

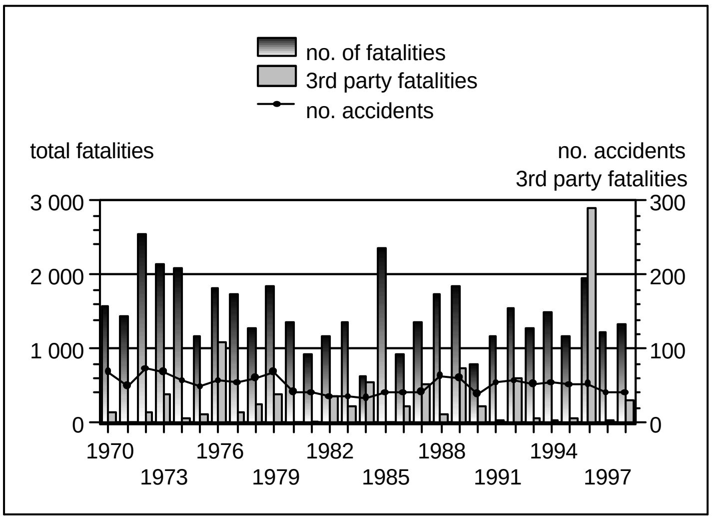


Figure 9 Number of aircraft accidents per year (continuous curve, right-hand scale), total number of fatalities (vertical bars, left hand scale) and number of third party fatalities (vertical bars, right-hand scale). From [200].*

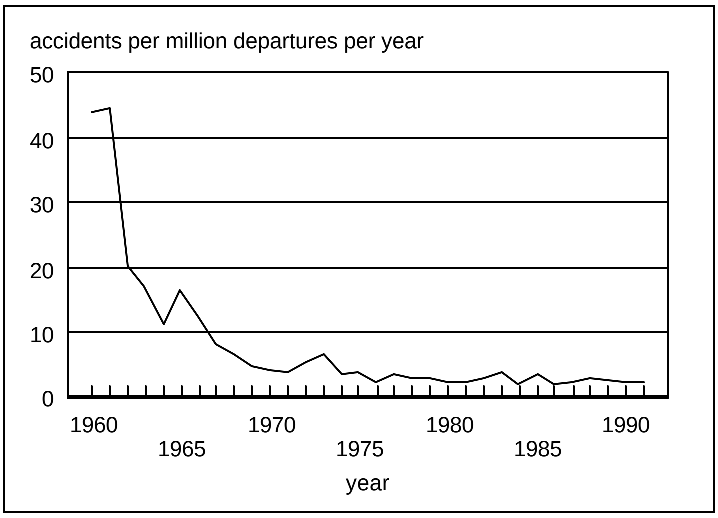


Figure 10 Accident frequency (accidents per million departures per year) between 1960 and 1990 (source: [194]). The accident frequency per million airport related movements (takeoffs and landings) is a factor of 2 lower. Accidents due to sabotage and military action, and accidents with only turbulence and evacuation injury are excluded.

The accident and fatality figures differ somewhat from one report to another, depending on the data sources used and the type of aviation taken into account. From the data in Figure 9 it follows that in the last decades on average 50 crashes occurred per year, resulting in about 1500 fatalities per year, among which 35 individuals of the general population. Hillestad quotes an average of 40 third party fatalities annually for

* In the reference list information on the background of this database is presented.

the period 1970-1992 for commercial air transport.[114] That the type of aviation matters follows from Figure 11. The services of the large airlines are associated with considerably less fatalities per aircraft hour than, e.g., general aviation (non-commercial aviation).

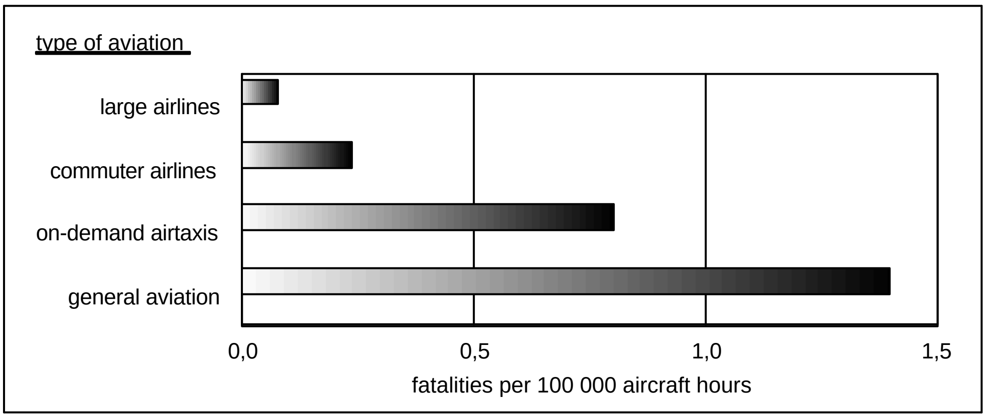


Figure 11 Accidental death rate per 100 000 aircraft hours by type aviation (Figure 1.5 of [114]).

There are also differences in accident frequency between airlines. These differences are supposed to depend on the composition of the fleet operated by the carrier, the quality in terms of instruction and training of personnel and the attention given to maintenance.

The primary victims of aircraft crashes are passengers and crew as was clearly illustrated by Figure 9. With some notable exceptions most aeroplane crashes do not lead to injuries and deaths among population groups in the vicinity of an airport.* Rescuers are also at risk, especially given the fires associated with most aircraft crashes.

Various factors have been shown or are likely to influence the accident rate. Crucial factors are the construction, maintenance, weight and cargo of the aircraft, and the air traffic control and guidance systems. The 'safety culture' in the various organisations involved in flying aircraft is deemed by the committee to be of paramount importance: training, instruction, attention to near-accidents, openness to learning, safety audits and quality control.[100),114),145] This applies specifically to airlines, airport authority, air traffic control, weather and other ground services for processing air planes. The availability and the preparedness of emergency services will affect the seriousness and size of the consequences.

* Examples of accidents with third party fatalities are the crash of an El Al Boeing 747-258F cargo plane into a high rise apartment building in Amsterdam on 4 October 1992 (47 deaths among inhabitants) and the crash of an African Air Antonov 32B cargo plane on a marketplace in Kinshasa adjoining the airport on 8 January 1996 (237 deaths among people at the market).[200]

About two thirds of the aircraft crashes occur during the landing and takeoff part of a flight, *i.e.* at or near airports. The assessment of accident risks is usually carried out in three steps:

- assessing the probability of a crash
- assessing the geographical distribution of crashes
- assessing the consequences of a crash.

Historical accident data can be used for assessing crash risks. Despite the efforts by several organisations to keep databases up to date and complete, the assessment of crash risks still has many uncertainties. For example, the frequency of flights of certain types of aircraft is not exactly known, or the data on the accident consequences in terms of material or personal damage may be incomplete. Also there is the fundamental question as to what extent historical data are relevant to predicting risks in the future. Up to now air transport has become safer in terms of accident frequency (see Figure 10), but is it to be expected that this trend will continue? Answering this question depends on an evaluation of the possibility and impact of technical progress and of human resource management.[119] Can, e.g., successive generations of aircraft be constructed and operated more safely given an increase in air transport? Can such improvements further reduce risk without being offset by other risk factors that are at present considered irrelevant or that are as yet not identified? These questions, that will also be touched upon in the final chapter (Section 9.4), can only be answered with some confidence when all underlying causes of accidents have become clear and are evaluated. The emphasis on underlying causes is only of a relatively recent date.[100]

The consequences of an aircraft crash can be categorised as:

- loss of life, injuries and long term or late health effects (crew, passengers, local population, rescuers)
- economic losses to the airport and airline in question and locally; these losses may indirectly impact on the health and well being of the population
- a more general societal impact related to the aftermath of the accident (cause analysis, care for the victims, etc.). The relationship of this impact to health and well-being of the local population and other people involved is complex and often diffuse; it may contribute to the dread associated with living near airports.

The consequences of a crash depend on nature and location of the accident, on the size, weight and cargo of the aeroplane, and on the availability and preparedness of emergency services.

Generally third party risk assessments are confined to the direct loss of life and injuries of the population. The result of a quantitative assessment of the risk associated with aircraft crashes is usually expressed in the risk metric ‘individual risk’. Outside the perimeter of large airports, even in the direct line of the runways, the individual risk is generally less to much less than one per ten thousand (10^{-4}) per year; at the airport, especially at or in a direct line with the runways, the risk values may be higher.[74)] Around major airports the zones where individual risk is of the order of magnitude of one per hundred thousand (10^{-5}) or one per million (10^{-6}) include residential and business areas (examples: London Heathrow, Amsterdam Schiphol). This is illustrated for Heathrow airport in Figure 12.

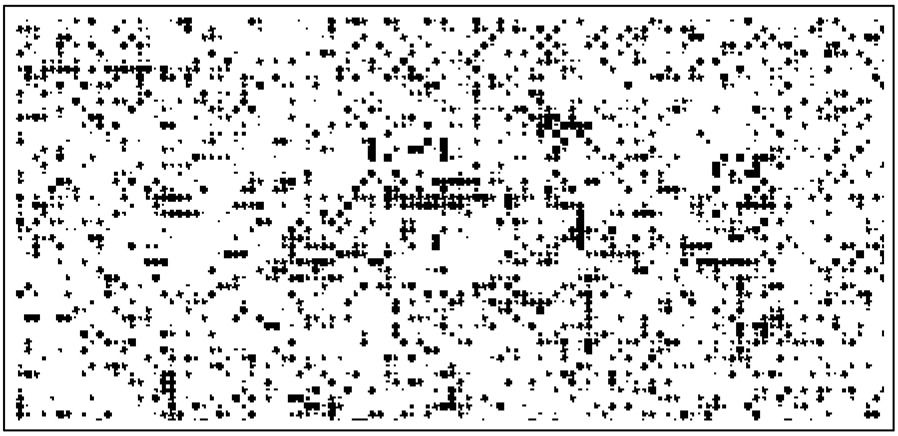


Figure 12 Calculated individual risk (third party safety) contours for Heathrow airport (1994).[74)]

The individual risk metric tells only part of the third party risk story, given the fact that the accident consequences are restricted to the relatively small area around the point of the crash impact and that the time interval between successive crashes at a given location is usually many years. With the trend of increasing weight and passenger capacity of modern aeroplanes the crash rate may decrease but the consequences of a single crash may increase; such trends are not well represented by 'individual risk'. In this respect the population risk and societal risk metrics provide additional insight into the accident risk.

The present crash frequency in the vicinity of an airport, such as Amsterdam Schiphol or London Heathrow, is roughly one to two crashes per ten million movements (takeoffs and landings).[74)] The larger airports have between about 300 thousand and 1 million movements per year (see Section 2.2). This implies an average crash rate in the vicinity of larger airports of roughly one to two per decade.* For Amsterdam Schiphol RAND estimated for 1992 situation that the expected number of third party fatalities is on average 0.5 per year (5 per 10 years). The mean time between aircraft accidents with any third party fatalities — roughly one third of the accidents — would be about 30

* Because of the differences between airports in the distributions of the different aviation services, the type of aircraft calling at an airport, the prevailing weather, etc. presenting a more precise figure is not warranted.

years. The possibility of a year without any crash related fatality among the general population is 98 in 100. [114]

A characteristic of aircraft crashes (and many other types of accidents) is that identifiable victims can be related to the 'exposure'. This contrasts with, e.g., exposure of populations to toxic or radioactive substances due to general environmental pollution, that lead to non-identifiable, 'statistical' victims. The fact that accidents lead to identifiable victims, together with their catastrophic potential, make third party risks, including risks associated with air plane accidents more dreaded than other types of environmental risks (cf. [95], [116]). This perception of the accident risk may contribute to anxiety and interact with other public health impacts of an airport (see Chapter 8 and 5).

6.3 Other accident risks and risk comparison

For non-aircraft accidents in an airport operations system statistics are scarce. The committee cannot now provide information on the risks of such accidents that would enable some form of quantitative risk assessment. Airport fires, accidents during fuelling operations and terrorist attacks have occurred, albeit infrequently. In such situations risk management measures to prevent such occurrences or to mitigate the consequences, similar to such measures to mitigate aircraft accidents, will usually be based on qualitative considerations and driven by economic considerations related to public confidence in the aviation system.

General information does exists on the risk of road traffic accidents. These data may also be helpful to put aircraft crash data into some perspective. In the Netherlands, e.g., in the period 1990-1997 the number of flights was about 4 million (3.8×10^6), excluding so-called terrain flights. [49] In the same period four aircraft crashes with altogether 120 fatalities took place, among which one with a scheduled airliner. [200] * According to Statistics Netherlands, in 1990-1997 about 10 thousand persons died in traffic accidents, half of whom were occupants of passenger cars. US data on fatalities as a function of mode of transport provide a similar picture: the total number of road traffic fatalities is about a factor of 100 larger than aircraft crash fatalities (see Figure 13, [41]).

* 1992 - El Al Boeing at Amsterdam Schiphol with 51 fatalities (4 aircraft occupants); 1994 - KLM Cityhopper Saab at Amsterdam Schiphol with 3 fatalities (all aircraft occupants); 1996 - DC3 Dakota at Den Oever (small aerodrome) with 32 fatalities (all aircraft occupants); 1996 - Hercules at Eindhoven with 34 fatalities (all aircraft occupants).

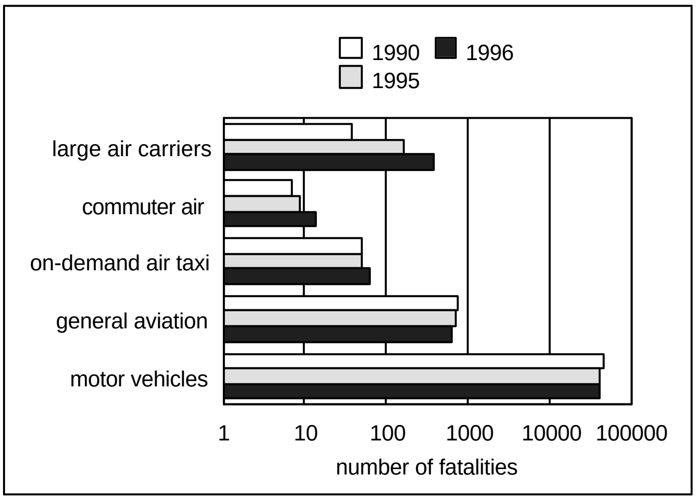


Figure 13 Number of fatalities per year from different modes of air transportation and for road traffic in the US. [41)]

A somewhat different picture is presented by comparing fatalities expressed per *vehicle-distance travelled*. In the US in 1995 there were about 2 deaths per 100 million aircraft miles; the corresponding figure among passenger car occupants is similar: 1,5 per 100 million car miles*. [41)]

Hazardous operations may be carried out in businesses in an airport operations system, directly or indirectly related to the airport activities. Accident risk associated with these operations may be estimated, but only in specific cases. With respect to occupational hazards, the committee expects these not to be out of line with other, similar types of industrial activities, but could not obtain data to confirm this (cf. Section 7.4).

6.4 Evaluation

In absolute numbers aircraft crashes only contribute to a small extent to mortality in the vicinity of a large airport. Figures for road traffic accidents near airports are expected not to differ drastically from other areas with intensive road traffic. Using the Dutch data about 1 per cent of the annual mortality is estimated to be due to traffic accidents. The number of injured persons at fatal traffic accidents is a factor of about 100 higher than the number of fatalities. Data on the public health impact of other types of accidents in an airport operations system do not lend themselves to generalised statements in any quantitative form. In terms of the classification of Chapter 3: accidents do occur (sufficient evidence), the health consequences are always severe and the whole

* For the Netherlands the figure for car travel is somewhat less: in the period 1990-1997 0,7 per 100 million kilometres, *i.e.* 1,1 per 100 million miles.

population in the airports operation system is at risk, be it that only a small number of people will actually be affected.

Chapter 7

Other issues

7.1 Overview

In this chapter the committee deals with:

- soil and water pollution, in particular through de-icing operations at the airport
- the spread of infectious disease through air travel
- occupational health risk at the airport
- visual aspects of the environment.

In addition risk perception will be discussed here.

7.2 Soil and water pollution (de-icing or anti-icing)

Various activities at the airport and elsewhere within an airport operations system have a potential for soil and surface and ground water pollution. Pollution may damage soil and water ecosystems and affect functions of these system, such as agricultural production, drinking water quality and recreational value. The loss of these functions will have a negative impact on public health, although it is not easy to assess the magnitude and severity of the effect.

In industrialised societies the possible serious and long term consequences (also in an economic perspective) of loss of soil, surface and ground water ecosystems have led to policies to avoid or minimise these consequences. The committee judges that the public health impact is relatively minor if such policies are in force. Examples of sources at the airport that may lead to water and soil pollution are leaking underground storage tanks and pipes, fuel spillage or leakage during ground handling of aircraft, washing of aircraft and vehicles and fire-training for which flame-retardant chemicals are used.[178)]

A pollution pathway specific for airports is related to operations to prevent the formation of ice on aircraft parts and runways (de-icing or anti-icing). Of course the operations have also an economic aspect: to avoid airport closure and flight delays and cancellations. The most commonly used de-icing fluids contain ethylene- and propylene-based glycol mixtures as the major component.[178)] The amounts used are considerable; Environment Canada estimated a throughput of 52 thousand cubic metres per year in the US and Canada.[71)] At 'northern' airports de-icing is a main contributor to the contamination of surface water around airports, unless adequate measures to collect used fluid have been taken.

The principal environmental impact of de-icing and anti-icing activities is a decrease of dissolved oxygen levels; this effect is higher for propylene-glycol than for ethylene-glycol and affects fish and other aquatic organisms.[167)] For humans (airport workers) ethylene-glycol is more toxic than propylene-glycol; the reported effects at lower inhalatory exposures are headaches and irritation of eyes and upper respiratory tract. Ingestion of ethylene-glycol leads to kidney damage.[251)] In a study at Montreal airport intake of ethylene-glycol by airport workers was demonstrated, but no chronic kidney damage that could be attributed to the exposure, was observed.[87)]

Toxic effects of de-icing fluids have been shown that appear not to be associated with glycols and that are believed to be associated with de-icing fluid additives.[81), 112), 195)] De-icing fluids contain between 10 and 20 per cent of additives, such as wetting agents, corrosion inhibitors, surfactants, dyes and thickeners.[167)] Cancilla and colleagues identified benzotriazole and tolyltriazoles, commonly used as corrosion inhibitors in anti-icing and coolant formulations (e.g. automobile antifreeze mixtures), as the primary agents in de-icing fluids to be responsible for toxicity in bacteriological tests.[46)] Various other studies on tolyltriazoles have shown that these compounds are moderately to highly ecotoxic.[47), 211)] In a recent study, tolyltriazoles were measured in groundwater water samples from a major Northern American airport in concentrations at which ecotoxicological effects would be expected.[47)] No human effects were reported for tolyltriazoles; however, contact sensitivity after occupational skin exposure to benzotriazole was observed.[69)]

This short overview of de-icing and anti-icing compounds supports the general conclusion above that the primary effects of soil and water pollution from airport operations are to be found in soil and water ecosystems. Effects on humans due to inhalation or ingestion appear to be unlikely in practice.

7.3 Importation of infectious diseases by air traffic

World-wide air traffic increases the potential for transmission of infectious diseases from one country to another. [206] A recent study in Norway reports that every year some cases of serious infectious diseases are imported, especially malaria, shigellosis and typhoid fever. [1] Although travellers and their families run an infection risk, the probability that people living in the airport region will be infected through imported cases is negligible. These citizens might be infected through vectors imported by aircraft (so-called secondary cases), but epidemics are unlikely. [1]

Only for malaria secondary cases have been reported. ‘Airport malaria’ occurs when mosquitoes infected with *Plasmodium falciparum*, originating from airports in regions where malaria transmission occurs, contaminate people around airports and elsewhere. Contamination can take place among airport and airline personnel, among people living in the vicinity of the airport, and among people farther away after a secondary transport of vectors and by vectors transported in luggage. In the past 30 year 63 cases of airport malaria were reported in Western Europe. [88), 101]

Some countries require treatment (disinsection*) of aircraft with insecticides. If resistance against the compounds used increases, the efficacy of such treatment may decrease in the future. This might increase malaria prevalence around the world and increase the risk of infected vectors entering aircraft. [101]

Given the small number of cases, drastic measures appear not to be warranted at present. However, airport authorities and airline companies should keep an eye on the situation in order to prevent any deterioration of the situation.

7.4 Occupational health risk at the airport

Many workers are involved in keeping operations at large airports going. Also many people are employed in businesses in the vicinity of an airport. These occupations, just as all others, involve health benefits and risks. The benefits for health and quality of life are primarily indirect, such as income and social status. The risks are more direct and relate to exposure to physical factors, to ergonomic conditions and to psycho-social and organisational factors. In industrialised societies occupational health risks are generally well regulated and kept within accepted limits, although there remains room for improvement.

* The practice of spraying pesticides on aircraft to kill ‘stowaway’ insects. Many US-registered pesticide products are currently labelled for use in unoccupied aircraft cabins or cargo holds. Active ingredients of those products include organo-phosphates, carbamates, pyrethrins, and synthetic pyrethroids, and more. Some of these products are labelled as ‘residual’ sprays, meaning they are intended to leave long-lasting insect-killing residues. [203]

In general the nature of the work in the vicinity of an airport is not expected to have characteristics specific to an airport operations system. This may be different for work at the airport and for the operation of aircraft. For ground personnel the incidence of musculoskeletal disorders appear higher than what might be generally expected.[86) Some studies have been published on mortality among flying personnel, especially pilots.[27) Accident mortality was clearly increased among pilots in the studies published, but other causes were not exceptionally different from what would be expected.[22) Some studies reported an increased breast cancer risk among female flight attendants.[198) Cosmic radiation was put forward as a possible risk factor, but it is, given the radiation doses involved, not very likely that radiation plays a role; other selection factors related to job requirements should be studied.

The jobs at the airport and 'in the air' may be categorised as:

- aircraft crew (pilots and cabin personnel) - the largest group
- personnel involved in aircraft ground handling, maintenance and repair
- aircraft catering and cleaning, baggage and cargo handling
- personnel involved in passenger services (such as ticketing, check-in, car rental)
- air traffic controllers
- emergency services
- security personnel, including police and customs
- personnel involved in hotel services, shops and restaurants
- administrative personnel.

Not all of these workers run specific occupational risks. For example, the occupational health aspects of administrative work at an airport office will not be different from those of administrative work elsewhere.

The committee will review below data on noise, vibrations, chemicals, fatigue and job stress and ergonomic factors. Published data on actual exposure levels are limited.

Noise and vibrations

Airport and aviation operations — ground and air — are quite noisy. At the ground the most exposed people are ground handling crews and personnel engaged in maintenance, specifically in engine testing. Noise-induced hearing loss, to be expected at equivalent sound levels above 75 dB(A) for the working day (cf. Annex H), has been documented for these workers. Hearing conservation programs are instrumental in avoiding this risk or at least reducing it considerably.[118),218) Especially in older, noisier aircraft crew members run a risk of noise-induced hearing loss.[24) Work in modern civil aviation jet aircraft, also given the fact that crew members would be flying at most half of a full time work year, would not be expected to contribute significantly to noise-induced hearing loss.

Annoyance is another effect to be expected. Apart from long-term health effects this might also affect the functioning of the workers in a negative way and compromise the quality and safety level expected.

Speech interference would be expected at levels common in civil aircraft. Interference with the communication between air traffic control and pilots has been studied extensively in military aviation (cf. [165]). Electronic amplification to improve communication may have a counterproductive effect as it increases sound levels above hearing loss thresholds. Solutions have been proposed and practised in using anti-noise generators to reduce general noise levels. For cabin crew noise levels may interfere with communication between crew and passengers and may contribute to passenger dissatisfaction and thus to job stress for the flight attendants.

The possibility that noise exposure induces hypertension and thus susceptibility for cardiovascular disease, has also received some attention. A recent Italian study suggests that noise is a factor for hypertension among pilots and may place them at increased risk for cardiovascular disease. [240]

Aviation personnel is also exposed to vibrations generated by aircraft engines. In civil aviation this does not appear to be a major problem, as the only literature retrieved on this subject is related to helicopter pilots. [149] *

Toxic substances

Platform and repair and maintenance personnel are exposed to toxic chemicals. At the platform evaporated jet fuel and combustion products from aircraft and ground vehicle engines and other equipment are the chemicals of concern. Levels are definitely higher than in the general environment, but for individual compounds will usually be below occupational limit values. Given the amount of fuel burned, aircraft exhaust will be the major contributor to air pollution at the ramp area, apron and runways, but as airports are open spaces, the pollution is expected to disperse, depending on the prevailing meteorological conditions.

In aircraft maintenance and repair a variety of solvents, paints, resins, sealants and metal compounds are used. Epidemiological studies in the aircraft manufacture industry have not shown an increase in solvent related impairments, although dermal effects were noted. [219], [221], [229], [253] It appears that, given an adequate level of occupational

* Recently a Portuguese research group published a series of articles on vibroacoustic disease among military aircraft maintenance and repair personnel due to exposure to large amplitude low frequency noise exposure. [48]

hygiene, occupational risks related to these or other exposures (e.g. metals) can be reduced to accepted levels.

At northern airports platform workers are exposed to de-icing compounds (See Section 7.2).

Fatigue, job stress

Several jobs in the aviation system are quite demanding psychologically due to safety reasons, irregular work schedules or due to having to deal with demanding customers. Especially air traffic controllers and pilots have been the target of studies on vigilance and fatigue. Factors that may negatively affect performance and were confirmed empirically are shift work and — for flying personnel — time zone differences on long flights.[44),157),209)] For the personnel in question this situation may contribute to job stress. Apart from adapting work schedules and promoting good sleep habits, it is not easy to influence and reduce job stress, as a variety of factors related to the individual's personality and private life are of importance.[59)]

Surprisingly few data were found on job stress among cabin personnel and ground staff involved with airline passengers (check-in, ticketing, etc.). There is ample anecdotal evidence that demanding customers can behave quite aggressively (not only in aviation but in other modes of public transport as well).

Ergonomic factors

Musculoskeletal disorders, especially low back pain, appear to be more frequent among aviation ground workers than in general.[86)] Especially cargo and baggage handling personnel are at risk. Increasing automation may have a beneficial impact, but probably more in terms of the number of cases (fewer workers are required to perform the jobs) than in terms of the seriousness of the individual impairment.

From this short overview the committee concludes that large airports and aviation involve occupations with specific risks. However, the literature data reviewed do not warrant the conclusion that occupational health problems are greater than in comparable industries or activities. As concerns for the quality of services and for safety are paramount in the aviation industry, the quality control systems introduced may also affect occupational health risks in a beneficial way. The committee concludes that activities within an airport operations system, do affect occupational health and quality of life, but not in any extraordinary way.

7.5 Appearance of the environment

Everyday experience points to the appearance of the environment as a factor that determines perceived environmental quality. The appearance of a neighbourhood is an important factor in selecting a house insofar as people have a choice. Moreover, the view available from within a residence is a noteworthy factor in residential satisfaction.[60),132)] For everyday leisure time as well as for extended vacations, many people seek out parks, nature reserves, beaches, old towns and villages, and other types of natural and built surroundings that not only afford opportunities for particular activities, but that are also pleasing to the eye.

Numerous studies of visual environmental preferences indicate that European and North American adults consistently register greater liking for environments that can be classified as natural, given a predominance of trees, water, or other natural features.[107),133)] When there are structures in a predominantly natural landscape, preference for the landscape tends to be greater to the extent that those structures are congruent with the natural surroundings.[237),254),272),273)] Incongruent structures reduce liking for the landscape in which they are embedded.

The importance of the appearance of the environment, and in particular the natural character of its appearance, is an issue that extends beyond aesthetic judgements. Non-spectacular natural environments have been compared with commonplace urban environments in field and laboratory experiments with respect to their relative effects on emotional states, physiology, and capacity to focus attention. These studies have had a primary concern for the relative stress reducing or restorative power of the natural environment. In field experiments[108),109)] and in laboratory experiments that used photographic slides or videotapes to represent the comparison environments[111),248)], a restorative advantage of natural environments has been found in emotional states (e.g., greater positive affect, less anger) after standardised administration of a stressor. Similar differences have been found in physiological indicators of autonomic arousal (e.g., systolic blood pressure) in laboratory[189),248)] and in field experiments[108)]. A restorative advantage of natural environments in the ability to focus attention has been found with standard performance measures in field experiments.[110)] This latter effect is noteworthy in the light of the heavy demands placed on the capacity for concentration in contemporary occupations and in urban life. Salutary effects of natural visual environments have also been found in field studies with patients recovering from medical treatment. Viewing natural scenes appears to have had a beneficial effect on patient stress and certain health outcomes such as pain.[247),250)]

The mechanisms behind these observations have not yet been elucidated. Several evolutionary explanations have been developed to account for environmental preferences. These regard a biological preparedness to respond positively to visual configurations that would have been of significance for survival in prehistoric natural environments.[13),133),186),246),249)] Other explanations refer to sociocultural influences on the learning of preferences (for reviews, see [25),109),141)]) Evolutionary, cultural, and individual learning explanations are not necessarily mutually exclusive, and there have been attempts at integration.[13),33),34),107),133)]

Two bodies of theory have extended environmental preference explanations to explicitly consider restorative effects of environments. Both of these restoration theories start from evolutionary assumptions, but one focuses on emotional and physiological stress recovery.[246),248)] whereas the other focuses on recovery of a depleted capacity for directed attention[133)]. Hartig and colleagues have investigated restoration along attentional, emotional, and physiological dimensions with a view to the possibility that attention restoration and psychophysiological stress recovery are processes that can run concurrently, but that require differing amounts of time, with recovery of attention capacity being more time intensive.[108),110),111)]

Within the framework of the present report, the importance of the appearance of the environment relates to the physical planning of an airport operations system region. It has already been mentioned that the surroundings of large airports have a tendency to change into urbanised settings.[135)] One implication of this research is that when natural surroundings are eliminated or negatively impacted by development, there will likely be a reduction in opportunities for restoration. Thus, an increase in adaptive demands is concurrent with a decrease in opportunities for recovery. Over time this may well adversely affect public health. Is it possible to guide development in such a way, as by retaining or introducing natural ('green') areas in the landscape, that changes in the appearance of the environment less negatively affect public health? Laboratory studies and the type of field studies mentioned cannot easily answer such questions. Yet such measures would be consistent with measures that individuals in large numbers undertake on their own through selection of residential locations, through gardening and landscaping around the home, and so forth.

To what extent would a positive influence of the appearance of the environment on public health be diminished or disappear given the presence of other stressors, such as noise? In the US, field studies have been performed on the impact of aircraft noise (usually from sight-seeing flights) on the way people experience natural parks. The aircraft noise is valued negatively, but it is not clear to what extent that is due to interference with the experience of the natural surroundings.[98)]

7.6 Perception of public health risk

In evaluating public health risks individuals and institutions appear to select and weigh attributes of the risk, and of the benefits they may acquire in running the risk.[202] Risk perception has been a research subject for the past two decades (see recent reviews of Fischhoff *et al.*[82] and of Renn[202]), but there are still discussions about the general validity and interpretation of the research results (see a recent paper of Sjöberg[217]). Many risk perception studies were concerned with large accidents, particularly those of the chemical and nuclear energy industry, or were performed with students in laboratory situations.

However, a picture is emerging pointing to various risk attributes people (experts, decision makers and lay people alike) take into account in evaluating risk and deciding on undertaking activities that generate the risk. The resulting judgements will depend on the knowledge available (expert-laymen difference), social environment (e.g. difference between industrial and university scientists[144]) and a variety of risk attributes. Table 12 presents a list of risk attributes and their influence on risk tolerance. Similar and more extensive lists have been presented by Vlek[256), 257] and by Sjöberg and Drottz-Sjöberg.[216]

Table 12 Qualitative risk attributes that affect risk perception.[202]

attribute	direction of influence
personal control	increases risk tolerance
institutional control	depends on confidence in institutional performance
voluntariness	increases risk tolerance
familiarity	increases risk tolerance
dread	decreases risk tolerance
inequitable distribution of risk and benefits	depends on individual utility, strong social incentive for rejecting risks
artificiality of risk source	amplifies attention to risk, often decreases risk tolerance
blame	increases quest for social and political responses

It would be false to presume that people just tick off a list of factors in order to come to a judgement on risks; they act much more intuitively. Psychometric research, particularly that of Slovic's group, suggests that one might categorise risk using two composite dimensions: novelty — risks are rated higher if they are unknown, involuntary and have delayed effects, and dread — risks are rated higher as consequences are judged to be fatal and involve many people.[82] Examples of high novelty risks are food colourings and spray cans, whereas mountain climbing scores low on the novelty dimension. Nuclear power and commercial aviation score high on the dread dimension, contrary to power mowers and skiing that are found on the low side. Renn used this data to derive four characteristic categories ('semantic images') of risk, that are presented in Table 13. Sjöberg, who also studied risk decisions of everyday life, proposes to interpret decisions on risk taking according to a simple scheme: people decide to take a risk by judging the perceived probability (car accidents are judged of small probability and therefore neglected), whereas in demanding (or taking) mitigation measures the consequences play a predominant role (traffic lights at a pedestrian crossing near a primary school). His view is not at odds with the earlier research results as a judgement of a negligible probability may well be influenced by, e.g., the degree of novelty. Furthermore, risks that score high on the dread factor and thus on the severity of the consequences are often risks that are out of control for most people and against which protection will be demanded.

Table 13 The four semantic images of risk in public perception. [202] See also Annex I.

semantic image	attributes
pending danger (Damocles' sword)	artificial risk source large catastrophic potential inequitable risk-benefit distribution perception of randomness as a threat
slow killers (Pandora's box)	(artificial) ingredient in food, water, or air delayed effects; non-catastrophic contingent on information rather than experience quest for deterministic risk management strong incentive for blame
cost-benefit ratio (Athena's scale)	confined to monetary gains and losses orientation towards variance of distribution rather than expected value asymmetry between risks and gains dominance of probabilistic thinking
avocational thrill (Hercules' image)	personal control over degree of risk personal skills necessary to master danger voluntary activity non-catastrophic consequences

Only a limited number of studies on the perception of risks at large airports have been performed. Within the framework of the Amsterdam Schiphol health impact assessment a survey on annoyance, sleep disturbance and perceived health was carried out; also questions on risk perception were included.[239] In the Amsterdam Schiphol region 10 to 20 per cent of the population is concerned about aircraft crashes. The perceived risk is related to the level of aircraft noise, although this effect appears to level off at the highest (outdoor) noise exposures. Furthermore people are more concerned about the health effects of air pollution from aircraft than about those of aircraft noise (40 against 20 per cent). A British study sought to elicit relative judgements of the population living near airports in order to determine public safety zones for third party safety.[74] Only a few considered individual (third party) risks of about 1 in 10 000 per year from aircraft crashes too small to worry about, but an appreciable number of interviewed persons considered financial compensation instead of relocation as acceptable. On the other hand, an individual risk level of 1 in 1 000 000 per year required financial compensation according to a fair amount of people. Another finding was that there was only a slight preference for spending resources on avoiding a large accident above using the money for mitigating a series of smaller ones. Goldstein and colleagues have proposed to use changes in lifestyle, e.g. moving the children's bedroom to the basement, as a risk communication tool.[97] Such a tool could be used in risk comparisons, but its application near airports has not been studied as yet.

The attributes of Table 12 can be applied to the perceptions of people living in the vicinity of the airport. The risks are outside their personal control*, involuntary and artificial. There is a high degree of institutional control, but in the case of airports the direction to which this influences risk perception is difficult to predict as the confidence in the institutions may strongly vary from one person to another and from one institution to another. This variation between population groups and in time depends, *inter alia*, on the decision making process, the communication strategy of the airport operator and the authorities and unforeseen events like serious accidents; the Amsterdam Schiphol situation provides examples. All risk factors and associated effects — possibly those related to air pollution excepted — are familiar and for crash risks dread is a relevant attribute, although the British study suggests that accident size is not a very strong factor. The role of 'inequity' and 'blame' is more difficult to pinpoint. A significant fraction of the population in the vicinity of the airport is economically dependent on the airport operations system, and so experiences both the bright and the dark side of the airport operations. Furthermore, in western industrialised societies the use of air transport is becoming available to people of all social strata, especially as a means for reaching recreational destinations. Although the committee is not aware of empirical evidence in this respect, it hypothesises that considerations of 'inequity' do not strongly shape risk perception in the airports' case. 'Blame' does play a role, especially when decisions on

* Alternating runway use (see case study Heathrow, Annex C) is an example of a measure that may transfer some degree of control to the affected people.

expansion plans are being developed, as is demonstrated at Amsterdam Schiphol and at London Heathrow. Operating limits are easily exceeded and for economic reasons this situation is tolerated. Citizen groups are then triggered to attribute blame to the licensing authorities.* This evaluation does not lead to a clear conclusion about risk tolerance, as several factors may point in different directions.

Also referring to the semantic images of Table 13 does not provide more insight. If crash risk would dominate perception, 'pending danger' would be an appropriate image. However, risks associated with air pollution point to the 'slow killers' image. In the case studies (Annex C), air pollution associated with the airport operations system did not appear to be a strong public issue, which may be due to the fact that pollution is perceived as not being associated with aeroplanes but with road traffic. However, survey data for Amsterdam Schiphol indicated strong concern for health effects due to air pollution associated with aircraft operations.

Interpreting the scarce data on risk perception at large airports, the committee concludes that noise and odour trigger awareness of the airport and its operations. For groups of people, possibly the more noise sensitive ones, noise exposure is related to fear and anxiety for aircraft crashes (and vice versa), and probably decreases risk tolerance, although the chance of being a crash victim is remote for people living near large airports (Chapter 6).** Generally speaking there is not a common risk perception among people living in the airport operations system. However, crash risk aside, there is no indication that some groups have strong misconceptions on the impact of the airport and related operations on their health and quality of life. At Amsterdam Schiphol an estimated 80 per cent of the people living near the airport rated their general health as good and 20 per cent as poor, figures that correspond well with data for the Netherlands as a whole. The responses correlated with (calculated) aircraft noise exposures, *i.e.* there is a tendency for rating perceived health lower at higher noise levels. This would be expected from the data presented in Chapter 5.

* The Munich and Berlin case studies (Annex C) show that authorities and airport operators at the outset ask for approval for additional airport capacity that might be needed only after a decade or more. In this way they avoid lengthy approval procedures for expansion and, referring to Table 13, they may thus lessen the significance of the 'blame' attribute.

** Calculated third party safety risks around Amsterdam Schiphol do at some locations exceed the standards applied in the Netherlands for residential areas around industrial installations.[35), 114)]

Chapter **8**

Public health and large airports

8.1 Lack of comprehensive assessment

In Chapter 2 the committee introduced the airport operations system as a framework for discussing the public health effects of large airports. In the subsequent chapters the committee reviewed exposure and effect data for major environmental factors such as air pollution, noise and safety risk. For people living and working in the vicinity of or at a large airport this exposure inevitably has a cumulative character. Apart from being multi-factorial, it has spatial and temporal aspects. At least in a region of a few hundred square kilometres around an airport everyday activities at different places — such as shopping, going to school, commuting to work, working at the airport or a local business, local recreational and sporting activities — are affected. Furthermore, as history demonstrates large airports do not stop operations after a few years, but continue operating for periods of several decades at least. So people can only escape the influence of the airport operations system in their everyday life by moving elsewhere.

Is the public health impact of the cumulative exposure to environmental factors within the airport operations system the sum of the effects induced by the single factors, or does the cumulative exposure introduce extra (or reduce) effects? Empirically such a question could be answered on the basis of environmental epidemiological studies and health impact assessments. Most airport related public health studies investigated the relationships between single factors, such as noise, and single effects, such as annoyance or learning difficulties. This work has provided important pieces to complete the jigsaw puzzle of the public health impact of airports. However, the committee notes that in the scientific literature there is a lack of reports on studies directed at elucidating accumulation effects. Such research is deemed absolutely necessary to give robust answers to the central question of the present report.

The committee has been informed on the present state of the health impact assessment at Amsterdam Schiphol co-ordinated by the Dutch National Institute of Public Health and the Environment (RIVM).[84] This study is an example of the type of research the committee advocates.* Unfortunately such studies are the exception rather than the rule. As is illustrated by the case studies reported in Annex C, only a limited assessment of the public health impact of an airport is often part of an environmental impact statement. At London Heathrow, in relation to the Terminal 5 inquiry (see Annex C), several studies on noise, air pollution and aircraft crash risk have been performed.

So the major question of the Netherlands ministers to the Health Council cannot be answered on a sound basis of empirical research. The committee strongly recommends that integrated public health impact assessment should be performed routinely at each large airport, to be followed with a comprehensive, efficient monitoring programme, in order to timely detect improvement in or deterioration of the situation. Such a research and monitoring programme requires international co-operation; the international organisations that could be instrumental in this respect already exist.

8.2 Do large airports have an impact on public health?

'Do large airports have an impact on public health?' The committee answers this question with a simple; yes. In the foregoing chapters evidence was reviewed that document the impact of environmental factors on public health. Furthermore, in the discussion of models for the relationship between environmental factors and public health in Chapter 3 (Figure 3, Figure 4) the committee indicated that for specific individuals of specific population groups an environment related deterioration of quality of life, with which large segments of the exposed population are able to cope, may lead to clinically observable health effects.

Some factors operate, at least to some extent, in a beneficial direction. By deliberate land use and landscape planning, the appearance of the living environment may contribute positively to public health.** The satisfaction of people with their living environment is the result of an evaluation based on a variety of attributes, such as are listed in Table 15, Annex D (cf. [152] and references quoted). This was also observed in one of the health impact assessment studies at Amsterdam Schiphol.[84], [239] Some

* The Dutch name of the study is: Gezondheidskundige Evaluatie Schiphol (GES). The committee strongly recommends that the results of 'GES' are all published in the international scientific literature.

** Many airport authorities have planted trees to reduce noise levels and to make the landscape more pleasant.[63]

people expressed satisfaction with their residential environment even though they felt seriously annoyed by noise. It appears that compensatory mechanisms operate. Some empirical evidence that different attributes may operate in different directions comes from a study into the variation of house prices in the vicinity of Manchester airport.[241] Noise appeared to be a negative factor, and airport access a positive one, which in some situations outweighed the noise impact. The evaluation of one's living environment, including the degree of personal control of that environment will be reflected in the way and the degree the airport operations system affects public health. The committee will come back to this point in the next chapter.

From a policy point of view the following two, related specific questions may be more relevant than the general one in the title of this section. Is the airport operations system characterised by specific public health risks? Are the public health risks in the airport operations system different from elsewhere? The first question is relatively easily answered on the basis of the data presented above. The second question is more difficult, as it is not clear what to take as a reference risk.

Aircraft noise and the possibility of aircraft accidents are risk factors specific to the airport operations system. Also the cumulation of these risk factors with others could be considered as typical. In Section 7.4 the committee has discussed some specific occupational health risks.

But how does this risk compare with risks in other settings? This question is not easy to answer, at least not within the framework of the present report which discusses a large airport in general. The problem is twofold: (1) what setting should be used as a reference, and (2) what are the relevant attributes to compare the two settings. One could argue that an industrial setting would be an appropriate reference; in the Netherlands one might compare the Amsterdam Schiphol system with the Rijnmond area near Rotterdam with its ports and chemical industries. Others might prefer a rural surrounding as a reference, *i.e.* the situation (often long ago) before the airport was there. The committee is of the opinion that, from a scientific point of view, it is impossible and hardly fruitful to recommend a common reference point for all situations. If risk comparison is deemed useful it should be agreed upon in a specific situation through the political process.

If a risk comparison is part of policy decision process the choice of risk attributes deserves particular attention, as the comparison outcome is strongly dependent on the attributes chosen. In Dutch environmental policy risk comparison is usually done on a factor by factor basis.[94] For example for third party accident risk the individual risk measure (see Section 6.2) is usually chosen for comparisons (and norm setting), and for noise exposure the number of people that are highly annoyed is used. However, one may also opt for aggregation methods, in which several attributes are combined in a single or a few measures.[95] The final choice of attributes is not something to be made by expert committees, but by stakeholders and decision makers.[55),95)] The role of experts, such as the present committee, is to estimate risks using the preferred attributes and to delineate the uncertainties in the estimates.

8.3 Environmental factors

In the foregoing chapters the committee evaluated the evidence for the impact of single environmental factors on public health. The evidence, in so far rated as sufficient, is summarised in Table 14.

Table 14 Public health effects of environmental factors in an airport operations system for which the committee judges there to be sufficient evidence.

response	severity [1]	number affected [2]	observation threshold
responses to air pollution			
premature death (response after an episode in susceptible groups)	***	*	data do not allow the determination of thresholds for the responses to air pollution
aggravation of respiratory and cardiovascular disorders after an episode (resulting in hospital admissions)	***	*	
decreased lung function after an episode	*	[3]	
premature death (decrease in life expectancy) due to chronic exposure	***	*	
reduced lung function due to chronic exposure	**	**	
increase in chronic respiratory conditions (bronchitis) due to chronic exposure	**	**	
odour annoyance from chronic exposure	*	***	
response to odour			
annoyance	*	***	threshold difficult to define
response to environmental noise exposure			
hypertension	**	**	equiv. outdoors sound level (06-22 h) of 70 dB(A)

response	severity [1]	number affected [2]	observation threshold
ischaemic heart disease	***	*	equiv. outdoors sound level (06-22 h) of 70 dB(A)
annoyance	*	***	outdoors day-night level of 42 dB(A) [4]
sleep disturbance	**	***	depending on effect, indoors SEL of 35-50 dB(A) [5]
performance at school	**	**	equiv. outdoors sound level (school hours) of 70 dB(A)
aircraft crashes			
death, severe injury	***	*	[6]

1 * = slight, ** = moderate, *** = severe

2 * = susceptible individuals, ** = specific subgroups, *** = substantial part of exposed population

3 A mean fall in lung function has been observed, but it is difficult to classify the number affected on the basis of the available data.

4 Threshold for 'severe annoyance'; the day-night level is the equivalent sound level over 24 hours, with the sound levels during the night (period of 22:00 - 07:00) increased by 10 dB(A).

5 SEL is the equivalent sound level during the noise event normalised to a period of one second

6 the whole population is at risk, but only very few are affected

Other responses have been described in the literature, some of which are rated by the committee as severe, but the scientific evidence to date is considered to be limited, inadequate or lacking. The extent to which such effects warrant prevention or protection measures is not for the committee to decide (see also Section 9.3). In the chapters above the committee endeavoured to describe the responses in such a way that appropriate decisions can be made through the political process.

Chapter 9

The way ahead

9.1 Strategic options

At present civil aviation is expanding in terms of number of flights, number of passengers transported and destinations served by scheduled flights. Government policy was identified as a primary cause for the development of hub-and-spoke networks (see Section 2.1)[62]. Some have argued that point-to-point networks might become the more profitable choice for the airlines, depending on how governments use taxation tools, e.g. to compensate for environmental 'costs'. [179] However, an expanding civil aviation network with major 'hubs' as network nodes seems to be the most plausible development, at least in the short run. If this is the case, the choice that governments, especially those of smaller countries such as the Netherlands, have with respect to airport development is: either give room to expansion or let the airport develop into a secondary destination. In the latter case it is easier to protect public health. If expansion is allowed or even stimulated and if the airport succeeds in becoming and remaining a hub in the global aviation network (*i.e.* a large airport in the context of the present report) the room for manoeuvring with respect to public health interests is limited.* It is clear that questions related to the expansion of large airports are not simple operational questions, but are of a strategic nature.

* On request by the Netherlands Government RAND has developed scenario's for the development of civil aviation and the position of the Netherlands in this development. The supposition whether a hub airport is located in the Netherlands strongly determines the consequences of a given scenario for the country. [260, 261]

Policy decisions, especially those of strategic nature, require normative decisions. The Netherlands Scientific Council for Government Policy analysed the notion of sustainable development and risk policy in terms of different views on environmental resilience and on the possibilities and desirability of changes in production methods and consumption.[264] The Council argued that risks can not be determined by scientific endeavour alone, but that risk estimates also depend on normative principles. The committee adheres to a similar view on the public health risks associated with aviation in general and airports in particular. In countries that have a large stake in civil aviation there will be general consensus in policy circles, that public health (including quality of life) should be safeguarded and that governments have to play a controlling role in this respect. However, those believing that a flowering economy is a prime factor in fostering public health will strike a different balance between airport expansion and efforts to control environmental factors that have a direct health and quality of life impact, than those who believe that already now aviation is threatening life on earth in the long run. Furthermore, several intermediate views can be envisaged. The preference for, e.g., building an airport in the North Sea* to replace Amsterdam Schiphol in order to safeguard public health, above the cheaper option of controlled expansion at the present location, or some other alternative, will depend on the way public health risks and consequences are evaluated.

A previous Health Council Committee pointed to the necessity of creating an ‘environment’ in which justice is done to the variety of political views and cultures, when preparing and taking strategic risk management decisions.[95] That this is easier said then done is demonstrated by the situation at Amsterdam Schiphol. In spite of formalised channels for stakeholder participation, the differences in interests often result in distrust and clashes.[193] Another problem is the large number of people affected and the difficulty of representing their interests in a meaningful way. Not withstanding this, the present committee supports the recommendation of the former Health Council committee, that ties in with recommendations made elsewhere, e.g. by the US Presidential/Congressional Committee on Risk Assessment and Risk Management[55] and by de EU Trustnet Concerted Action**. Following these proposals might enable

* Examples of airports on an artificial island are Kansai International Airport at Osaka, Japan and Chek Lap Kok at Hong Kong, China.

** The European Concerted Action on Risk Governance (TRUSTNET) involves some 80 participants: national and European regulators, experts (risk assessment and safety, regulation, sociology, psychology, economics, public health), industry representatives, and local authorities. The aims of TRUSTNET are: (1) to determine the factors which influence the credibility, the effectiveness and the legitimacy of the regulatory framework of hazardous activities, (2) to set up an European Network of decision makers in the civil services, government departments, experts and stakeholders to identify deficiencies and other features of the problems, (3) to develop more coherent, comprehensive and equitable approaches for evaluating, comparing and managing health and environmental risks, and (4) to establish a common basis for an interdisciplinary approach involving the stakeholders to determine the main thrust for a future research programme covering fruitful discussion between the parties involved, including the population living and working within the airport operations system, before government takes decisions about accepting certain risks and about associated conditions.

The decisions related to establishing or expanding a large airport are of a strategic nature. Such type of decisions: [95]

- require the development of new decision methods and criteria
- should be based on consistent arguments and a well thought-out vision
- take various protection objectives into account
- balance the societal benefit with the risk in multiparty interactions
  should be efficient after consideration of opportunity costs.

The main message is that in the case of a large airports no established protocol exist, as the case studies (Annex C) illustrate. Of course one might draw lessons from the course of the events elsewhere, especially with respect to technological developments and boundaries to these developments, but each case requires a new strategy that fits in with the local and national political culture. Given the strategic nature of the decisions involved it is inevitable that general questions related to mobility and mobility structure have also to be discussed. This will imply comparing the public health impact of different modes of transport. A current example is the replacement of relatively short distance air travel, up to about 600 km, in Europe by high speed train travel; this discussion is supported by economic and behavioural assessment but hardly by a full comparative environmental and public health impact assessment. [261]

9.2 Land use planning and zoning

Land use planning, including zoning, is one of the obvious instruments to shape developments at and around large airports such that public health is safeguarded.* The effectiveness of this instrument will considerably differ from one country to another, depending on the prevailing political culture. However, it has been found that the application of different principles for restricting hazardous activities may lead to similar outcomes. [51] Even in the Netherlands, with a long tradition of strict planning procedures with formalised public involvement procedures, suggestions have been made, particularly with respect to the development of infrastructure like the expansion of Amsterdam Schiphol, for the system to be adjusted in a way that enables integrated assessment and stakeholder participation. [266] One might envisage that the integrated public health assessment structure proposed below can also play a role in this respect.

industrial and natural risks, protection of health and environment. The TRUSTNET report will be published in 1999.

* In a recent book Dempsey presents an overview of the application of land use planning instruments at large airports in different parts of the world. [63]

Several measures affecting land use have been proposed, that might enhance safety (and exposure to other environmental factors as well).[114), 35)] Examples are public safety zones — practised in the UK and the Netherlands — restricting residential development within certain crash risk and noise contours, restricting industrial development at certain locations, etcetera. As was indicated above, the 'greenness' of the landscape — partly controlled through land use planning rules — will influence the visual impact of the environment, may be instrumental in reducing noise levels, will restrict urbanisation and industrialisation ('green corridors') and so might impact on public health in a beneficial way. Here there would be a possibility for co-ordinating such measures with efforts directed at ecological restoration.

In the vicinity of airports zoning appears to be the common policy instrument to restrict certain practices. The zones are often delineated by contours determined by environmental noise levels — expressed in a suitable metric[96)] — and by calculated individual and societal risk levels. Usually a distinction is made between existing and new activities. The first may be tolerated or mitigation measures are implemented, whereas in the latter case the activities are forbidden or tolerated under strict conditions. For example in a zone with the highest noise levels existing houses may be insulated, either financed publicly or by the airport authority, but the construction of new houses would not be allowed. Safety measures discussed in the Netherlands include prohibiting residential buildings in the inner safety zone, as well as businesses with a large number of employees.

Here too the committee underlines the necessity of integration in view of an effective and efficient public health protection. Safety and noise contours have a similar form (compare Figure 7 with Figure 12), which will facilitate some form of integration. Land use planning areas, at least in the Netherlands, are often determined by historical landscape elements, such as rivers and woods, and infrastructure elements such as roads and waterways. Given the order of magnitude character of accident risk estimates and the variability in exposure-response relationships for noise induced effects, the committee advocates a flexible implementation of zones that would also enable integration between public health zones and land use planning areas. Similar proposals have been made by others.[227)] This would improve the transparency of the zoning instrument and embed the procedures for establishing zones in the physical planning policy structure.

With respect to air pollution, zoning seems a less suitable instrument, as air pollutant levels are much less geographically determined than noise levels (see Figure 6). Traffic corridors may be candidates for zoning, both with respect to air pollution and noise.

9.3 Tolerability

The question arises as to what extent one could manipulate the various factors that determine benefits and the public health disadvantages of working and, particularly, of living in the airport operations system in such a way that benefits (including public health benefits) are maximised and negative impacts are reduced. Apart from reducing exposures — a primary risk management target — the structured list of attributes that are important in valuing the living environment in Annex D may provide an entrance. Several of the desired factors can be controlled, at least partly, by public or private institutions. Examples are public gardens, trees, community facilities such as libraries and schools, and natural elements in the landscape between residential settings.* Factors such as the degree of openness of the communication between the government and the airport authorities on the one hand and the population and other stakeholders concerned about operations and developments on the other, and adjusting, e.g., flight times, flight paths and runway use, may to certain extent make the negative effects of living near the airport tolerable. In following such an approach people in deprived situations (accumulations of environmental factors at the same time together with low social-economic status) would warrant special attention, at least if policy-makers would weight environmental fairness or equity.

Such a policy approach differs from the zoning one discussed in the previous section, that is based on the enforcement by the public authorities of a predetermined level of environmental and public health quality. Here the attainable quality of the living environment is the outcome of a communication and negotiation process between stakeholders, that should — ideally — lead to a situation tolerable for the affected populations groups. The process is a dynamic one: the airport operations system will change as the aviation industry will change and likewise will the public health impacts and the benefits change and thus the risk levels tolerated by the affected population.

Which method or combination of methods is used depends on the political culture in the state or country concerned and the preferences of the stakeholders involved. In the Netherlands traditionally an approach in which ‘universal’ environmental and health standards would apply to all citizens was and probably still is preferred.[115), 244)] However, as a consequence of deregulation policies and stimulating market forces, other approaches may be deemed more effective and become accepted. In this respect the committee points again to the Health Council reports on environmental risk management, that advocated a structuring of the decision-making process depending on the strategic character of the decision to be made (see Section 9.1) 95) For example, the

* For example, in 1998/1999 BAA, the operator of London Heathrow and six other British airports, spent 200.000 sterling (about 300.000 Euro) on the local environment and local education.[15)]

decision about relocating the airport operations of Amsterdam Schiphol to an artificial island in the North Sea is of a different, more encompassing and more uncertain, nature than strengthening the curfew on night flights, even though both have strategic consequences. This difference will have an impact on the decision-making process in each case and on the policy principles and arguments used to reach a decision.

9.4 Technology and quality control

An expanding global civil aviation network may not only lead to intolerable public health risks, but will also be unable to function operationally at a certain point in time, unless technology changes. This threatening scenario has been recognised in aviation circles for some time. One solution to accommodate the increasing number of passengers and flights is the use of improved and new technology. The National Aeronautics & Space Administration (NASA) in the USA has proposed an ambitious technology development programme to address these issues.[119] The safety goals set are:

- aircraft and aviation systems — prevent malfunctions by improved design, quality controlled manufacture, monitoring, better means of prediction and repair before malfunction
- people — eliminate mishaps due to human error through human centred aircraft and system design, quality procedures and processes, and trained, skilled, fit, engaged and co-ordinated personnel
- environment — ensure separation between aircraft and other aircraft in their wake, hazardous weather, terrain and obstructions, and hostile action (military, security).

Included in this programme is the development of cleaner and quieter aircraft engines, in an effort to reduce noise exposure and air pollution despite the expected increase in air travel. These goals should be met, according to the US planners within the first quarter of the next century, and also lead to faster and less expensive air travel. Although one may put place questions marks against such an overly optimistic technology oriented scenario, the committee rates the NASA proposals as comprehensive, i.e. it takes into account the various environmental and public health issues mentioned or discussed in this report. Also the proposals built upon the quality control processes that are already strong in the aviation industry.

An important aspect of quality control processes are certification schemes. This has been recognised both in industry and in government policies. The ISO 9000 family of standards for quality management systems and the ISO 14000 family for environmental management systems are increasingly applied.[124] Airport certification is a requirement in the USA (Federal Aviation Regulations, Part 139) and is being introduced in Europe. The committee recommends the further development of certification schemes, also for airlines and airports, as an effective means to ascertain that quality control is actually practised.

The committee also recommends that a technology assessment programme should complement the technology development endeavour. Such a programme should probe the societal (including public health) consequences of the technological solutions found. This is important as often technological improvements are dominated by economic considerations. A case in point is the (re)introduction of supersonic flight, which appears technologically feasible, but still would raise short term public health questions and long term ecological questions. At present this is not considered to be an economically viable option for long distance transport. [261] A technology assessment programme by definition tries to look at all the factors (and possibly trade-offs) simultaneously.

9.5 Information availability

Quality control in an organisation also depends on the exchange of information, especially on abnormal events, incidents and procedures that do not work well. To set up systems that enable organisations to learn is complex and requires thought and experimenting. [166] Airlines and airport authorities have channels for reporting unusual events or ineffective procedures. Within organisations openness appears to be a prerequisite for effective organisational learning as long as reports are used constructively and not punitively.

Reasoning along these lines, information on safety and environmental performance of the operators in the airport operations system should be made publicly available. This because airline passengers and people living in the vicinity of a large airport are important stakeholders in the system. Some have argued that such a degree of openness would lead to misconceptions. In a study in the US, all large air carriers were rated as equally safe, despite differences in incident and accident rates. [12] Publicising accident and incident frequencies might convey an incorrect message and be of limited use to the general public.

The committee did not have the opportunity to discuss this subject in depth and will refrain from making a definite recommendation. However, keeping information away from some parties in the system from fear of misconceptions or because of perceived competitive disadvantages, appears to be counterproductive. The subject certainly warrants further attention and the committee recommends that governments take the initiative to discuss the quality of reporting systems with all stakeholders concerned.

9.6 An integrated structure

As was illustrated in Figure 1 (Chapter 2) the airport operations system encompasses an interacting network of many parties, each necessary for the functioning of the system. The decision of any single party will, at least in principle, influence the public health impact of the operations at the airport and its vicinity. For example changing aeroplane takeoff and landing routes in order to reduce noise exposure at populated areas in the vicinity of the airport, may negatively influence accident risk. Another example is the introduction of aircraft engines that produce less noise but emit more air pollutants. Also passenger transport by high speed trains to reduce road traffic congestion and air pollution has physical planning consequences, more especially because they do not replace roads and highways, and introduces new safety risks. The committee therefore calls for a structure in which developments are monitored and assessed before the consequences are irreversible. It concurs with views expressed in safety studies related to Amsterdam Schiphol, that a structure should be set up in which integrated assessment is possible.[35),105),114)] * As implied above, the committee recommends to extend these ideas to all public health questions.

The political and administrative structures in which such an integrated assessment system for large airports should be embedded, is not for the committee to determine. The options for consideration range from a 'clearinghouse' structure which leaves the existing allocation of discretionary powers over public and private agencies intact, to a completely restructured, publicly accountable, forum for airport use with a substantial reallocation of discretionary powers. Whatever the form, the structure proposed should be well suited to supervise the public health monitoring system recommended in Section 8.1.

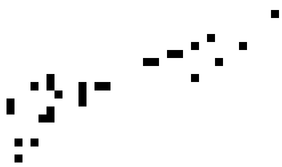
9.7 Epilogue

The present report concludes that the operations of a large airport, including the variety of activities that it generates and attracts, will also negatively impact on health and quality of life, although options exits for reducing the effects. These impacts are part of more global and long term impacts of the aviation industry. Therefore the more general question of mobility can not be ignored when developing sustainable solutions. The aviation industry is increasingly dominated by global players and dependent on international agreements between private and public parties. If civil aviation is not a part of internationally accepted mobility policies, that take into account both short and long

* At Amsterdam Schiphol steps have been set to implement an integrated safety management system.

term, local and global environmental and health impacts, then the aviation endeavour that started with the Wright brothers might become an important contributor to permanent loss of health and quality of life.

The Hague, 2 September 1999,
for the committee



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Chapter **10**

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Annexes

Annex **A**

Committee membership

Committee

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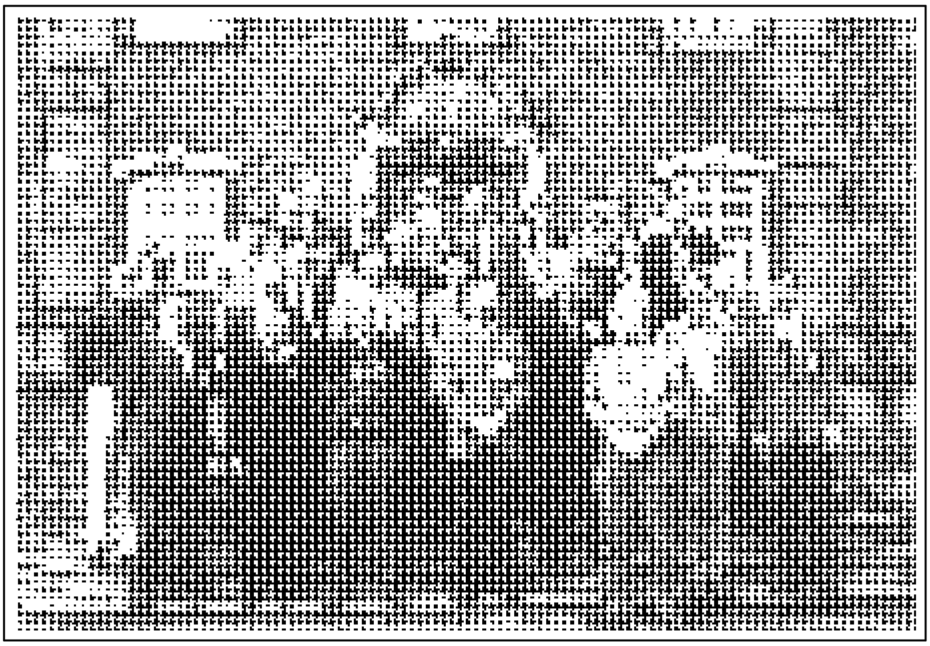
- ir IC Walda, Health Council of the Netherlands

Consultant

- AEM de Hollander, National Institute of Public Health and the Environment, Bilthoven, the Netherlands (Chapter 3 and Annex E and F, greatly profited of his working paper on Environment and Health for the Rolduc workshop).



The participants of the workshop in the Rolduc Abbey. Last row, from left to right: Visser, Sixma, Miedema, Anderson, ms Albering, ms Walda, de Hollander. Next row: Winneke, Ising, ms Griefahn, Mackenbach, ms van Kan, Ayres, Stansfeld. Next row: Armstrong, Fields, Ulrich, Lebret, ms Drottz-Sjöberg, ms Berglund, ms Haines. Next row: Hartig, Goldstein, Dempsey, Sturmans. Front row: Morgan, ms Latowsky, Hale, Knottnerus, Passchier, Ball, Vlek. Not on the photograph: Brunekreef, Hoppe and Maschke.

Annex **B**

Literature

The staff consulted the following databases for literature on airports and public health:

Embase	Psycinfo	Compendex
Medline	DHSS Data	Flightline
Current Contents	Healthstar	Enviroline
Chemical Abstracts	CAB Health	Inspec Engineering
Biosis	Science Citation Index	NTIS
Pascal	CAB Abstracts	Pollution Abstracts
Elsevier Biobase	Biobusiness	IAC Aerospace
Toxline	Cancerlit Business Industry	Umweltliteraturdatenbank
IAC Health	Chemical Engineering Biotech Abstracts	Jist-Eplus (Jpn Sci Technol)

The searches were performed in September 1998. At later dates some additional searches were made for specific subjects, usually in MEDLINE, TOXLINE or PSYCHINFO. Keywords using in the various searches were:

tolyltriazoles	aircraft	health impact
aircraft icing and anti-icing fluid(s)	airport(s)	kerosene
de-icing fluid(s)	mainport	malaria
anti-icing fluid(s)	airplane(s)	airportmalaria
cancer	aeroplane(s)	vibration

tolyltriazoles	aircraft	health impact
neoplasms	annoyance	safety
volatile organiccompounds	noise effect(s)	infections
PAH	sleep disorders	TGV
polycyclic aromatic hydrocarbons	health	
emission(s)	health effect(s)	

Annex **C**

Case studies*

Issue

Three major airports, one in the UK and two in Germany, were selected to evaluate the health issues connected with airport development. In the UK, the British Airport Authority (BAA) and Heathrow Airport Ltd proposed to build a fifth terminal (T5) at Heathrow Airport. One case study in Germany addresses Munich's newly built Franz Josef Strauss Airport. Berlin's Airport Schönefeld was selected as subject of the third case study. This airport will be expanded to become Berlin Brandenburg International (BBI) as the main airport for the Berlin-Brandenburg region.

Generally, the environmental effects of airport development are addressed by an environmental impact assessment (EIA), and the findings with proposals for mitigation are set out in an environmental statement (ES). In the UK, for major projects such as airport development (T5) a formal public inquiry as part of town and country planning legislation is usually held. The ES together with the planning applications are considered during the inquiry. In the case of Berlin, an environmental impact assessment will be carried out together with an assessment of the health impacts of noise and an assessment related to air quality, as part of the planning application process. The new Munich airport has been built without a formal environmental impact assessment. However, various studies related to the environment were carried out as part of the planning application process.

* The case studies report was prepared by dr HJ Albering of the Universiteit Maastricht, at the request of the Health Council.

Below the three case studies are described briefly. The focus is on the way health issues are being dealt with as part of the planning application process.

In all three cases views of airport representatives, authorities and environmental groups were gathered in person and by telephone. Information was also collected from the documentation submitted. The Heathrow case a particular wealth of documents available .

Heathrow Airport Terminal 5

Airport description

Heathrow airport is one of the busiest, international airports in the world. Stansted and Gatwick are two other major airports in the South East of England. The development of the airport began in 1944. In its first year of operation the airport handled 8000 air transport movements (atm)* and 60 000 passengers. At present, the airport handles over 430 000 atms and more than 58 million passengers and 1.2 million tonnes of cargo (BAA98a). The airport covers a site of 2.958 acres and is equipped with two parallel runways and one cross wind runway (used in certain high wind conditions), four passenger terminals and one cargo terminal. Heathrow's existing runways have the potential to accommodate 80 million passengers a year. However, the present terminal capacity is limited to 50 million (BAA98b).

At Heathrow, runways are used in an alternating fashion, in order to provide relief from noise disturbance to communities around the airport. Alternation applies only under westerly preference, *i.e.* when aircraft arrive from the east and takeoff to the west. Landing aircraft use one runway from 7 a.m. to 3 p.m. and the other runway from 3 p.m. to 11 p.m. The following week the pattern is reversed (DET98).

Case

According to the BAA, the owner and operator of Heathrow Airport, level of passengers that are expected to use Heathrow airport in the future will be beyond the capacity of the four terminals of the airport. To meet this demand a new terminal should be built. This new terminal is planned within the boundaries of the airport and should handle 30 million passengers a year. At the moment the site is used as a sludge works (BAA98b).

* An air transport movement is a landing or a takeoff of an aircraft. Each flight between two airports consists of two movements.

As suggested by BAA, the expansion of the airport with a new terminal does not necessitate the construction of another runway. Neither does it imply an increase in night flight quota, nor will it lead to more noise exposure in the vicinity of Heathrow than the exposure in the noise climate today. The use of larger aircraft will enable Heathrow to handle an extra 30 million passengers, with only a small increase in flights (about 8%). Furthermore, T5 does not require a change in the runway alternation system (BAA98c).

BAA Plc and Heathrow Airport Ltd submitted the Terminal 5-outline application on 17 February 1993. Subsequently a full application will be submitted, which contains detailed information such as location and design as required by the local planning authority of London Borough of Hillingdon (Inq98). Together with the T5 application BAA Plc and Heathrow Airport Ltd have submitted other planning applications related to T5 such as Highways and Transport and Works Act orders, which will be considered before the inquiry.

Planning application process, inquiry

For a major project in the UK, such as a new airport terminal, a formal public inquiry is usually held to hear the views from different parties including the general public. The aim of the public inquiry is to advise the Secretary of State for the Environment, Transport and the Regions on the significance of the arguments for and against the submission. The role of the Inquiry Inspector is to consider all the evidence presented at the inquiry, to write a report about that evidence, and recommend to the Secretary of State whether permission should be given or not. The final decision on the application rests with the Secretary of State. In the present case the Secretary of State for the Environment, Transport and Regions wants to be advised about the following issues; justification of the proposals in terms of air transport, development pressures and socio-economic impacts, land use policy, surface access, noise, air quality, public safety, fuel supply, construction, associated applications and conditions. Mitigation measures might be considered if this should be necessary (Inq98). The inquiry started on 16 May 1995 and ended in the spring of 1999.

The major parties involved in the inquiry include the developer, the local planning authorities, environmental groups such as West London Friends of the Earth, HACAN (Heathrow Association for the Control of Aircraft Noise) and resident associations. At present the inquiry library contains more than 5000 documents.

Airport operations and health

Health was not a separate issue in the environmental impact assessments performed in relation to the T5-expansion. However, health impacts were considered, *inter alia* the change in the number of people annoyed by noise likely to result from the airport development was calculated (LAT97a). Air pollution was considered by comparing existing levels of air pollutants with the air quality standards (Dry99). Furthermore, a number of health related studies were submitted to the inquiry Inspector. These studies concerned noise and air pollution exposure, and public safety. Experts reviewed the relevant literature and gave evidence on behalf of major participants. In addition, health studies were carried out among the population in the surroundings of the airport on the initiative of the local authorities and of BAA.

For instance, a local health authority (HHA97) presented a qualitative report on the potential health implications of the airport with respect to noise, air quality, communicable diseases, major incidents and accidents. The local authorities asked the developer to undertake a health impact study as part of its environmental assessment obligations. However, the developer declined to do so and the inquiry inspector did not press the issue.

The local authorities have objected to the T5 proposals. The main objections were related to the noise environment around Heathrow airport. Much evidence was given on the impact of aircraft noise today, because the present noise levels were considered to be intolerable (HAC97c, LAH97a). However, at the inquiry the effects of additional noise exposure arising from the use of the proposed terminal is at stake. According to BAA, Terminal 5 will not make the noise problem an worse than it alread is (BAA98c). The airport authority restricted its assessment of the existing noise exposure climate around Heathrow to that of annoyance among people exposed to equivalent noise levels above 57 dB(A) ($L_{Aeq,16h}$). The 57 dB(A) level emerged from an annoyance study around Heathrow in 1982 as indicating the onset of annoyance due to aircraft noise. In 1996, the population within the 57 dB(A) noise exposure contour was estimated to be 299 000 (DET98). Heathrow Airport has used noise contour maps generated by the Civil Aviation Authority as the standard method for monitoring and predicting the impact on the community of air noise from aircraft. Opponents to T5 discussed the validity of the 1982 study results for predicting effects today and the use of average contours for assessing and predicting the impact of noise on health (LAT97ab, HHA97, Sta99).

The population within the 57 dB(A) noise exposure contour has decreased over the last decades (DET98), but the number of noise related complaints is on the increase. Many local residents regard the intense frequency of overflights as the major problem.

The assessment used by BAA appears to underestimate the level at which many people become annoyed or impacted by aircraft noise.

The effect of noise on sleep is of serious concern to the people living near Heathrow airport (HAC97bc). Sleep quality as well as the amount of sleep may be impaired by noise. At Heathrow the night restriction regime was partly based on a field survey of sleep disturbance of people living around Heathrow, Gatwick, Stansted and Manchester airport (Oll92). No curfew period exists, but a movement limit and noise quota system is in operation between 11 p.m. and 7 a.m. In general 16 night flights per day are allowed (DET98). The night-time landings at Heathrow, especially those between 4 and 7 a.m., are a most significant source of noise complaints from local residents, mainly as a result of growth in traffic between 6 and 7 a.m. (DET98). The UK Government's Sleep Disturbance Study concluded that "once asleep, very few people living near airports are at risk of any significant sleep disturbance due to aircraft noise, even at the highest levels" (Oll92). This conclusion differs from the perception of people, thousands of whom complain about noise and sleep disturbance. The anti-noise group HACAN has strongly criticised the Sleep Disturbance Study (HAC97ac). Additional research into the effect of aircraft noise on sleep disturbance has been commissioned by the UK Government. As part of this research a field study at the Manchester airport will be performed (Por99).

A cross-sectional pilot study on the effects of chronic airport noise on school children's reading comprehension, long term memory and motivation was commissioned jointly by local authorities and health authorities around Heathrow (LAH97c); 340 school children participated in this study. Chronic exposure to aircraft noise did appear to influence childrens's reading ability and quality of life athough the results were not consistent across all schools.

To assess the implications for human health likely to result from the effect of Heathrow Airport on air quality a study was commissioned by BAA (BAA98d). The diseases considered in this study were asthma, chronic bronchitis and emphysema, cancer of the respiratory tract, lymphatic and haematological cancers, leukaemia, myocardial infarction and ischaemic heart disease. This study showed no significant increase in the prevalence of chronic respiratory diseases within 4 to 5 km from the airport as compared with a control population in West London. However, no information was available about the exposure of air pollutants in the control population (HIL98). Over the one year period between the beginning of April 1997 and the end of March 1998, only 47 complaints related to air quality has been registered at the Heathrow Community Information Office (BAA98b).

Public safety has not been a key issue at the inquiry (Eva99, Dry99). Although, some evidence on the impact of health was presented by the local authorities (LAH98). Fear and anxiety about aircraft crashes appear to impact on quality of life and to contribute to stress. However, the data are limited. People in the vicinity of Heathrow airport did not participate in a study on attitudes to third party risk near UK airports (Eva99).

In general, aircraft noise is regarded to have the most significant impact on people living in the vicinity of the airport.

Public involvement

At Heathrow airport various groups are involved in stakeholder consultations about airport matters. Representatives from the local authorities, environmental groups, the airport and the airlines, consumer and tourism groups, constitute the Heathrow Airport Consolation Committee. Issues such as new development proposals, airport operation procedures and community complaints are discussed. A significant source of complaints by the local community are the early morning landings between 4 and 7 a.m. Recently, the perception of people of the impact of night time runway alternation was studied on behalf of the committee following a request from the local community (MVA97). Consultations also take place with local authority councilors. Furthermore, forums exist for citizens and community groups (Dry99).

Complaints are generally received and dealt with by the community information office of the airport. With respect to noise over the period between April 1997 and March 1998 the community information office received 3300 complaints. Of these 28.2% related to early morning flights (BAA98a).

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Munich Airport Franz Josef Strauss

Airport description

Munich International Airport Franz Josef Strauss is the second largest air gateway in Germany. It was originally designed in 1992 to accommodate 15 million passengers per year, with the possibility to expand to 30 million passengers. In 1997, the airport handled a total of 256 000 aircraft movements and about 17.9 million passengers. There is a growing number of transfer passengers (‘hub-function’) (Mun98).

The airport appears to be a model of an “airport in the green” (Bre95). More than 70% of the airport grounds are green areas. The airport is situated in the comparatively low-density population area Erdinger Moos, 30 km north-east of Munich. The airport has one terminal and two runways that can operate independently. Each runway is designed for takeoffs and landings once every two minutes.

Subsequent stages of growth provide for two more runways and an extra terminal. Approval to build the second terminal, that would add a capacity of 15 million passengers per year, has recently been given by the local authorities. In 2002, the new terminal will probably be opened (Mom97).

Case

The former Munich-Riem Airport was planned and built between 1936 and 1939. When the old airport opened in 1939 it had two runways, each 1800 m long, one terminal and an annual capacity of 100 000 passengers (Bre95). The old airport was unable to grow due to its location near to the inner city of Munich. The runway system could not be extended, because of the urban development in the region. Furthermore, the arrival and departure routes passed over densely populated areas of Munich. In the beginning of 1992, more than 11 million passengers and more than 160 000 commercial aircraft movements were handled at the old airport, even though this amount of traffic was beyond the airport's capacity.

A site selection for a new airport was carried out in the late 1950s, but it did not result in definite choice as the necessity for a new airport was not sensed at that time. However, the crash of a US Air Force aircraft near the centre of Munich in December 1960, triggered an extensive site selection (Bre95). The airport authority expected to finish the construction of the new airport before the Olympic Games in 1972 (Avi91).

In 1963, a committee evaluated 20 locations within a 40 km radius from the centre of Munich. The committee had to cope with various difficulties; the lake and forest district in the south, which has been designated as a recreational area, military airfields in the north-west, groundwater and fog problems in the north-east.

The Bavarian State Government, which was responsible for the approval of the airport, decided in 1966 and 1967 to examine two sites, Hofolding Forest south of Munich and Erdinger Moos, north-east of Munich. Based on navigational, land-use planning and cost aspects, Erdinger Moos was selected in 1969 as the location for the new airport (Bre95). During the spring of 1985 the Munich Airport Authority started with the construction of the new airport. The government of Germany (26%), the city of Munich (23%) and the Free State of Bavaria (51%) provided the funding.

Planning application process

In 1969, the Bavarian State Government selected Erdinger Moos as the site for the new airport. The regional authority (government of Oberbeiern) was responsible for the approval of the planning application. A health assessment (‘Medizinisches Gutachten’) of noise exposure, required by federal regulations, and a similar assessment related to air quality were prepared. The latter concentrated primarily on the influence of aircraft emissions on agricultural products. The effect of aircraft emissions on human health was evaluated by a comparison of expected exposure levels with relevant standards (Ren99).

Both people living at or near the location of the new airport and the local authorities were against the new airport. They believed that the character of their villages would change enormously and the quality of life for local residents would be reduced (Knu99).

The site selection and the implementation of plans for the new airport led to many state and federal court actions. A court-ordered temporary construction stop delayed the planning process by 4 years. In 1986, the airport obtained absolute court permission for construction to begin (Avi91). Later court actions dealt with other aspects related to the planning application process such as financial compensations for the local residents. Health was not a separate issue in the court sessions, but broad aspects of health, quality of life issues and the effects of noise (night flights) were raised (Ren99).

The present expansion of the airport with a second terminal did not trigger new assessments of environmental and health effects, because the second terminal was included in the approval procedure for the new airport.

Airport operations and health

In general, noise appears to be the dominant issue in debates about the environmental impact of the new airport. The airport authority did address this issue and put a lot of effort in noise reduction and noise monitoring measures. The airport is situated in a low-density population area. Besides, the configuration of the parallel runways and takeoff and landing procedures has contributed to the improvement of the noise climate (Bre95). At the airport a night curfew exists between midnight and 5 a.m. In total 38 aircraft movements per day are allowed between 10 p.m. and 6 a.m. The limit for night aircraft noise has been set at 6 nightly noise events with adjusted *SEL* levels of 75 dB(A)* or more outside. Furthermore, the airport has started phasing out operations by

* A measure used in Germany for aircraft noise exposure that forms the basis for the ‘Störindex’.

Chapter 2 aircraft.* At present, about 98% of the air planes are Chapter 3 aircraft (Ren99).

The airport authority recognises that although the equivalent noise level is decreasing the number of complaints is not. At present, according to the airport authorities, noise complaints are often not related to noise levels or departure or arrival routes and therefore difficult to handle (Ren99).

The health impact of the operation of Munich airport has not been evaluated by the airport authorities, apart from the assessments provided as part of the approval procedures. No studies have been initiated into the health of the surrounding population.

Some aspects of the impact on health associated with chronic aircraft noise exposure around the Munich airport were studied by Evans and colleagues (Bul99a, Eva95,98, Hyg96,97, Mei97). This study was an initiative of the researchers and not carried out at the request of the local and airport authorities; it was not related to the approval procedures for the new airport. It was designed as a prospective longitudinal study to evaluate psycho-physiological (resting blood pressure, overnight levels of neuroendocrine hormones), cognitive (attention, reading, memory), motivational and quality of life effects of noise exposure in children aged 9-13. Before the inauguration in 1992 of the new airport, children at the old airport and at the new site were divided into one experimental and one control group. The children were matched according to their socio-economic status. In total 327 children were tested over a period of two years. The first measurements were carried out 6 months prior to the change over, followed by measurements 6 and 18 months after the change over.

The results showed minor, but statistically significant differences in quality of life indicators, motivational deficits, cognitive measures and an increase in psycho-physiological stress (except cortisol levels) measured over a two-year period in the new airport area. In the old airport area the same effects were present before the airport relocation, but two years after the closing of the airport these impairments had disappeared. A shortcoming of the study was that no data on individual noise exposures were available. The outcome of the study had no impact on the noise policy of the airport (Bul99b, Ren99).

Air quality, in and around Munich airport is continuously monitored by or on order of the Flughafen München GmbH (Bre95). Air quality is also measured by soil-survey, dry and wet deposition, fog, groundwater and a bio-indicator programme (Hop95). The main contributor to outdoor air pollution around Munich airport appears to be road traffic

* Chapter 2 aircraft meet the standards in Annex 16 vol. I, of the ICAO (International Civil Aviation Organization) convention, which are applicable to jet aircraft designed before October 1977. Chapter 3 contains more stringent standards applicable to aircraft designed after that date.

(Sch99). Levels of pollutants measured by the monitoring stations are very similar to those in the centre of Munich. Possible health impacts of air pollution do not appear to be a matter of concern for the general public, nor for the airport authority (Knu99,Ren99).

After the inauguration of the new airport in 1992, many of the complaints were related to the physical overhead presence of large aircraft, which lead to feelings of anxiety. People around the new airport were not familiar with aeroplanes. Landing aircraft may be a beautiful sight, but they also trigger worries about the adequacy of the procedures at the airport to preclude disasters (Knu99, Ren99). One of the present key issues of public concern appears to be the planned increase in night flights.

Public involvement

The airport has an aircraft noise commission, which acts as a link between the airport authority and the neighbouring vicinities. This commission is mandated by law. The aircraft noise commission consists of representatives of the airport and the airlines, the local, regional and federal authorities and anti-noise groups. At the biannual meetings of the commission issues such as departure routes, day and night protection areas, noise prevention programmes, new development proposals and community complaints are discussed.

The airport publishes a monthly report, dealing with issues such as the amount of air movements (category 2 or 3 aircraft), the results from the noise and air monitoring stations and the number and subjects of complaints. Complaints are recorded and dealt with by the local authorities (Government of Oberbeiern) and the airport itself.

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Berlin Brandenburg International (BBI)

Airport description

The current Berlin airport system consists of three airports: Tegel, Tempelhof and Schönefeld. Tempelhof airport is located in the centre of the city. Tegel airport is located to the north-west of the city and was the West Berlin airport until the two parts of Germany were re-united in 1989. Air transportation to and from East Berlin was handled by Schönefeld airport located in the south of Berlin.

The three airports have quite different facilities. Tegel handles most traffic (8.7 million passengers in 1997). The airport is close to the limit of its capacity (Nie98). Tempelhof serves as the airport for regional traffic and registered 0.8 million passengers in 1997. Schönefeld is specialised in charter flights and reported 2.0 million passengers in the same year (Pro98).

In order to co-ordinate the operation of the three airports, the states of Brandenburg and Berlin and the federal government decided in 1991 to found Berlin Brandenburg Flughafen Holding (BBF). The holding decided to concentrate its activities on a new or single airport in the mid-term to be known as Berlin Brandenburg International (BBI). Initially, the new airport would be equipped with two runways and should be able to handle 18-20 million passengers in 2000, rising to more than 40 million in 2010. Further stages of development would include for two more runways (Hil92). However, in 1996 the decision was made to redevelop Schönefeld airport to become the single airport for the Berlin-Brandenburg region. The plan is to close Tempelhof and Tegel in 2002 and 2007, respectively.

The Schönefeld airport will be equipped with a new terminal and a second runway. The current runway will be lengthened. The two parallel runways can be operated independently. The area covers 1600 hectares. BBI should be capable of handling 20 million passengers by 2010 and, according to plan, will be inaugurated in 2007 (Tav97).

Case

With the fall of the Berlin Wall in November 1989, the unification in 1990 and the transfer of the federal government administration and parliament from Bonn to Berlin, the air traffic conditions around Berlin have drastically changed. The predicted number of passengers using Berlin Airports by 2000 is 18-20 million, which is beyond the capacity of the existing three airports (Hil92). Studies were performed to determine to what extent Tegel and Schönefeld could be developed and where to build a completely new airport (BBF93, BBF94).

Among the candidate sites that have been studied in more detail were the military air base at Sperrenberg, the agricultural region of Jütebog and Schönefeld-Süd.

The construction and operation of a new airport might result in effects on humans, nature and landscape that have to be evaluated by means of an environmental impact assessment. The effects of noise and air pollution have been taken into account by a comparison of predicted exposure levels with relevant standards (air quality) and by a calculation of the number of people within certain noise contours. In Germany, 'adjusted' equivalent sound levels of 62, 67 and 75 dB(A) are of relevance. The corresponding noise contours were calculated according to statutory rules.

The decision in 1996, by the State of Berlin, the State of Brandenburg and the federal government to redevelop the existing facility of airport Schönefeld rather than to build a new international airport was made on political and financial considerations with technical and human health considerations being of minor importance (Hil96, Oth99).

Planning application process

As part of German legislation, planning application documents are required in order to expand Schönefeld airport with a second terminal and second runway. At the moment, the airport authority is preparing an environmental impact assessment (EIA). The airport authority will consider noise and pollutants emitted by aircraft, by the operation of airports themselves and by road and rail traffic to and from the airport (Pro98b). Furthermore, the effects on flora, fauna, soil, ground and surface water, climate and landscape will be evaluated. The available scientific evidence about the impact of noise (*i.e.* aircraft noise and ground noise) on human health (both physical and mental) will be evaluated in a detailed separate document ('medizinisches Gutachten'). The conclusions of the 'medizinisches Gutachten' are used as reference for the EIA. The health effects of noise pollution to be considered will include hypertension, heart disease, stress related disorders, behavioral and performance disturbance, impaired cognitive development and sleep disturbance. In addition, the quality of the outdoor air on human health (both mental and physical) will also be evaluated in a detailed separate document. The methodology for the assessment is based on the following steps: gathering of health and demographic data from the area that is potentially affected by air pollutants emitted by airport related activities, evaluating the existing air quality and performing a quantitative health risk assessment. The pollutants taken into account are nitrogen oxides (NO_x), carbon monoxide (CO), particulates (PM_{10}), particulates of soot, polynuclear aromatic hydrocarbons (PAHs), odour, benzene, ethyl benzene, toluene, xylene and hydrocarbons (Pro98b).

The airport authority will also evaluate the impact of airport development on nature and landscape, such as the loss of countryside or the reduced quality of enjoyment of the countryside. By law it is required that certain effects on nature and landscape will have to be 'repaired' by ecological compensation and substitution actions and these will be described in a landscaping supplementary plan as part of the planning application documents (Pro98b). In mid 1999, the planning application documents will be submitted to the competent authorities.

Airport operations and health

As mentioned above, the effects of the proposed new airport development on human health will be addressed by a health assessment of noise exposure and an air quality impact study as part of the planning application documents which are required by federal regulations. No further projects or studies related to population health in the communities surrounding the airport will be initiated by the local or the airport authorities (Kac99, Oth99). The local communities asked the airport authorities to undertake a full health impact study as part of their environmental assessment obligations (Kac99). However, as such an assessment is not an official requirement within a planning process, this request was not granted. In addition, the airport authority had no indication of a fundamental impact on human health on the surrounding population or that special predisposition of the population exists (Oth99).

The noise-climate is the most common concern of people living close to the airport (Kac99). At the airport no night curfew exists. The limit for night aircraft noise has been set on '6 x 75 dB(A)'*. For Chapter 2 aircraft a curfew exists between midnight and 6 a.m. The noise protection programme (soundproofing windows) for the neighbouring communities and noise monitoring programme will be expanded at the time the new airport will be developed (Ber98). To expand the airport Schönefeld, one village has to be relocated. There is some resistance from the local people to the relocation.

In addition to noise, gaseous emissions from aircraft are of concern among the public. The air quality will be monitored continuously by adjacent monitoring sites. Another concern within the community is the fear and anxiety induced by the possibility of aircraft crashes (Kac99). In 1998, an air security study for the airport extension was carried out, which investigated the security of the airport layout, the risk of aircraft crashes in the surrounding area of the new airport and effects of turbulence by planes on buildings (Oth99). The results of this study will be taken into account within the airport planning process. Third party safety is an issue that mainly will be addressed qualitatively.

The airport authorities will compensate the effects on nature and landscape by substitution measures. Furthermore, the airport authority plans to develop a commercial complex in front of the main terminal building with a 24-hours shopping mall and restaurants and hotels (Hil96). The airport authorities value this as a marketing tool and a means of airport promotion (Oth99).

* Noise levels are expressed as adjusted *SEL* values, a measure used in Germany for aircraft noise exposure that forms the basis for the 'Störindex'.

Public involvement

In Germany, the public is enabled to participate in the planning application process at the stage when the airport authority submits the planning application documents to the competent authorities. The developer and the competent authorities have defined the scope of the environmental impact assessment (Pro98a).

The airport has set up an information office to provide general information about the airport development process. Most questions and complaints concern noise and proprietary rights (Ber98).

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Lessons learned

This study was targeted at the human health issues addressed in relation to three airport development plans in Europe

- Heathrow airport's proposal to build a fifth terminal (T5)
- the upgrading of Berlin's Schönefeld Airport with a second runway to become the major Berlin airport, and
- the recently completed new airport at Munich (Franz Josef Strauss).

In general, the environmental and some health effects are normally addressed through an environmental assessment. Moreover, in Germany health assessments ('medizinisches Gutachten') of noise and air pollutant exposure have to be performed and included in the application documents. A 'medizinisches Gutachten' provides an assessment of the potential health effects resulting from the airport development.

In the case of Heathrow, health was not a separate issue that was addressed in the environmental impact assessment procedures. However, a number of health based studies were submitted at the public inquiry into the proposed fifth terminal. Much evidence was given at the inquiry related to the environmental and health impact of Heathrow airport today.

In all three cases the developers appear to believe that the expansion of the existing airport or the construction of the new one does not has a major and long-lasting health impact on the population in the vicinity of the airport. The local authorities around Heathrow airport and the community groups around Berlin asked the developers to perform a health impact assessment at the planning stage. However, as such an assessment was not a legal requirement, the request was not granted by the developers.

Populations near Heathrow and Munich airport have been studied in some detail. In the case of Munich, additional studies were carried out related to the effect of chronic noise exposure and psychological stress on children. These studies had no influence on the decision making process related to the new airport. The health effects of aircraft noise on children have also been investigated around Heathrow airport. Furthermore, measures of mortality and morbidity in relation to chronic respiratory diseases have been analysed to determine the health status of the surrounding population at Heathrow airport.

When asked for their opinion on the major health issues in relation to airport development all the persons interviewed considered noise as the major concern of people living close to airports. In addition, local communities expressed concern about the night flight regime at the airports, which in their view is too lenient.

In general, the collective noise exposure levels around Heathrow airport and Munich airport have decreased, although many people living in the vicinity of the airport feel that the noise climate is getting worse.

The interviewees in the UK all agreed that the inquiry provides a means to all parties, the general public included, to state their views.

All three airports have an airport consultative committee to discuss issues such as community complaints, airport operations, and development submissions. These committees include representatives from all stakeholders.

Annex **D**

Attributes of the physical environment

People rate the quality of their living environment by a variety of factors. In an exploratory study of a policy instrument to assess changes in the physical environment the National Institute of Public Health and the Environment in the Netherlands distinguished more than fifty attributes grouped according to geographical scale (dwelling, quarter, region, state; Table 15).[204] The physical environment was defined as consisting of (stocks of) various objects in a certain (spatial) arrangement. These objects were evaluated from three perspectives: ecological, economic and social/psychological. Several attributes are culture-specific and so not universally applicable.

Table 15 Proposed attributes to characterise the residentiabilty of the physical environment.[204]

	scale			
	dwelling	quarter	region	state
desired	number of rooms	shops	greenery	monuments (cultural)
	size	post office	open landscape	facilities for events
	suitable for family	bank		airport
	(large) garden	schools	water supply	oil and gas supplies
	private parking place	children day care	hospitals	infrastructure roads/ train to connect with foreign countries

	scale			
	dwelling	quarter	region	state
	privacy	park, trees, public garden	theatres	spatial distribution of functions
		public transport stops	skating rinks	environmental diversity
		community centre	soccer stadiums	
		pub	infrastructure (public transport, roads, bicycle paths)	
		library	employment and housing	
		sports accommoda-tions (indoors, outdoors)	monuments	
		pharmacy, family doctor		
		architectonic value		
		cosiness		
		children's playgrounds		
undesired	neighbour noise	dangerous traffic points	flood risks	airborne particulates
	radon	noise annoyance	annoyance from aviation	UV radiation
	geysers without outlet	hustle and bustle	swimming water quality	lack of space for agriculture
	draughts	dirty streets	visual pollution	dependence on space abroad
	damp house	dog's dirt	air pollution	climate change risks
	leaks	unsafe corners	industry	
	leaden water piping	air pollution city (road traffic)	traffic jams	
	vermin	polluted soil		
		untended houses		

Annex **E**

Concepts of health*

A key question in any attempt to evaluate health impacts associated with environmental exposures is 'what is health'? The concept of health may differ from era to era and from region to region, since it reflects changes or differences in social and cultural beliefs, in medical technology, and economic conditions.[207]

Health as successful adaptation

Several authors conceptualise health as an *optimal dynamic equilibrium* between individual capabilities and exogenous circumstances, enabling individuals to deal with external disturbances and pressures.[68, 207, 208] In such an approach health, is regarded as an individual's ability to cope with the demands of everyday life.[56, 85, 89] Successful adaptation to environmental circumstances in the broadest sense implies living an independent and productive life and maintaining optimal economic conditions and social interactions in all stages of life. Thus it may very well include well-adjusted people with physical handicaps.[106] Health problems may arise among those who lack the mental and physical resources to cope with exposures to environmental factors, such as noise, air pollution, lack of open space, traffic density or the threat of a large accident.[172]

* This Annex is derived from a working paper for the Rolduc workshop, prepared by AEM de Hollander of the Netherlands Institute of Public Health and the Environment, at the request of the Health Council.

Health as a state of well-being

In its founding charter (1946) the World Health Organisation states that health is 'a state of complete physical, mental and social well-being and not merely the absence of disease and infirmity'.[276] The merit of this definition is the explicit appreciation of the subjective experience of health and the inclusion of psychological and social dimensions. Clearly this broad concept of health encompasses social responses, such as annoyance, anxiety, disturbance of sleep, communication and cognitive performance. Several authors have drawn attention to its shortcomings: its lack of operational value. Or as Richard Doll once put it: "this definition is a fine and inspiring concept and its pursuit guarantees health professionals unlimited opportunities for work in the future, but it is not of much practical use".[67] In a recent discussion of the WHO health concept, Saracci argued that "a state of complete physical, mental and social well-being corresponds much closer to happiness than to health". He proposed to view health as "a condition of well being free of disease and infirmity and a basic and universal human right", but at the same time to link the concept to appropriate indicators of mortality, morbidity and (health-related) quality of life.[210]

Healthy until clinically proven otherwise

In its report on Health Care the Dutch Scientific Council for Governmental Policy (WRR) advocated a more or less similar position. Well-being and coping with everyday life requires much more than good health alone. The Council proposes to limit the definition of health to: "the absence of disease and other health problems of a physical or psychological nature".[265] Of course, such a view bears first and foremost on controlling the costs of health care and cure in ageing populations, allocating scarce resources in most cost-effective way. However, in the field of environmental health protection one is confronted with similar needs for effective and efficient allocation of resources (including opportunity costs).[95],[187]

Health status measures

Conceptualisations of health can also be found, implicitly as well as explicitly, in proposals of health status measures. Initially clinicians and clinical psychologists developed such instruments to assess and compare quality of life after different options for medical intervention (e.g. quality adjusted life years: QALY's). In recent years these instruments were adapted to measure 'disease burden' on the level of populations, primarily to support the planning of public health programs and to assess the efficiency of different options.[89]

The most straightforward health status measurement approach is probably the International Classification of Impairments, Disabilities and Handicaps (ICIDH). Impairment is defined as *any loss or abnormality of psychological, physiological or anatomical structure or function (organ level).* Impairment may lead to disability defined as *any restriction or lack of ability to perform an activity in the manner or within the range considered normal* for human beings (individual level). Disability may lead to handicap, defined as *any disadvantage that limits or prevents an individual's fulfilment of a role that is normal*, given age, gender, environmental conditions and social-cultural context.[275] It is important to note that the degree to which a disability becomes a disadvantage depends also on the societal response, e.g. the 'conviction' one is unable to work properly or social isolation amongst mentally retarded persons.

The slightly divergent framework of health-related quality of life (HRQoL) encompasses a broad range of health metrics. On the highest level one can distinguish broad concepts such as *opportunity*, *health perception*, and *functional status*.[191] 'Opportunity' comprises issues such as cultural and socio-economic disadvantages, or loss of resilience. Health perception relates to expectations about health (and health care) and satisfaction, and of course often reflects the cultural images of health.[68] Functional status includes physical, psychological and social functioning, for instance the (dis)ability to perform 'activities of everyday life' in four domains; procreation, occupation, education and recreation, as applied by Murray and Lopez in their first Global Burden of Disease report.[274]

A common feature of all HRQoL measurement instruments is their multidimensional nature. Pain and anxiety can only be perceived by the individual, while for instance cognitive or affective disorder can only be experienced by an observer. Blindness or limpness may be experienced by both. Of course self-reports and observations may diverge substantially, as self-reports will be influenced by socio-economic status, level of health care, base line health status, health culture etc.[89],[173] EuroQOL, one of several well-studied examples of an instrument to measure HRQoL, rates health by employing a 3-point scale for 5 health attributes: mobility, self-care, daily activities, pain/discomfort, and anxiety/depression.[139] Sometimes, cognitive function is added as a sixth health attribute.[230]

A third, merely utilitarian perspective on health measurement is probably of less relevance here: loss of health measured as loss of the individual's utility. In most cases this boils down to measuring preferences with respect to time spent in a certain health state, as compared to complete death (0) or perfect health (1).[85] Several techniques are available to measure these preferences, such as time trade-off, person trade-off, standard gambling or rating scales.[183] Again one has to solve an important dilemma with respect to the perspective one wants to take and that is who's preference should be measured: the general public, health care providers, individuals in certain health states, or their family and friends.

Annex **F**

Health and the social environment*

A comprehensive body of evidence clearly demonstrates the key role of the social environment in the health status of populations as measured by mortality rate, life expectancy, perceived health, the prevalence of chronic disease and limitations.[160), 161), 176)] Even in a relatively egalitarian society such as the Dutch, individuals from the highest socio-economic groups live around 3.5 years longer than individuals from the lowest group. In terms of healthy life expectancy the difference is almost as high as twelve years. In general socio-economic status is measured using education level and income as well as professional status. Of these the first attribute appears to be most closely associated with health status. Other important attributes of the social environment are employment status (entrepreneur, employed, jobless, or incapacitated for work), marital status and household composition, and ethnicity. Furthermore, geographical differences in health status are highest on the level of residential neighbourhoods, in particular in large cities, again implicating an important role for the social environment.[161)]

These social-demographically determined health differences are to some extent explained by an unequal distribution of unfavourable lifestyles, such as smoking, alcohol abuse, intake of fat, fruits and vegetables. Furthermore, social support, employment rates, number of life-events and use of care facilities (in particular specialist care) appear to be less favourable among individuals of the lowest social groups. The same applies to the occupational (blue-collar labour) and environmental conditions (including

* This Annex is derived from a working paper for the Rolduc workshop, prepared by AEM de Hollander of the Netherlands Institute of Public Health and the Environment, at the request of the Health Council.

noise and air pollution, traffic density and safety, crime rates). This unequal distribution of exogenous determinants across groups with differing social-economic status is reflected in the distribution of endogenous (or intermediate) factors, such as hypertension, unfavourable blood lipoprotein composition, and obesity. Most analyses show that education level and material standards are more important than psycho-social factors. [161), 208)] Aside from these causal mechanisms, social-demographic health differences may in part be due to selection as people in poor health are more often excluded from education and employment. In particular with respect to geographically determined health differences selection might be a significant mechanism. Over the last decades people from higher-income groups have moved out of the older neighbourhoods of cities and from the vicinity of industrial zones to settle down in suburbia and dormitory towns where they found better conditions with respect to housing, working, transport and the quality of the local environment. The more socially disadvantaged groups are left behind increasing the geographic accumulation of unfavourable social-economic conditions. [176), 212)]

Apart from the indirect causal mechanisms discussed above, there are indications that socio-economic status has a direct influence on health status. Intermediate factors might not explain the full extent of social-economic health differences. Furthermore some evidence for a direct influence can be derived from the fact that mortality rates are more closely linked to relative income within countries than to differences in absolute income between them. Secondly, national mortality rates tend to be lowest in countries that have smaller income inequalities and thus have lower levels of relative deprivation. [103)] * Thirdly, most of the long-term rise in life expectancy seems unrelated to long-term economic growth, implicating some threshold beyond which further growth of the gross national product (GNP) no longer induces extension of life expectancy (life expectancy reaches a plateau). [269)]

Some authors argue that the increase of income inequalities is accompanied by reduced social cohesion, a higher level of material insecurity, social exclusion and isolation. [134), 137)] A lower position in the social hierarchy, lower personal control, chronic insecurity and low self-esteem may by itself affect endogenous factors, such as serum levels of stress hormones, blood pressure, immune function, central obesity, lipoprotein composition and coronary artery atherosclerosis, largely independently, for the most part, of from lifestyle factors. However, these theories are of a hypothetical nature. So far evidence for these direct effects of social disruption is primarily found in animal and occupational studies. [158), 159), 268)]

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* This mechanism is consistent with developments of public health indicators in the UK during the Thatcher administration and in Russia and Eastern Europe after the Wall tumbled down.

Among the strong and consistent health impacts of social-economically-determined factors discussed here one will often search in vain for an independent effect of environmental exposures in available health statistics, such as mortality and morbidity rates or medical consumption.[67] The strong association between socio-economic and environmental conditions, the expected small increases of health risks attributable to environmental exposures combined with random variation produce a 'signal-to-noise'-ratio that goes way beyond the resolution of available epidemiological methods.[188] Only when health outcomes are more or less specific for a certain environmental exposure, might one use health statistics to reveal a quantitative association (see Figure 4). However, examples of such relationships are rare and mostly derived from occupational exposures to high levels (asbestos and mesothelioma, vinyl chloride and angiosarcoma, benzene and leukaemia).

Therefore, to detect environmental exposure specific health impacts one needs to investigate more specific end-points, such as body burden, lung function parameters, specific respiratory or psychological symptoms. However, there is a geographic association between socio-economic status and poor residential environmental quality in the vicinity of important sources, such as airports, freeways, and industrial areas.[83, 146, 172, 176, 212, 233, 239, 262] One has to acknowledge the fact that social studies of a cross-sectional, sometimes ecological nature often simply lack the potential for an unbiased unravelling of all the possible relations and interactions dealt with in this chapter. Most study designs offer only limited possibilities to deal with socio-economic confounding in a satisfactory manner.[172]

Annex **G**

Air pollution data

Table 16 WHO air quality guidelines and limit values and European Union (EC) guide values. [278), 156)]

com-ponent	description	time weighted mean	averaging period
CO	WHO guideline	100 mg m^{-3}	15 min
		60 mg m^{-3}	30 min
		30 mg m^{-3}	1 h
		10 mg m^{-3}	8 h
NO_2	WHO guideline	200 µg m^{-3}	1 h
		40 µg m^{-3}	annual
	EC limit value	200 µg m^{-3}	98% of hourly means
	EC guide value	135 µg m^{-3}	98% of hourly means
		50 µg m^{-3}	50% of hourly means
SO_2	WHO guideline	500 µg m^{-3}	10 min
		125 µg m^{-3}	24 h
		50 µg m^{-3}	annual
	EC guide value	40-60 µg m^{-3}	1 yr (mean of daily values)
		100-150 µg m^{-3}	24 h (daily mean value)
O_3	WHO guideline	120 µg m^{-3}	8 h

component	description	time weighted mean	averaging period
CO	WHO guideline	100 mg m^{-3}	15 min
	EC guideline population information threshold	180 µg m^{-3}	1 h mean
	EC guideline population warning threshold	360 µg m^{-3}	1 h
	EC guideline health protection threshold	110 µg m^{-3}	88 h mean
black smoke	EC limit value	68 µg m^{-3}	1 yr (median of daily values)
		111 µg m^{-3}	6 months (median daily values October-March)
		213 µg m^{-3}	1 yr (mean of daily values)
	EC guide value	34-51 µg m^{-3}	1 yr (mean daily values)
		85-128 µg m^{-3}	24 hr (mean)

Annex **H**

Health effects of noise

A Assessment of evidence

The Health Council committee on Noise and Health assessed the effects of occupational and environmental noise exposure on health and quality of life. A summary of the results obtained are reproduced in Table 17 (Table 1 from [93]))

Table 17 (Possible) long term effects of exposure to noise, classification of the evidence for a causal relationship and data on the observation threshold

effect	classification of evidence[a]	situation[b]	observation threshold		
			measure	value in dB(A)	in/out[d]
hearing loss	sufficient	occc	$L_{EX,occ}$[c]	75	in
		env recr	$L_{Aeq,24h}$	70	in
		occ unb	$L_{EX,,occ}$	<85	in
hypertension	sufficient	occ ind	$L_{EX,occ}$	<85	in
		env road	$L_{Aeq,06-22h}$	70	out
		env air	$L_{Aeq,06-22h}$	70	out
ischaemic heart disease	sufficient	env road	$L_{Aeq,06-22h}$	70	out
		env air	$L_{Aeq,06-22h}$	70	out
biochemical effects	limited	occ			
		env			

effect	classification of evidence[a]	situation[b]	observation threshold		
			measure	value in dB(A)	in/out[d]
immune effects	limited	occc env			
birth weight	limited	occ env air			
congenital effects	lack	occ env			
psychiatric disorders	limited	env air			
annoyance	sufficient	occ off occ ind env	$L_{EX,occ}$ $L_{EX,occ}$ L_{dn}	<55 <85 42	in in out
absentee rate	limited	occ ind occ off			
psycho-social well-being	limited	env			
sleep disturbance, changes in:					
sleep pattern	sufficient	sleep			
awakening	sufficient	sleep	SEL	60	in
sleep stages	sufficient	sleep	SEL	35	in
subjective sleep quality	sufficient	sleep	$L_{Aeq,night}$	40	out
heart rate	sufficient	sleep	SEL	40	in
hormones	limited	sleep			
immune system	inadequate	sleep			
mood next day	sufficient	sleep	$L_{Aeq,night}$	<60	out
performance next day	limited	sleep			
performance	limited	occ env			
	sufficient	school	$L_{Aeq,school}$	70	out

a Classification of evidence of causal relationship between noise and health.

b occ = occupational situation, ind = industrial, off = office, env = living environment, recr = recreational environment, road = road traffic, air = air traffic, sleep = sleeping time, unb = unborn: exposure of pregnant mother, school = exposure of children at school.

c $L_{EX,occ}$ is the equivalent sound level over a presentative working day, standardise to 8 hours

d Value relates to indoor or outdoor measurement. In the Netherlands, the difference between the level measured outdoors and that indoors is 15 to 25 dB(A) for dwellings with single glazing.

e Observation thresholds for traffic and industrial noise; the observation threshold is lower for environmental impulse noise.

The committee described its findings as follows:

In [...] this report noise-induced health effects were specified according to the type of noise source and also a differentiation was made with respect to the living, working and recreational environment. An overview is given in [Table 17], which specifies possible long-term health effects, together with a classification of the evidence for a causal relationship. If there is sufficient evidence for a causal relationship, observation thresholds have been specified in the table. The observation threshold is the exposure value above which, on average, an effect from exposure to noise has been observed in epidemiological studies. The observation thresholds concern an average population of adults or adult workers or average populations otherwise specified, such as babies of women exposed to noise during pregnancy.

For those adverse health effects for which sufficient evidence is available to show a causal relationship between noise exposure and effect, it was examined whether reliable exposure-effect relations do exist. For some of these noise-induced health effects, exposure-effect functions are simply expressed in terms of relative risk above the observation threshold. This holds for ischaemic heart disease and hypertension. With respect to noise-induced hearing loss exposure-effect functions are given in ISO 1999; for occupational noise exposure $L_{EX,occ}$ is taken as noise measure, and for environmental noise exposure and exposure during leisure, $L_{Aeq,24h}$ is the measure to be used.

Also for severe annoyance from traffic and industrial noise in the living environment, exposure-effect functions de exist. However, exposure-effect functions regarding annoyance for occupational noise exposure in offices as well as in industrial situations are lacking.

Although there is sufficient evidence for a causal relationship between night-time noise exposure and various effects on sleep, exposure-effect functions have only been derived from field studies for some effects. For awakening and for sleep stage changes due to exposure from intermittent night-time noise, these exposure-effect functions have been derived, with the exposure specified in SEL. With these exposure-effect relations as a basis, the number of awakenings and sleep stage changes has been estimated in the special case of night-time aircraft noise around main airports, with the equivalent sound level during the night as exposure measure [...].

With respect to the adverse noise-induced health effects from a cumulation of exposures to different noise sources, information which allows the determination of these effects is available only for the noise-induced effects hearing loss and annoyance. Concerning noise-induced hearing loss, the effect of any exposure to several noise sources can be calculated from the equivalent sound level over the total exposure period. For annoyance from exposure to several environmental noise sources at one location, there is a calculation scheme for determining accumulated annoyance due to these combined exposures [[96)]].

Effects on health from a combination of exposure to noise and that to other physical or chemical agents have rarely been the object of epidemiological research. Since the number of studies and sizes of the populations studied are too small, the data available, have yet to demonstrate sufficient evidence of interactions.

Populations whom epidemiological research has shown an increased susceptibility for acquisition of a noise-induced health effect, are:

- children, who are probably more vulnerable to acquiring noise-induced hearing loss than adults
- males exposed to occupational noise and having high blood cholesterol levels have an increased risk of noise-induced hearing loss in comparison to occupational noise exposed male populations with normal cholesterol levels
- with respect to stress-related health effects, exposure of hospitalised patients to relatively high levels of noise from inside and outside noise sources delays recovery and wound healing
- pregnant women exposed to high levels of industrial noise show an increased risk of hypertension during pregnancy, relative to pregnant women not exposed to occupational noise
- people highly annoyed by low levels of road traffic noise have an increased risk of hypertension
- men exposed to road traffic noise in the living environment and also exposed to occupational noise have an increased risk of ischaemic heart disease compared to men exposed to road traffic noise only
- people annoyed by noise in the workplace show an increased post-work irritability, which might affect well-being at home
- the sick, people with sleeping difficulties and older people show more noise-induced sleep disturbance, especially with respect to the inability to fall asleep (after being awakened), than other adults. Older people also have an increased risk of being awakened by night-time noise
- people with noise-induced sleep disturbance have an increased risk of hypertension, ischaemic heart disease and negative effects on psycho-social well-being compared to people in the same living environment without sleep disturbance
- noise sensitive people, people with fear of certain noise sources and people feeling they have no control over a noise situation (in this respect, feeling an abuse of power) have an increased risk of severe annoyance.

B Exposure-response relationships for noise induced general annoyance, sleep disturbance annoyance and awakenings

The figures below are based on analyses of data in the so-called Database Verstoring (environmental disturbance) of TNO Prevention & Health, that encompasses original data of studies on the effect of residential and recreational noise. The figures below have been taken from a recent publication of Miedema [169] and the 1997 Health Council report on Assessing noise for public health purposes [96].

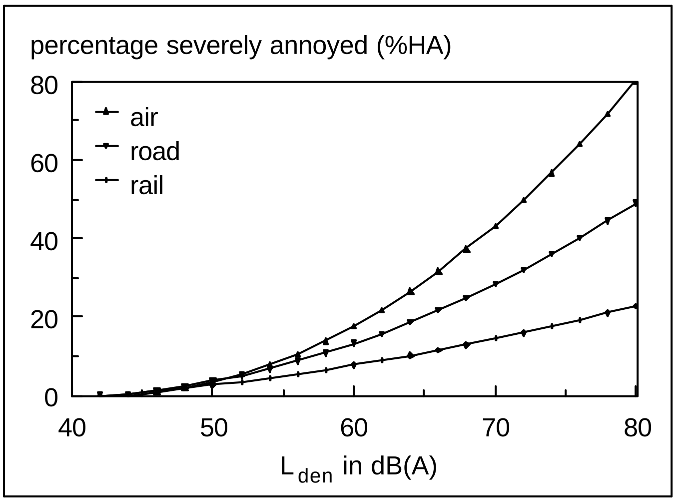


Figure 14 Percentage seriously annoyed as a function of the day-evening-night level for air, road and rail transport noise.

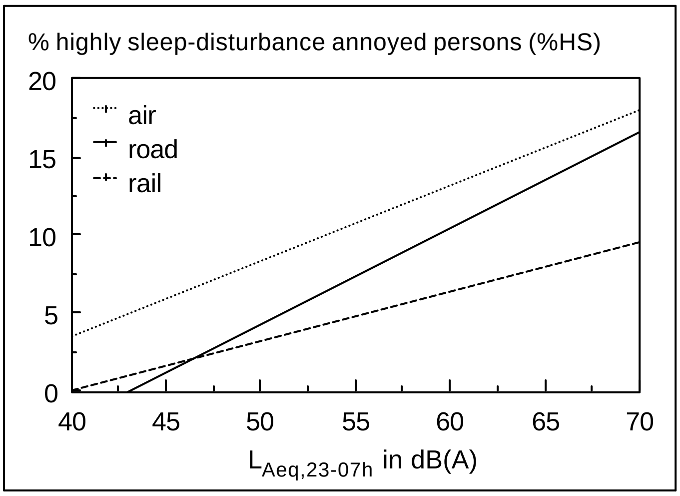


Figure 15 Percentage seriously annoyed by sleep disturbance as a function of the equivalent sound level during the night for air, road and rail transport noise.

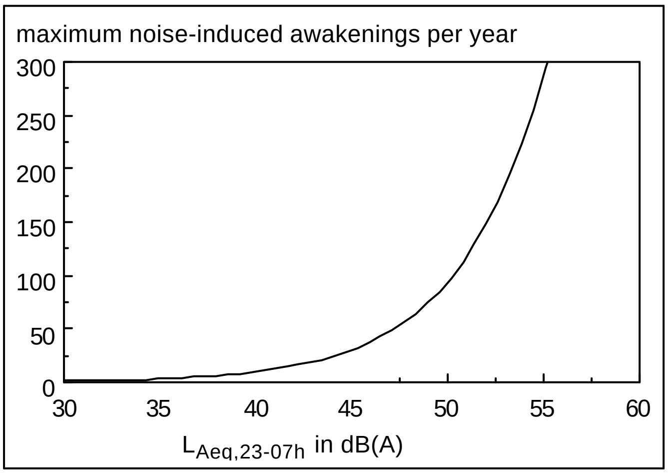


Figure 16 Maximum number of awakenings per year as a function of the equivalent sound level during the night.

Annex I

Categories of risk in the form of semantic images

The text below is taken from Renn's paper and describes the four semantic images of risks listed in Table 13. [202)]

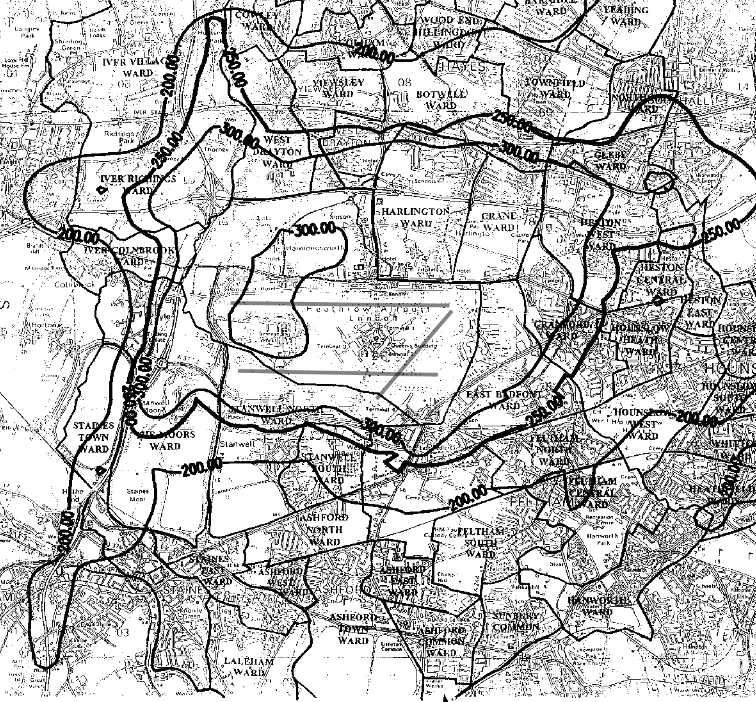
"Psychological research has revealed different meanings of risk depending on the context in which the term is used. In the technical sciences the term risk denotes the probability of adverse effects, whereas the everyday use of the term risk has different connotations. [Table 13] illustrates the main semantic images with respect to technological risk [...].

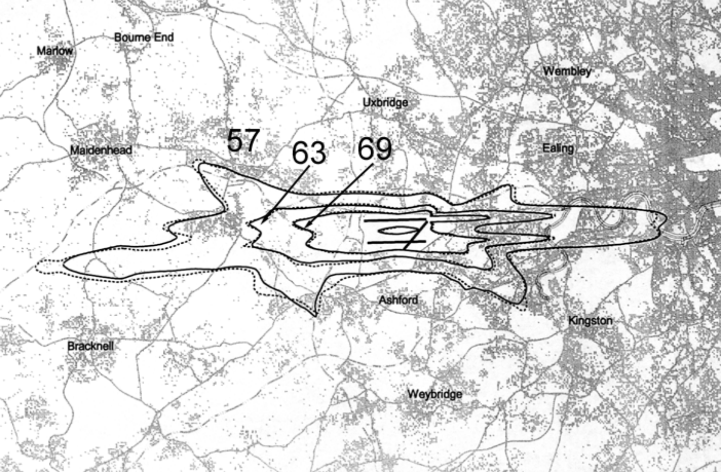
Risk as a pending danger (Damocles' sword). Risks are seen as a random threat that can trigger a disaster without prior notice and without sufficient time to cope with the hazard involved. This image is linked to artificial risk sources with large catastrophic potential. The magnitude of the probability is not considered. It is rather the randomness itself that evokes fear and avoidance responses. Natural disasters, in contrast, are perceived as regularly occurring and thus predictable or related to a special pattern of occurrence (causal, temporal or magic). The image of pending danger is therefore particularly prevalent in the perception of large-scale technologies. Nuclear power plants are a prime example of this semantic category.

Slow killers (Pandora's box). Risk is seen as an invisible threat to one's health or well-being. Effects are usually delayed and affect only few people at the same time. Knowledge about these risks is based on information by others rather than on personal experience. These risks pose a major demand for trustworthiness in those institutions that provide information and manage the hazard. If trust is lost, people demand immediate actions and assign blame to these institutions even if the risks are small. Typical examples of this risk class are food additives, pesticides and radioactive substances. Due to the importance of trust in monitoring and managing slow killers, nuclear risk managers should place a major effort to improve their trustworthiness and credibility in the community. [...]

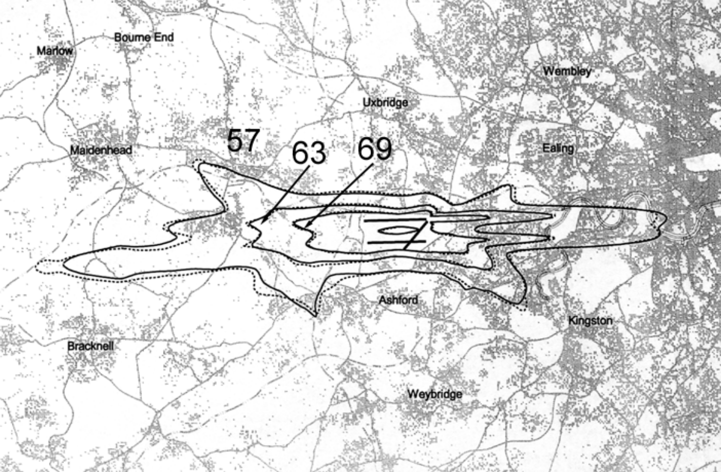
Cost-benefit ratio (Athena's scale). Risks are perceived as a balancing of gains and losses. This concept of risk comes closest to the technical understanding of risk. However, this image is only used in peoples' perceptions of monetary gains and losses. Typical examples are betting and gambling, both of which require sophisticated probabilistic reasoning. People are normally able to perform such probabilistic reasoning but only in the context of gambling, lotteries, financial investment and insurance. Laboratory experiments show that people orient their judgement about lotteries more towards the variance of losses and gains than towards the expected value [...].

Avocational thrill (Hercules' theme). Often risks are actively explored and desired [...]. These risks include all activities for which personal skills are necessary to master the dangerous situation. The thrill is derived from the enjoyment of having control over one's environment or oneself. Such risks are always voluntary and allow personal control over the degree of riskiness."


COWLEY WARD
WOOD END HILLINGDON
YEADING WARD
IVER VILLAGE WARD
YIEWSLEY WARD
BOTWELL WARD
HAYES
TOWNFIELD WARD
WEST DRAYTON WARD
IVER RICHINGS WARD
GLEBE WARD
HARLINGTON WARD
CRANE WARD
HESTON WEST WARD
IVER COLNBROOK WARD
HESTON CENTRAL WARD
HESTON EAST WARD
CRANFORD WARD
HOUNSLOW HEATH WARD
Heathrow Airport London
Terminal 1
Terminal 2
Terminal 3
Terminal 4
Queens Building
Harmondsworth
Sipson
EAST BEDFONT WARD
HOUNSLOW SOUTH WARD
HOUNSLOW WEST WARD
STANWELL NORTH WARD
STAINES TOWN WARD
MOORS WARD
STANWELL SOUTH WARD
FELTHAM NORTH WARD
FELTHAM CENTRAL WARD
FELTHAM
ASHFORD NORTH WARD
FELTHAM SOUTH WARD
STAINES EAST WARD
ASHFORD WEST WARD
ASHFORD EAST WARD
ASHFORD
STAINES
HANWORTH WARD
ASHFORD TOWN WARD
ASHFORD COMMON WARD
SUNBURY COMMON
LALEHAM WARD
HOUNSLOW
200.00
250.00
300.00



Marlow
Bourne End
Wembley
Uxbridge
57
63
69
Maidenhead
Ealing
Ashford
Kingston
Bracknell
Weybridge


Bourne End
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Maidenhead
Ealing
Ashford
Kingston
Bracknell
Weybridge


A ☧ Ω