A Comparison of the Health Impact Assessment of the proposed Third Runway by the Hong Kong Airport Authority with Other Airports

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Report by

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1 Background and Objectives of Study

In mid-2014, the Hong Kong Airport Authority (HKAA) submitted an Environmental Impact Assessment (EIA) Report of the proposed construction of the third runway in Hong Kong International Airport to the Environmental Protection Department (EPD). In this report, an assessment of the impact of the proposed runway on the health of residents in the vicinity – a health impact assessment (HIA) study was performed.

HIA is a tool that quantifies the effects of adverse environmental risk factors on the health and wellbeing of a community. It has been widely used to assess the impact of a project or policy on health and assists the policy maker in the decision. HIA has been advocated in the past two decades, and has been incorporated in the legal framework in some European countries. In other European countries, even in the absence of legal requirements, HIA has been widely practised. The leading organization that has developed and standardized HIA methodology and practice is the World Health Organization (WHO) Regional Office for Europe. Other countries, including the UK and New Zealand, develop guidelines and practice on their own, making reference to reports and recommendations published by WHO Regional Office for Europe. The US lags behind Europe in this development. Developing countries are now actively pursuing the concept of HIA, but most lack a legal framework for its implementation.

Based on the published HIA report, Dashun Policy Research Centre commissioned this study to compare the environmental health standards, the methodology used for HIA and the results of HIA studies on airport projects that have been conducted in different countries. The study was based on reports conducted by / in relation to major airports in other countries and available in the public domain.

The aim of this comparative study is to benchmark the Hong Kong study with airports in cities in developed countries, in terms of methods and standards used, and nature and magnitude of the health impact. The specific objectives are:

(i) to compare the methodology used in the HIA in different airports;
(ii) to compare the environmental standards used in different countries where the HIA reports are available, and
(iii) to compare the health impact of the Hong Kong study with study results in other airports.

2 Methodology of Study

First, data on national regulatory standards in terms of air pollution, noise and health impact were collected. A literature search for EIA reports of airport projects was then conducted to identify the methods used for HIA and the results of these studies. They were then compared with the EIA report that the AA submitted to the EPD.

3 Steps in Health Impact Assessment

In HIA, the health endpoints resulting from the environmental risks are first identified. This is followed by the collection of data on the exposure-response function of different environmental risk factors in relation to their health endpoints. Such data usually are derived from epidemiological studies (studies of the link between the health of a population and the exposure to environmental risk factors). Data obtained from local studies are preferable in the HIA, whenever available. The next step involves an estimation of the population affected by the environmental risk factors. Finally, the health risks to the affected population are quantified.

4 Environmental Standards

4.1 Introduction

Air pollution and noise are major factors that may affect the health of residents in the vicinity of airports. Hence, environmental standards of relevance to the health impact assessment of airport projects include those pertaining to air pollutant concentrations and noise levels in 'sensitive receivers' (residents in areas that are potentially affected by noise and air pollution generated from the construction of the runway and operation of the airport with the new runway).

There are two main categories of air pollutants – the criteria air pollutants, so-called because there are legal standards for their concentrations (that need to be complied with before an EIA submission can be approved), and the toxic air pollutants (TAPs). TAPs are a heterogeneous group of different chemicals, including metals and organic chemicals (both aromatic and aliphatic). Among the TAPs are known carcinogens (cancer-causing substances), as well as chemicals that affect different organs and systems of the human body from short-term or long-term exposure.

In general, separate standards are set up for short-term and long-term exposure to criteria air pollutants. For TAPs, most countries have not set legal standards, but threshold levels (below which the effects on health are considered to be negligible) are available. Likewise, there are no set standards for carcinogens, but the environmental health community generally regards certain cancer risks to be acceptable when such risks are close to the background risk for cancer.

For noise, specific noise metrics are used for different health endpoints. They are expressed as equivalent energy levels taking into account the hours of the day, night time exposure being given a higher weight than evening hours, which are higher in weighting than daytime exposure. For HIA they are usually expressed as L_{den} (equivalent energy levels weighted by day, evening and night) expressed dB(A) for the assessment of annoyance, and L_{night} (equivalent energy levels for noise experienced at night time) for the assessment of sleep disturbance. For airport planning purposes in Hong Kong, a different metric, (NEF) is used under the regulatory framework.

4.2 Comparison of environmental standards across countries

Most countries set their own environmental standards according to local legislations. In the European Union, a uniform set of standards are applicable to all member countries, while in the US and Australia, standards differ considerably from each other (Table 1).

Table 1: Air quality and noise standards used in airport environmental impact assessment studies

	Air pollutants (averaging time: annual, unless otherwise stated)					Aircraft noise
	NO_2 (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (µg/m^3)	*O_3 (µg/m^3)	
Hong Kong	40	50	35	125 (24-hr)	160 (8 hr mean)	NEF 25#
US	99.7 ^	150 (24-hr)	12	196 (1-hr) (=75 ppb)	147^ (8 hr mean)	65 dB (DNL)
UK and EU	40	40	25 (12 for Scotland)	125	100 (8 hr mean)	57 dB(A)
Australia	56.4 (=30ppb)	50 (24-hr)	8	52.35 (=0.02 ppm)	1 hr mean: 196 (=100 ppb) 4 hr mean: 157 (=80 ppb)	ANEF <20

* 8 hr daily mean for Hong Kong, UK and US; for Australia, 2 standards: for 1-hr mean and a 4-hr mean respectively.

NEF 25 is roughly equivalent to Leq (24 hr) 62 dB(A) or Ldn 63 dB(A), based on the following formulae: Leq (24 hr) = NEF + 37 dBA, and Leq (24 hr) = Ldn -1 (Reference: "Bradley JS., "NEF Validation Study: (1) Issues related to the Calculation of Airport Noise Contours", IRC Contract Report A-1505.3, 1996). See Section 5.3.1, p9.

^ For NO_2, 99.7 µg/m^3 = 53 ppb; for O_3, 147 µg/m^3= 75 ppb

The Air Quality Objectives (AQOs) presently adopted in Hong Kong (which came into effect on 30 Dec 2013) are based on the Air Quality Guidelines (either interim 1, 2 or final) proposed by the World Health Organization (WHO, 2005). For nitrogen dioxide (NO_2), the Hong Kong AQOs are comparable with those used in the United Kingdom and the European Union, while for particulates with an aerodynamic diameter less than 10 μm (PM_{10}), Hong Kong's AQOs are identical with the National Ambient Air Quality Standard used by the US. Notable exceptions are particulates with an aerodynamic diameter less than 2.5 μm ($PM_{2.5}$) and ozone (O_3), for which Hong Kong adopts a more lenient standard compared to Europe, the US and Australia. Australia has the most stringent standard among all the countries that have been compared, especially for $PM_{2.5}$ and sulphur dioxide (SO_2). Its standard for nitrogen dioxide (NO_2), however, is slightly more lenient than the Hong Kong standard (which has adopted the World Health Organization guideline). The US adopts similar (PM_{10}) to more stringent ($PM_{2.5}$, SO_2 and O_3) standards than Hong Kong except for NO_2.

For noise, different countries have their own noise metrics in accordance with their legal requirements. In general, Australia has the most stringent standard (ANEF 20 is roughly equivalent to 55 dB leq), while the standards used in Hong Kong (NEF 25) is equivalent to that used in UK and EU 9 (57 dB(A)). US adopts the least stringent standard (65 dB) of all.

5 Health impact assessment

In the US HIA reports, estimated concentrations of criteria air pollutants are assessed against the US National Ambient Air Quality Standards (NAAQS). The US studies do not report the impact of these air pollutants on the health of the population potentially affected, but merely whether the NAAQS have been complied or otherwise. In the European and Australian reports, the effects of O_3 have not been included in the HIA. O_3 a 'secondary pollutant' not directly generated by aircrafts and airport operations, but is produced from photochemical reactions from primary pollutants.

For noise, most European approaches use a European standard – the exposure response function published by Miedema et al (2001), for the assessment of annoyance and sleep disturbance by aircraft noise. Ischaemic heart disease and hypertension as health endpoints are commonly adopted in European HIA reports. Publications by European experts in environmental noise and health suggest that environmental noise is a risk factor for these diseases. By contrast, a local study by the EPD, after reviewing the evidence, concluded that the *evidence is insufficient* (Wong et al, 2011). There are still controversies in this aspect. Annoyance and sleep disturbance are two well-research areas in the health impact of aircraft noise. It has been well recognized that the response to aircraft noise as annoyance and sleep disturbance varies between communities, and are highly dependent on the building environment, social and cultural factors. There are also wide variations in their individual responses, depending on their susceptibility to environmental noise. For example, shift-workers and people with long-term physical and mental health problems are more susceptible to noise. Children's learning may also be affected.

5.1 Health end-points used in health impact assessment

Different countries have used different methods in the HIA of the construction of new airports or extension of existing ones. As mentioned earlier, an obvious difference between the approaches in US airports from those adopted in other countries is that in the US, the EIA typically excludes the effects of criteria air pollutants in their HIA. This is related to the legal status of the national ambient air quality standards (NAAQS) used in the US. The US Environmental Protection Agency (EPA) under the Clean Air Act, adopts NAAQS for different criteria air pollutants for its states to follow. Hence, the EIA must (and only needs to) comply with the NAAQS.

In air pollution research, it is well known that the impact of some criteria air pollutants, notably the particulate matter (PM_{10}, $PM_{2.5}$), on health can still be observed at concentrations *below* the NAAQS, or even the World Health Organization (WHO) Global Air Quality Guidelines. Hence, HIA in European countries and Australia typically includes the health impact of criteria air pollutants, such as their impact on premature deaths and illnesses, while most US HIA do not carry out such an assessment. Instead, they simply states the compliance (or otherwise) with the NAAQS.

For other toxic air pollutants (TAPs), commonly known as air toxics, the conventional approach is to assess both the short- and long-term impact on health. The criteria for the short-term health impact are whether the concentrations of the TAPs being assessed are above their respective short-term thresholds as promulgated in internationally acclaimed toxicology databases. The criteria for long-term health impact of TAPs depend on whether they cause cancer or not. For non-cancer causing TAPs, the criteria are similar to those used for short-term health impact, that is, whether the concentrations of the TAPs have breached the threshold for long-term exposure. For cancer-causing TAPs, the conventional method in HIA is to assess the increase in the number of cancer cases caused by the increase in the concentrations of these TAPs, based on a 'no-threshold' assumption for carcinogenic substances. The above methods are adopted by the US, some European countries and Australia.

5.2 Assessment of impact on health by air pollutants

5.2.1 Major air pollutants

Concentrations of major air pollutants are – particulate matter with an aerodynamic diameter less than 10 micrometers (PM_{10}), oxides of nitrogen (NO_x), ozone (O_3) and sulphur dioxide (SO_2). Data from local and international epidemiological studies on short- and long-term risk estimates of these pollutants on cardiovascular and respiratory diseases have been collected by the research team through literature review. Data on the population of the affected communities can be obtained from estimates published by the Census and Statistics Department (C&SD) of Hong Kong.

NO_2, SO_2 and PM_{10} are used in the HIA process.[1] The concentration of $PM_{2.5}$ can be estimated from the following equation:

$$[PM_{2.5}] = 0.71 \times [PM_{10}]$$

The Air Quality Objectives (AQOs) currently adopted by the Environmental Protection Department (EPD) of the Hong Kong Government are:

Annual mean NO_2 concentration: 40 $\mu g/m^3$
Annual mean PM_{10} concentration: 50 $\mu g/m^3$
Annual mean $PM_{2.5}$ concentration: 35 $\mu g/m^3$
24-hr mean SO_2 concentration: 125 $\mu g/m^3$

5.2.2 Assessment of impact on health

The methods for assessing the increased deaths and illnesses attributed to air pollution are as follows[2]:

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1 Ozone is a secondary air pollutant formed by photochemical reaction. In addition, it reacts with nitric oxide (which is generated from airport activities) to form nitrogen dioxide and is therefore not considered a key pollutant. For SO_2, only 24-hr (short-term) AQO is available.

2 Source: APHEIS: Health Impact Assessment of Air Pollution and Communication Strategy. Third Year Report. ISBN: 2-11-094838-8; Institut de Veille Sanitaire; June 2005. Downloaded from: http://www.apheis.org/vfbisnvsApheis.pdf

Attributable proportion (AP) =Σ [(RRc – 1) x Pc] / Σ [RRc x Pc]

Where RRc = relative risk in category c of exposure, Pc = percentage of population in category c of exposure

For short-term impact on mortality and morbidity, relative risks derived from local time series studies (Wong et al, 2010) are used in HIA. (Appendix 1, Table A1). For long-term impact on mortality, relative risks derived from a large cohort study (Pope et al, 2002) in the US are used. (See Appendix 1, Table A2).

5.3 Assessment of impact on health by environmental noise

5.3.1 Noise contours

The "noise exposure forecast" (NEF) was developed by the U.S. Federal Aviation Agency to predict the degree of community annoyance from aircraft noise and airports. A noise contour of 25 (NEF) has been used by the HKAA in delimiting a boundary above which the operation of an airport is considered acceptable.

There is no fixed mathematical relationship between NEF and the 24-hour equivalent continuous sound level ($Leq_{24\ hr}$). The following equation is a rough approximation only (Bradley, 1996).

$Leq_{24\ hr}$ in dB(A) ≈ NEF +37 dB(A)
$L_{dn} = Leq_{24\ hr} + 1$ dB(A)

Hence, 25 (NEF) corresponds to an $Leq_{24\ hr}$ of 62 dB(A) and L_{dn} of 63 dB(A). The existing noise contour of 25 (NEF) covers the Airport Island at Chek Lap Kok and a small area in the adjoining Sha Lo Wan village of Lantau Island. The residential district of Tung Chung is outside this noise contour.

5.3.2 Assessment of impact on health

Two impacts of noise on health are assessed – annoyance and sleep disturbance.

Annoyance can be defined as a negative psychological reaction of displeasure to environmental noise. Passchier-Vermeer and Passchier (2000), in a comprehensive review of noise exposure and public health for the Dutch Health Council, note that "*Noise annoyance is a feeling of resentment, displeasure, discomfort, dissatisfaction, or offense when noise interferes with someone's thoughts, feelings, or actual activities*".

Sleep disturbance or sleep disorder (somnipathy) is defined as a medical disorder of the sleep patterns of a person. Some sleep disorders are serious enough to interfere with normal physical, mental and emotional functioning. Noise-induced sleep disturbance includes difficulties to fall asleep, awakening from sleep, reduced sleep time, and poor sleep quality. These two effects of aircraft noise on health are well researched and have been used as "health endpoints" in health impact assessment studies in other airport projects.

In the absence of local data on risk estimates and dose-response relationships between aircraft noise and annoyance and sleep disturbance, data from overseas studies, risk estimates of environmental noise on several health outcomes – annoyance and sleep disturbance have been collated and compared. Using these risk estimates, the estimated population in the environmental noise-sensitive receivers, and the projected noise contour, the overall health impact of aircraft noise attributed to the third runway, in terms of annoyance and sleep disturbance of residents in these communities have been assessed.

5.3.3 Exposure-response functions

The following exposure-response functions have been used in the HIA of noise, based on 3 Working Papers (Lam et al, 2011):

For annoyance: Miedema and Oudshoorn, 2001:

(Aircraft noise)

$$\% \text{ annoyed} = 1.45 \times 10^{-5} (L_{dn} - 37)^3 + 1.511 \times 10^{-2}(L_{dn} - 37)^2 + 1.346(L_{dn} - 37)$$

$$\% \text{ highly annoyed} = -1.395 \times 10^{-4}(L_{dn} - 42)^3 + 4.081 \times 10^{-2}(L_{dn} - 42)^2 + 0.342(L_{dn} - 42)$$

L_{dn} = Equivalent noise level (day and night) with 10 dB(A) penalty for night time noise (11 pm–7 am)

For sleep disturbance:

(Aircraft noise)

Only dose-response relationship between L_{night} and % of sleep disturbance is available (Miedema & Vos, 2007).

High sleep disturbance:

$\%HSD = 18.147 - 0.956L_{night} + 0.01482L_{night}$

L_{night} = Equivalent noise level from 11 pm to 7 am.

The AA adopted exposure response functions used in European countries, the Miedema curve (Miedema et al, 2001) in the HIA process. This is considered to be "conservative", as the local exposure response function for road traffic noise and annoyance and sleep disturbance, according to a study commissioned by the EPD (Lam et al, 2011), shows that the same noise level is associated with a smaller proportion of people that is highly annoyed and highly disturbed in their sleep, compared to the European findings. This observation has also been reported in a smaller study in Vietnam (Phan et al, 2008). It could be interpreted that Hong Kong people are more adapted to a noisy environment. On the other hand, it has been shown that projecting into the future, the noise threshold is gradually falling, suggesting that younger generations are less tolerant to noise than the older generations. This observation must also be taken into account.

6 Health Impact Assessment by Hong Kong Airport Authority

6.1 A brief summary of the results of the HKAA HIA

The methodology of the HIA for air pollution in the EIA report submitted by the HKAA follows conventional approaches used in most European countries and Australia by quantifying the health impact attributed to criteria air pollutants. First, the AA report assesses whether the projected concentrations of air pollutants have exceeded the current Hong Kong Air Quality Objectives (AQOs) adopted by the EPD. This approach is similar to that used in US airports. In addition, the AA report presents the additional risks of premature deaths and hospital admissions for cardiovascular and respiratory diseases among the populations affected that may arise from an increase in concentrations of most criteria air pollutants ($PM_{2.5}$, SO_2 and NO_2). As with the European and Australian reports, the effects of O_3 have not been included. For TAPs, the approaches are similar to HIA methodologies used in US, European and Australian airports.

For noise, the HKAA report does not assess the potential health impact on cardiovascular diseases. This is different from some European approaches. One major limitation in the AA's report is the lack of local data on the exposure response relationship between aircraft noise and these effects.

6.2 Air pollution

Predicted concentrations of criteria air pollutants with and without the third runway are presented in Tables 2a and b.

In general, the air quality worsens when compared with the 2-runway scenario. Of the criteria air pollutants, NO_2 and particulate matters (PM_{10} and $PM_{2.5}$) do not meet their respective air quality objectives in certain areas.

For criteria air pollutants, the impact on health was assessed by the use of local exposure response functions when available, and for long-term effects, by internationally accepted research findings that have been widely used (Pope et al, 2001). The increase in the number of hospital admissions for cardiovascular and respiratory diseases, and the mortality risks of residents in the sensitive receivers are at 3-5 cases per 100,000 and one deaths per 100,000 population respectively. The additional health risk is considered to be small.

For the non-criteria toxic air pollutants (TAPs), the projected concentrations were well within the short-term threshold concentration limits. This means there is no health risk on short-term exposure to the TAPs generated in the populations in the sensitive receivers. For long-term exposure, the non-carcinogenic health risks are similarly within the long-term threshold concentration limits and thus interpreted as not causing long-term non-cancer health risks. For TAPs that are carcinogenic, the highest incremental cancer risk was 1.14 in 100,000 in one site near the airport, while in other sites the risk was much lower.

Table 2a: Predicted maximum concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) in most affected sensitive receivers in the 3-runway scenario (3RS) and 2-runway scenario (2RS):

	CO (μg/m^3) (max 1 hr)	CO (μg/m^3) (max 8 hrs)	NO_2 (μg/m^3) (max 1 hr)	NO_2 (μg/m^3) (annual)	SO_2 (μg/m^3) (max 10 min)	SO_2 (μg/m^3) (max 24 hr)
AQO	30,000	10,000	200	40	500	125
Airport Island						
3RS	2,240	1,233	369	41	357	66
2RS	1,717	1,076	241	40	186	55
Boundary crossing Facilities						
3RS	2,672	1,137	200	40	171	60
2RS	2,669	1,021	203	40	150	53
Tung Chung						
3RS	1,610	1,236	280	30	149	42
2RS	1,419	1,177	237	30	141	42
Tung Chung West (TCP7)						
3RS	1,671	1,305	199	28	146	41
2RS	1,600	1,241	187	28	140	41
Tung Chung Area 54 (planned residential development)						
3RS	1,290	1,264	232	26	133	40
2RS	1,464	1,197	215	26	126	40
Sha Lo Wan						
3RS	2,098	1,195	306	31	254	47
2RS	1,711	1,132	274	37	232	46
Siu Ho Wan						
3RS	1,466	1 177	256	29	127	44
2RS	1,262	1,040	241	28	126	44
Logistic Park						
3RS	1,495	1,067	193	26	112	45
2RS	1,272	1,037	163	26	120	46
Tuen Mun						
3RS	1,338	1,062	215	36	318	53
2RS	1,337	1,075	215	36	318	53

Table 2b: Predicted maximum concentrations of particulate matter with an aerodynamic diameter < 10μm (PM_{10}) and particulate matter with an aerodynamic diameter < 2.5μm ($PM_{2.5}$) in most affected sensitive receivers in the 3-runway scenario (3RS) and 2-runway scenario (2RS):

	PM_{10} (μg/m^3) (max 24 hr)	PM_{10} (μg/m^3) (annual)	$PM_{2.5}$ (μg/m^3) (max 24 hr)	$PM_{2.5}$ (μg/m^3) (annual)
AQO	100	50	75	35
Airport Island				
3RS	123	40	92	29
2RS	126	41	92	29
Boundary Crossing Facilities				
3RS	123	40	92	29
2RS	122	40	92	29
Tung Chung				
3RS	117	39	87	28
2RS	116	40	87	28
Tung Chung East Development (TCP10-11)				
3RS	119	39	89	28
2RS	118	39	89	28
Sha Lo Wan				
3RS	117	40	88	28
2RS	117	40	88	28
Siu Ho Wan				
3RS	117	39	88	28
2RS	117	39	88	28
Logistic Park				
3RS	117	39	88	28
2RS	117	39	88	28
Tuen Mun				
3RS	129	42	96	31
2RS	129	44	91	31

6.3 Noise

Predicted noise levels have not been presented in the HKAA HIA Report. Instead, sensitive areas are tabulated according to the respective predicted noise exposure forecast (NEF) values. The highly populated areas of Tung Chung and Ma Wan are within (i.e., less than) the NEF 25 range, while several villages in close proximity to the Airport, namely, Sha Lo Wan and the North Lantau villages, are within the NEF 25 – 30 range. Other areas such as Tuen Mun, Sham Tseng, Tsuen Wan, Tsing Lung Tau and Tsing Yi are well below the NEF 25 range. While noise contours in decibels have not been presented in the report, noise metrics based on L_{eq} were used in the health impact assessment.

According to an estimate by the EPD, about 200 people are affected by noise from Chek Lap Kok. This corresponds to the HKAA noise contour of 25 (NEF). The population of Sha Lo Wan is estimated to be less than 300 (Island District Council, 2007).

The HKAA HIA shows that the proportions of residents in the sensitive receivers who are highly annoyed and highly disturbed in their sleep are reduced, by 10% and 50% respectively. This can be accounted for by the shift of the runway towards the sea, away from the population in Tung Chung, while the increase in noise level in the shore of New Territories West is comparatively small. One kindergarten in Siu Lam area was within the noise band of 55 – 60 dB(A), which is associated with a negative impact on cognitive functions. However, the background noise level as measured on site was found to be of this order of magnitude, and the potential impact of aircraft noise is therefore considered to be small.

7 A Review of HIA Studies in Other Airports

The following is a synopsis of Health Impact Assessment Reports from a review of the literature. A summary is presented in Table 3.

Table 3: Summary of results of health impact assessment in different airports

Airport	Air pollution (quantitative health impact assessment)	Noise (quantitative health impact assessment)
Hong Kong 2014	Yes, see details in Table 4	Yes, see details in Table 4
Brisbane, Australia 2005	Yes, see details in Table 4	Yes, see details in Table 4
Birmingham, UK 2008	No, see details in Table 4	Yes, see details in Table 4
Schiphol, Amsterdam, the Netherlands 1994	Yes, see details in Table 4	Yes, see details in Table 4
Fort Lauderdale, Florida, US 2008	No, but no significant impact is assumed when NAAQS are attained. Evaluation of hazardous air pollutants not required by law.	No
Santa Monica, California, US 2010	No. A comprehensive but qualitative account of the harmful effects of air pollutants (heart and lung diseases, cancer, hormonal balance, reproductive abnormalities, lower IQ in children) was conducted.	No. A comprehensive but qualitative account of the harmful effects of noise on human health (hearing loss, mental stress, learning problems in children) was conducted; Levels of noise due to plane and jet take-offs from Santa Monica Airport are above Federal Aviation Airport thresholds (65 dB(A) DNL)
Chicago O'Hara, US 2005	No, but predicted ambient concentrations of CO, NO_2, SO_2 and PM are below the NAAQS.	No, a slight increase in affected residences (within the 65 dB(A) DNL Build Alternative contours) when compared to the 2002 baseline noise contour.
Finningley ,UK 2000	No, but literature review of health and social impact (cancer, cardiovascular disease, respiratory disease, allergies) was conducted	No, but literature review of health and social impact (sleep disturbance, annoyance, anxiety and stress, cognitive performance, risk perception, economic benefits) was conducted
Manchester, UK 1994	No	No
Berlin Brandenburg, Germany 1991	No	No
Toronto, Canada 2002	No, ↑ heart and lung diseases and deaths	No, ↑ noise-induced stress, ill health and poor quality of life

7.1 Fort Lauderdale-Hollywood Airport Project (Environmental Impact Statement, Final Technical Report, Landrum and Brown Incorporated, June 2008)

Approach

Criteria pollutants: comparison with National Ambient Air Quality Standards (NAAQS).

Hazardous air pollutants (HAPs): Health impact assessment (HIA) not done because "the Federal Aviation Administration (FAA) determined that the health effects of persons living in the vicinity of the airport could not be determined in a meaningful way when the HAP evaluation would be limited to a single source in a local area".

HAPs considered: 1,3-butadiene, 2,2,4-trimethylpentane, acetaldehyde, acrolein, arsenic, benzene, chromium VI, diesel particulate matter, ethylbenzene, formaldehyde, *n*-hexane, lead, napthalene, nickel, polycyclic organic matter (POM), propionaldehyde, styrene, toluene and xylene.

7.2 Santa Monica Airport Health Impact Assessment, a Report written by University of California at Los Angeles (UCLA) Medical Centre Pediatrician trainees, supervised by UCLA Department of Pediatrics Faculty, February 2010

Key Findings

Airport operations, particularly jet take-offs and landing, are contributing to:

(i) Elevated levels of black carbon in the area surrounding Santa Monica Airport. Elevated exposure to black carbon is associated with increased rates of respiratory and cardiovascular disease including asthma, bronchitis, and increased risk for sudden death, irreversible decrease lung function in children and an increased carcinogenic risk.

(ii) Elevated levels of ultrafine particles (UFP) are associated with aircraft operations and jet take-offs and are found in the area surrounding Santa Monica Airport. Elevated exposure to UFPs are associated with an increased inflammation and blockage of blood vessels in mice models, and greater lung inflammation with exposure to UFPs than exposure to larger particulates in rodent models.

(iii) Elevated levels of polycyclic aromatic hydrocarbons (PAH) are found in the area surrounding Santa Monica Airport. Exposure to PAH has been associated with increased carcinogenic risk, disruption of the hormonal balance in adults, reproductive abnormalities with exposure during pregnancy, and lower IQ scores in children.

(iv) Levels of noise due to plane and jet take-offs from Santa Monica Airport are above Federal Aviation Airport thresholds. Excessive noise is associated with hearing loss, higher levels of psychological distress, impaired reading comprehension and memory among children.

There is no buffer zone between the airport airfield and the surrounding community as observed in many other municipal airport communities.

Recommendations

(i) Eliminate or significantly decrease the number of jet take-offs to reduce exposure to both the by-products of jet fuel exhaust and the loud "single event" noise of jet take-off.
(ii) Install HEPA (high efficiency particulate absorbing) filters in surrounding schools and residential homes to mitigate the exposure to PAHs and particulate air pollution.
(iii) Enforce Federal Aviation Airport noise thresholds by implementing additional noise abatement strategies such as soundproofing of schools and significantly affected homes near Santa Monica Airport that would protect residents from hearing loss, psychological distress, and learning problems in children.
(iv) Adopt the precautionary principle, given the evidence of the potential harm of UFPs and other by-products of airport pollution on animal and human health.
(v) Notify all potential property buyers, residents, and affected community members in the vicinity of Santa Monica Airport of the noise and air pollution health risks.
(vi) Maintain a runway buffer zone of at least 660 meters to protect surrounding residents from the harmful health effects of jet fuel exhaust by-products during idling and take-off.
(vii) Closure of Santa Monica Airport would eliminate all health risks associated with airport air and noise pollution.

7.3 Chicago O'Hare International Airport (Federal Aviation Administration, July 2005)

Air Quality

Criteria pollutants: comparison with National Ambient Air Quality Standards (NAAQS).

Hazardous Air Pollutants (HAPs): Toxicity values were obtained from several databases: USEPA's Integrated Risk Information System (IRIS of the US Environmental Protection Agency (USEPA), the Risk Screening Environmental Indicators (RSEI) Chronic Human Health Methodology of the USEPA, Technical Appendix A (a companion to USEPA's Toxic Release Inventory database), the California Environmental Protection Agency (CalEPA), and a report prepared by the Argonne National Laboratory 80 in which regional emissions of HAPs were evaluated for Cook County, Illinois and Lake County, Indiana. The HAPs are evaluated with respect to their carcinogenicity (for carcinogens) and toxicity (for non-carcinogens).

HAPs studied: 1,3-butadiene, acetaldehyde, acrolein, arsenic, benzene, chromium VI, diesel particulate matter, formaldehyde, naphthalene, nickel and toluene. A qualitative health risk assessment was done.

When considering both individual HAP emissions and toxicity factors, the increases in 1,3-butadiene, diesel particulate matter, formaldehyde, and acrolein are of most concern; with the highest emissions-toxicity values. The source contributing the most to the increase in 1,3-butadiene, formaldehyde, and acrolein would be aircraft (89, 94, and 91 percent of the increase, respectively) while the source contributing the most to the increase in diesel particulate matter would be construction equipment.

Noise
No health impact assessment. Environmental impact expressed as noise contours DNL 65, 70 and 75.

7.4 Schiphol Airport, Amsterdam, (B.Staatsen, E Franssen and E.Lebret, July 1994)

Method
Analysis of existing data and literature on risk perception and exposure- response relationships; collection and analysis of routine health statistics; postal questionnaires and interviews on health status and risk perception.

Time scale
4 years.

Outcomes assessed
Sleep disturbance, annoyance, respiratory diseases, cognitive performance, medication use, cardiovascular diseases, perception of risks and health.

Conclusions
(i) Large impact of aircraft related noise exposure on well-being.

(ii) Annoyance, sleep disturbance and reduced performance are likely which may lead to increased medication use.
(iii) Hearing loss, increase in respiratory effects (including diseases) and cancer incidence are unlikely.
(iv) Odour annoyance likely.

7.5 Health Impact Assessment Report, Finningley Airport, Doncaster, UK (Doncaster Health Authority and Doncaster Metropolitan Borough Council, 2000)

Method
Stakeholder and key person interviews to establish the views and concerns of the community; Literature review on health and social impacts of airports regeneration and transport policies.

Timescale
5 months

Outcomes assessed
Cancer, cardiovascular disease, respiratory disease, allergies, sleep disturbance, annoyance, anxiety and stress, cognitive performance, risk perception, economic benefits.

Conclusions and recommendations
(i) Employment and regeneration were the main positive impact.
(ii) Negative impacts were noise and air pollution affecting the local population.
(iii) Recommendations were made to maximize the positive impacts and minimize the negative ones.

7.6 A Prospective Health Impact Assessment of the Proposed Development of the Second Runway at Manchester International Airport, 1994

Method
Literature review including data from National Health Service (NHS) and non-NHS sources, health service indicators, vital statistics forms, and mortality statistics.

Outcomes assessed
Increased employment and economic growth, negative effects on performance; mean increase in blood pressure, negative impact on cognitive development of children, increase in stress levels

and mental illness, generalised increase in the subjective annoyance levels of local residents, traffic accidents, benzene levels and risk of leukaemia.

Conclusions and recommendations

(i) Conduct a health effects study associated with the further development of the airport.
(ii) Investigate problems of delayed cognitive development and reduced achievement.
(iii) Monitor accident figures in the area by studying baseline accident figures and identifying any increases in death and injury as a result of road traffic accidents.

7.7 Airport Berlin Brandenburg International (1991)

Method

Ad hoc process that was identified as HIA but was part of the EIA.

Outcomes assessed

Sleep disturbance, annoyance, pollution by noxious agents, accident risk, impact on recreation.

Conclusions and recommendations

(i) Impact of aircraft related noise exposure on well-being.
(ii) Annoyance, sleep disturbance and reduced performance.
(iii) Odour effects.
(iv) Impact on recreation areas.

7.8 Toronto City Airport Expansion (2002)

The public health effects of expansion at Toronto City Centre Airport were considered in 2002. Toronto Public Health Department produced a report outlining its concerns regarding the expansion of the airport operations. The main concerns that were raised include noise leading to increased stress, ill health and poor quality of life. Air emissions from the aircraft and other transport were considered. These pollutants will contribute to smog and may include toxic pollutants which may result in increased lung and heart disease and premature death.

Benefits that were highlighted included the economic and income benefits in terms of recruitment and retention of businesses and generation of tourism.

7.9 New Runway of Brisbane Airport Expansion (2005)

Approach

(i) A conservative approach was used to model the health impacts of ambient regional air pollutants from the proposed new parallel runway (NPR). The pollutants considered were: benzene, CO, formaldehyde, NO_2, PM_{10}, $PM_{2.5}$, toluene.

(ii) The worst-case increases in air pollutants were used for assessing the potential worst-case health impact. Where improvements in air quality were forecast, they were not used to offset the worst-case estimates of adverse health effects.

(iii) The models used for estimating the health effects were based on published epidemiological studies in Brisbane, other Australian cities or overseas cities; long term studies of mortality and lung function from the United States; and challenge chamber studies and panel studies.

(iv) The health effects were modelled for the worst affected sites.

(v) Both acute and long term health effects were examined. The acute health effects examined were: mortality and hospital admission; lung function, symptoms and GP visits. The long term effects considered were: mortality; cancer incidence; and lung function growth in children.

(vi) Annoyance, sleep disturbance and children's cognitive performance are assessed.

Health Impact

Air pollution: Regional air pollution as a result of the NPR is not expected to have an impact on community health. In all cases the forecast increases in ambient air pollutants were small (0.0001 percent to 5.7 percent), relative to the current air quality goals. There is a negligible increase in health risk. For particulate matter (PM_{10} /$PM_{2.5}$), the increased mortality risk is one additional death per 100 million people exposed to the worst-case PM increase, while the most adverse increase in hospital admission is equivalent to one cardiovascular admission per 25 million people exposed to the worst-case PM_{10} increase. The long term effects of the increase in annual average PM_{10} as a result of emissions from the NPR are forecast to be extremely small.

Noise: Analysis indicates that on opening of the NPR in 2015 there is estimated to be:

(i) A minor net reduction of people who are annoyed and highly annoyed.

(ii) A minor net reduction of people who are little sleep disturbed, sleep disturbed and highly sleep disturbed.

(iii) An increase of 17 childcare and kindergartens subject to potential noise-induced awakenings.

(iv) An additional 5,000 shift workers potentially affected by daytime noise-induced awakenings resulting from aircraft noise. It is also estimated that there will 15,000 shift workers potentially affected by evening noise-induced awakenings.
(v) A reduction of approximately 185,000 people potentially affected by night time noise-induced awakenings resulting from aircraft noise.
(vi) An increase of approximately 9 schools subject to communication interference for the Summer Weekday Day.

(vii) An increase of approximately 7 places of worship subject to communication interference for the Summer Weekday Day. This increases to 27 for the Winter Weekend Day.

7.10 Birmingham International Airport (2008)

Approach
Literature review, collection of stakeholders' data, social and economic impact also studied.

Findings
(i) NO_2 levels in 28 sites are within air quality guidelines outside airport, exceedance in 15 sites within airport; PM_{10} levels are not exceeded. PM levels are not assessed.
(ii) Negative impact of noise on local residents, using annoyance and sleep disturbance as health endpoints. An estimated number of 24,848 people are estimated to be within the 57 dB noise contour in summer (day) and 7,073 for summer nights. About 8,000 people are estimated to have their sleep highly disturbed.

8 Comparison of Findings in Airport Projects with a Similar Approach

A comparison of findings by the HKAA report is made with three of the above reports that adopt similar approaches in HIA, namely, Brisbane, Birmingham and Schiphol Airports. Details of their results are shown in Table 4. Results show that while the Hong Kong findings do not significantly increase the health risks of populations in sensitive receivers, the health risks from air pollution are much smaller in magnitude in the HIA in Brisbane. In the Brisbane HIA, by contrast, more schools are affected than in Hong Kong. In the Schiphol study, there is no expected increase in hospitalization from the effects of air pollutants. The Birmingham study, however, did not quantify the health impact arising from criteria air pollutants. While the Birmingham and Schiphol airport studies reported the estimated number of persons affected by noise, the Hong Kong and Brisbane studies only reported a percentage decrease, a much bigger fall in Hong Kong than in Brisbane. Whereas the Schiphol study shows a small increase in the number of noise-related hypertension (94 cases per 100,000), the Hong Kong and Brisbane study would result in a net decrease in cases, if a similar approach is adopted. This is in line with the other health endpoints (annoyance and sleep disturbance) that result from an overall net reduction in noise exposure among the population in the sensitive receivers.

9 Conclusion

The HIA by the HKAA is considered to be acceptable. Despite the absence of a universal standard in the "threshold" of the health endpoints estimated in the HIA, the risks presented are considered to be sufficiently small (for the health impact of air pollutants) or even reduced (for noise, in some of the affected areas).

Table 4: Detailed comparison of results of health impact assessment in four airports

Airport	Air pollutants			Noise				
	Short-term effects		Long-term effects	Annoyance	Sleep disturbance	No. of community facilities subject to noise-induced awakening	Effect on children's learning	Other effects
	Deaths	Hospital admissions						
Hong Kong 2014	Not presented	↑ risk: 3-5 in 10^5 in a year	↑ risk: 1 in 10^5 in a year	10% ↓ in people highly annoyed	50% ↓ in people highly sleep disturbed	Not done	1 kindergarten within 55-60 dB(A)	Not assessed
Brisbane Australia 2005	↑ risk: 1 in $3x10^6$ in a day	↑ risk: 1 in $167x10^6$ in a day	0.03% ↑ in risk of lower respiratory tract symptoms in asthmatic children; negligible long-term risk of death, cancers and lung function growth	A minor net ↓ of people annoyed and highly annoyed	A minor net ↓ of people little sleep disturbed, sleep disturbed and highly sleep disturbed	Childcare & kindergartens: +17; Hospitals: +1; Nursing homes & aged centres: -1; Retirement homes: +1	Schools affected: 9	Place of worship: 7 affected in summer weekdays, 27 in winter weekdays
Birmingham 2008	Not done	Not done	No exceedance of UK air quality guidelines for NO_2 (40ug/m3) in 28 sites outside airport; some exceedance in 15 sites within airport; PM_{10}: No exceedance; $PM_{2.5}$: Not done.	In 2030, 24,848 people are estimated to be within the 57 dB(A)* summer day contour, and 8,532 within the 63 dB(A) summer day contour; the corresponding no. for summer nights are: 7,073 (57 dB(A)) and 38 (63 dB(A)).	In 2030, an estimated population of 8,203 are highly sleep disturbed, compared with 7,964 without the runway extension (difference: 239).	There will be a significant increase in the no. of schools exposed to noise levels >54 dB(A) (from 14 in 2008 to 31 in 2030) with runway extension, and without (27 schools in 2030), i.e., an increase of 4 schools.	Not assessed	Not assessed
Schiphol Amsterdam 1994	Hospitalization due to cardiovascular and respiratory diseases not clearly higher than other districts; respiratory effects, nose and eye irritation: not expected to ↑; cancer risk extremely low; $PM_{2.5}$ measurement needed.			100,000 people extremely annoyed	↑ no. of people with sleep disturbance, concentration disorder and medicine use	↑ 94 cases of noise-related hypertension in 100,000 population		

* The UK Government considers noise to have the potential for the onset of significant community annoyance above a level of 57dB(A), but recognises that some people are annoyed at lower levels (Parliamentary Office of Science and Technology 2003). The 57dB(A) limit is based on social surveys carried out in the early 1980s (ANIS) and is unlikely to represent current annoyance levels (van Kempen & van Kamp 2005; Guski 2004; Babisch et al. 2007).

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Appendix

Excess risks used in the health risk assessment by the HKAA for morbidity and mortality attributable to short- and long-term exposure to air pollution

Table A1: % Excess risk (95% confidence interval) of mortalities and morbidities for a 10μg/m^3 increase in air pollutant concentration (short-term exposure)

	Mortalities*			Hospital admissions*	
	All-cause mortality (all ages)	Cardio-vascular mortality	Respiratory mortality	Cardio-vascular diseases	Respiratory diseases
NO_2	1.03 (0.69-1.37)	1.38 (0.75-2.01)	1.41 (0.67-2.15)	1.00 (0.73-1.26)	0.75 (0.50 - 1.00)
PM_{10}	0.51 (0.23-0.80)	0.63 (0.11-1.16)	0.69 (0.08-1.31)	0.58 (0.36-0.80)	0.60 (0.40-0.80)
$PM_{2.5}$					
SO_2	0.91 (0.40-1.42)	1.23 (0.27-2.21)	1.31 (0.21-2.43)	0.98 (0.53-1.39)	0.13 (-0.24-0.50)
O_3	0.34 (0.02-0.66)	0.63 (0.04-1.23)	0.36 (-0.33-1.05)	0.12 (-0.12-0.37)	0.81 (0.58-1.04)

[Reference: * Wong et al, 2010]

Table A2: % Excess risk (95% confidence interval) of mortalities by cause attributable to long-term exposure to air pollutants

Air pollutant	All-cause mortality	Cardiopulmonary mortality	Lung cancer mortality
NO_2	Effects cannot be separated from PM_{10} or $PM_{2.5}$ effects		
*PM_{10}	5 (NS)	16.3 (NS)	28.5 (NS)
#$PM_{2.5}$	4 (1-8)	6 (2-10)	8 (1-16)
SO_2	WHO recommends a24 hr AQG of 20μg/m^3 . No annual AQG is recommended.		
O_3	WHO considers evidence for O_3 to produce chronic effects on health as insufficient to recommend an annual AQG.		

[References: # ACS study by Pope et al, 2002; *7th Day Adventist study by McConnell et al, 2000 (% ER adjusted to 10μg/m^3)]

Note:

1. Evidence for a separate relative risk (RR) of mortality for long-term exposure to PM_{10} is insufficient, but RRs for short-term exposure to PM_{10} are well-documented.
2. It is difficult to separate the long-term effects of NO_2 from PM and other traffic generated fumes. WHO maintains a long-term Air Quality Guideline of 40μg/m^3.