Health Impact Assessment: Cape Town International Airport Runway Re-alignment and Associated Infrastructure Project

Final Draft

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DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

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Application for integrated environmental authorisation and waste management licence in terms of the-

(1) National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2014; and

(2) National Environmental Management Act: Waste Act, 2008 (Act No. 59 of 2008) and Government Notice 921, 2013

PROJECT TITLE

Cape Town International Airport Runway Re-alignment and Associated Infrastructure Project

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4.2 The specialist appointed in terms of the Regulations_

I, Amy Burdzik, declare that –

General declaration:

I act as the independent specialist in this application;

I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;

I declare that there are no circumstances that may compromise my objectivity in performing such work;

I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;

I will comply with the Act, Regulations and all other applicable legislation;

I have no, and will not engage in, conflicting interests in the undertaking of the activity;

I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;

all the particulars furnished by me in this form are true and correct; and

I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Signature of the specialist:

EOH Health

Name of company (if applicable):

15th December 2015

Date:

Executive Summary

1. Introduction

Cape Town International Airport (CTIA) comprises two active runways: the primary runway and a secondary runway bisecting it. Airports Company South Africa (ACSA) proposes to re-align the existing primary runway. This will allow the runway to be lengthened (from 3 201m to 3 500m), which will enable the airport to accommodate larger aircraft such as the Airbus A380. The existing secondary runway will be decommissioned and incorporated into a new integrated taxiway system, which will entail the construction of parallel taxiways and rapid exit taxiways to increase the capacity of the system to handle air traffic.

In 2013, SRK Consulting (South Africa) (Pty) Ltd ("SRK") was appointed to undertake the Environmental Impact Assessment (EIA) for the project. The EIA process is relatively advanced, with a Draft EIA Report released for public comment in March 2015. In response to the potential air quality impacts (considered to be relatively limited beyond the site boundaries) and noise impacts (which are quite significant), residents of potentially affected communities surrounding the airport raised concerns about the potential human health impacts associated with atmospheric emissions and noise. In response SRK appointed EOH Health to conduct a Health Assessment.

This is a desktop exercise comprising review of the environmental engineer's Air Quality and Noise Reports; a literature review to evaluate current knowledge about the health effects of exposure to noise and air pollution; and an opinion on the probable significance of the exposures modeled by the environmental engineer for two scenarios – Scenario 2, (the No Go Scenario i.e. the current runway operating at maximum capacity) and Scenario 4 (a re-aligned runway operating at maximum capacity without the implementation of any mitigation measures).

2. Methodology

The Noise and Air Quality Assessments undertaken for the project by Demos Dracoulides and Associates (DDA) were reviewed and summarised. Population numbers quoted below are based on the findings of this study[1]. Various medical and scientific databases including PubMed and ScienceDirect were accessed between September and November 2015 using keywords and phrases such as "air quality", "air pollution", "health effects", "noise" etc. Systematic reviews and more recent articles were preferentially selected for inclusion in the study.

3. Impact Assessment

3.1 Summary of Impact Assessment Models

3.1.1 Noise Models

Current airport operations already expose 226 180 people in surrounding communities to day-night noise rating levels above the South African guideline of 55 dB(A). This is as a result of historically inappropriate land-use planning, increasing demand for housing in Cape Town and the growth of the airport. In the No-Go Scenario the number of people exposed increases to 367450 and in Scenario 4 it becomes 400 560. Scenario 4, without mitigation, therefore, represents a 9.01% increase in the exposed population over the current runway at maximum operation, a 50% increase in capacity. In both scenarios, there is an increase in numbers of noise sensitive receptors (schools, old age homes, hospitals, libraries, places of worship) that will be exposed to more than 55 dB and to potentially disturbing individual noise events.

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[1] Note that these population numbers do not take into account the implementation of mitigation measures for Scenario 4, as these figures were not yet available at the time of completing this study.

3.1.2. Air Quality Models

Air pollutants (SO_2, NO_2, O_3, CO and PM_{10}) have been measured 950m from the airport runway since 2008. Although there have been some hourly exceedances in levels of certain pollutants, overall measurements have fallen within South African air quality guideline levels. In both of the No Go Scenario and Scenario 4 there is expected to be an increase in emissions because of increased airport activity and related traffic. Although there may be some hourly exceedances in SO_2 and NO_2 levels, these are expected to occur less than 10 times per year beyond the airport boundary and would, therefore, fall within South Africa guidelines which allow up to 88 exceedances annually. Increases in CO, $PM_{2.5}$ and PM_{10} are all anticipated to be small and levels should remain within South African guidelines.

There is estimated to be a very small increase in relative risk of both short-term all-cause mortality and respiratory hospital admissions, as well as long-term all-cause mortality in communities beyond the airport boundaries due to changing exposure to air pollutants. This amounts to a 0.1% increased risk of long-term all cause mortality in the No Go Scenario and a 0.3% increased risk in Scenario 4. The potentially affected areas are very small pockets of surrounding communities including Bishop Lavis, Crossroads, Delft South and Elsies River.

3.2. Literature review on health effects

3.2.1 Typical health effects related to noise

Environmental noise exposure can cause annoyance and sleep disturbance. The proportion of an exposed population reporting annoyance rises with increasing noise levels, from around 12% of those exposed to 55 dB to 37% of those exposed to 70 dB. Sleep disturbance is due to increased numbers of awakenings, as well as disruption of the quality of sleep, and can lead to impaired performance the following day. It affects about 17% of people exposed to more than 60 dB at night. Noise exposure has also been associated with poor learning outcomes and cognitive function in school children.

There has long been thought to be sufficient evidence for an association between environmental noise exposure and the development of hypertension, and it is believed that the relative risk of hypertension increases by between approximately 7 and 17% per 10 dB increase in noise levels. There appears to be a threshold nighttime level of 50 dB below which illness is unlikely. Cardiovascular disease (particularly cardiovascular mortality) has similarly been linked with increasing noise exposure, but is less well studied. A recent German study has not confirmed previous findings of a relationship between aircraft noise exposure and raised blood pressure or myocardial infarctions, but findings are yet to be published formally. The relationship between noise exposure and development of cancer is not clear, but there is insufficient evidence to support a link at this time.

Certain subgroups of the population may be more vulnerable to noise exposure. These include children, the elderly, pregnant women and women with small babies, and those who already have a disrupted sleep pattern such as shift workers and people with pre-existing medical problems interfering with their sleep.

3.2.2. Typical health effects related to air quality

Changes in air quality can have acute (short-term) and chronic (long-term) health impacts. Short-term high exposures to air pollutants can cause respiratory irritation, particularly in those with pre-existing respiratory conditions such as asthma. Short term increases in PM_{10} and $PM_{2.5}$ levels have an association with an increase in daily mortality.

Long-term exposure to air pollution, particularly particulate matter, has been linked with an increased risk of cardiovascular disease and stroke. Air pollution has also been designated a definite carcinogen for lung cancer, and is estimated to cause around 9% of lung cancers globally. Other cancers have not been studied as extensively, but there is a suggestion that increasing exposure to air pollution from fuel that contains benzene may increase the likelihood of development of leukaemia. Recently concerns have been raised about exposure to air pollution during pregnancy causing abnormal pregnancy outcomes such as low birth weight and premature babies. While some studies have shown an association, others have not and the relationship has not been confirmed.

3.3. Probable significance of pubic health impacts related to increased airport capacity

Although it is clear that both air pollution and noise can have significant effects on human health, quantifying that effect is more difficult for a given population. The diseases that have been related to both noise and air pollution are relatively common diseases in the general population, and have multiple known risk factors. For an individual, exposure to noise and air pollution is generally likely to contribute a very small amount to his or her risk of disease, but we cannot quantify that risk. We can only work out what effect these environmental exposures are likely to have on the population as a whole rather than for an individual.

3.3.1 Noise and health effects

Exposure to noise in the communities around the airport could be a bigger public health risk than air quality because more people will be exposed, and levels of noise are outside guideline limits. With current airport operations, there are already 226 180 people exposed to noise levels above the recommended 55 dB(A) day night levels. This number increases substantially in Scenario 2 (367 450) and slightly more in Scenario 4 (400 560).

It is possible that estimates of annoyance and sleep disturbance from existing literature will over-estimate levels of annoyance in the local populations, as there is no relevant research in the South African setting, and very little from other similar countries in the developing world. With current airport operations, there have been only a handful of complaints related to noise at CTIA over a 5 year period. However, taking estimates of percentages of populations that report annoyance at different levels of aircraft noise from previous studies performed predominantly in the developed world, up to 52 837 people could be expected to experience annoyance in Scenario 2 and 59 240 in Scenario 4. Sleep disturbance is more difficult to estimate as the models do not report nighttime noise levels separately. However, one estimate suggests that around 1544 people could experience sleep disturbance in Scenario 2 and 3871 in Scenario 4.

South Africa has a very high prevalence of hypertension, estimated by the World Health Organisation to be around 42%, although in the Western Cape it appears to be around 25-30%. A 10-20% increase in risk of hypertension related to increased noise exposure in the affected communities (as suggested by studies from the developed world), could theoretically see a 3 to 6% rise in absolute numbers of cases, and a maximum prevalence of 36%. Although the leading risk factors for hypertension are lifestyle-related (obesity, lack of physical activity, poor diet), at least some of the current prevalence of hypertension may be caused by current unmeasured environmental and occupational exposure to noise in the affected communities, Therefore, it seems unlikely that a change in noise exposure related to airport operations will lead to a dramatic change in hypertension prevalence in the surrounding communities. It is not possible to calculate risk of other medical conditions related to noise.

3.3.2 Air quality and health effects

Air pollution is known to have significant health effects, including an impact on daily mortality rates as well as an association with lung cancer deaths specifically, and cardiopulmonary deaths more generally. However, the changes in air quality related to a change in airport operations are not dramatic, and there is not much difference between Scenario 2 and Scenario 4, particularly in terms of particulate matter, which is generally thought to be the major cardiovascular disease-causing culprit.

Exceedances of hourly levels of gases (NOx, SO_2, CO, O_3) are well within legal guidelines and are likely to be very infrequent, occurring less than 10 times per year. Therefore, they are not likely to contribute significantly to mortality or hospital admissions in the exposed population. Although the air quality models have estimated a relative increase in risk of hospital admissions between 2 and 4% in very small areas adjacent to the airport, it is not possible to contextualise this against an absolute risk as figures are not available for daily respiratory hospital admissions in Cape Town.

The American Heart Association estimates a 1% increase in daily (short-term) mortality for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentration. Cape Town's daily all-cause mortality rate is approximately 1.9 per 100 000 people and cardiovascular mortality is 1.9 per million people. A 1% increase in this rate – which is higher than expected given that the anticipated increase in $PM_{2.5}$ is only 3 $\mu g/m^3$ - is marginal and will have no effective impact on local mortality rates.

Whilst annual exposure to particulate matter exposure will increase, the relative increase in annual all-cause mortality due to air quality is expected to be only 0.1% in Scenario 2 and 0.3% in Scenario 4. A 0.1% increase in relative risk of all-cause mortality estimated in the model for Scenario 2 suggests that mortality rate in affected areas could go up to 7.77 per 1000 people (from 7.7 per 1000 currently reported). For Scenario 4, the relative risk of all cause mortality is expected to increase by 0.3%, which would suggest an absolute mortality rate of 7.93 per 1000 people. This increase is unremarkable, both in terms of absolute numbers and in terms of the difference between the two scenarios. The mortality rate in affected areas would still be well below the 2013 national South African average of 8.6 per 1000 people

4. Conclusion

Current airport operations may already have an impact on health, and the changes expected with full operation (Scenario 2) or with a re-aligned runway (Scenario 4) would increase the numbers of people exposed to pollutants, although with minimal differences between the two scenarios. Exposure to environmental noise has been associated with sleep disturbance, decreased cognitive function and cardiovascular diseases such as hypertension and myocardial infarctions (heart attacks). Evidence for other diseases is not conclusive. Air pollution exposure has been associated with increased risk of respiratory disease, cardiovascular disease and strokes, as well as lung cancer.

Quantifying the effects of exposure is difficult. However, because air quality changes from the current baseline are expected to be minimal based on the models, the likely overall effects on health and mortality in particular will be extremely small. Exposure to noise around the airport could have greater implications for public health. The noise levels to which people will be exposed are expected to cause annoyance and sleep disturbance in a significant proportion of the population, and impact on learning in schools as well as quality of life for people in hospitals and residential homes. The impact on prevalence of hypertension and heart disease in the local populations is harder to quantify, but the additional burden of disease in Cape Town from Scenario 4 compared to Scenario 2 will likely be extremely small because the additional numbers of people exposed to noise and air pollution are low.

The City of Cape Town, the aviation fraternity and ACSA should aim to reduce exposures of the surrounding communities to air pollution and noise related to airport operations as far as reasonably practicable. Managing air pollution from the airport would need to form part of a comprehensive plan to reduce air pollution from all sectors including road traffic, industry and the use of fossil fuels for cooking in informal settlements. The environmental engineer who conducted the impact assessments for both noise and air quality has provided comprehensive recommendations for ways to reduce emissions and noise during airport operations.

Terminology, acronyms and definitions

A-weighted sound level	A frequency weighting filter used for the measurement of sound pressure levels designed to reflect the acuity of the human ear, which does not respond equally to all frequencies.
ACSA	Airports Company South Africa
Acute (short-term) health effects	Health effects that usually occur rapidly after short-term exposure to high concentrations of a substance.
All-cause mortality	All of the deaths that occur in a population, regardless of the cause Usually expressed as a rate (per 100 000).
Asthma	A respiratory condition characterized by reversible episodes of wheeze and coughing.
Atherosclerosis	A disease of the arteries characterized by the deposition of plaques of fatty material on their inner walls.
Benzene	An organic chemical product derived from coal and petroleum, and often found in fuels.
Cancer	The disease caused by uncontrolled division of abnormal cells in a part of the body
Cardiovascular disease	Diseases of the heart and blood vessels.
Carcinogen	An agent that is known to cause cancer.
Chronic health effects	Health effects that develop slowly over time after prolonged exposure to a hazardous substance.
Chronic obstructive pulmonary disease (COPD)	A disease characterized by chronic obstruction of lung airflow that interferes with normal breathing and is not fully reversible. Includes emphysema and chronic bronchitis.
CO	Carbon monoxide
Cognitive function	Mental activities related to knowledge, reason, memory, judgment, decision making, language comprehension etc.
Decibel (dB)	A measure of sound. It is equal to 10 times the logarithm (base 10) of the ratio of a given sound pressure to a reference sound pressure. The reference sound pressure used is 20 micropascals, which is the lowest audible sound.
dB (A)	Unit of sound level. The weighted sound pressure level by the use of the A metering characteristic and weighting specified in the American National Standards Institute (ANSI) Specifications for Sound Level Meter.
Diabetes mellitus	A medical condition characterized by abnormal glucose metabolism.
Fine particulate matter	Particulate matter with aerodynamic diameter of 2.5 micrometers or less.
Hypertension	Raised blood pressure (usually defined as blood pressure persistently greater than 140/90).
Inflammation	The response of a tissue to injury or infection.
L_{Aeq}	Equivalent A-weighted sound level. A-weighted sound pressure

	level in decibels of continuous steady sound that within a specified interval has the same sound pressure as a sound that varies with time. This is an average sound level that would produce the same energy equivalence as the fluctuating sound level actually occurring.
$L_{R,dn}$	Equivalent continuous day-night rating level.
$L_{Req,d}$	Equivalent continuous day rating level.
L_{den}	Equivalent continuous day-evening-night rating level. Nighttime values are weighted to account for increased disturbance.
Myocardial infarction	Describes a portion of the heart muscle dying due to poor blood supply. Colloquially, a heart attack.
NOx	Nitrogen oxides
NO_2	Nitrogen dioxide
O_3	Ozone
Particulate matter (PM)	The general term used for a mixture of solid particles and liquid droplets in the air. It includes aerosols, smoke, fumes, dust, ash and pollen.
$PM_{2.5}$	Particulate matter with aerodynamic diameter 2.5 micrometres or less.
PM_{10}	Particulate matter with aerodynamic diameter 10 micrometres or less.
Prevalence	Number of existing cases of a disease in a population.
Respiratory disease	Diseases affecting the airways and lungs.
SO_2	Sulphur dioxide
Stress hormones	Hormones produced in response to stressful situations e.g. adrenaline, cortisol.
Stroke	A medical condition usually caused by a bleed or clot in the blood vessels of the brain, leading to neurological impairment.
Ultrafine particulate matter	Particles with diameter less than 100 nanometers.
µg	Microgram
VOCs	Volatile organic compounds
WHO	World Health Organisation

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1. Introduction

1.1 Background

Cape Town International Airport (CTIA) comprises two active runways: the primary runway and a secondary runway bisecting it. Airports Company South Africa (ACSA) proposes to re-align the existing primary runway. This will allow the runway to be lengthened (from 3 201m to 3 500m), which will enable the airport to accommodate larger aircraft such as the Airbus A380. The existing secondary runway will be decommissioned and incorporated into a new integrated taxiway system, which will entail the construction of parallel taxiways and rapid exit taxiways to increase the capacity of the system to handle air traffic.

In 2013, SRK Consulting (South Africa) (Pty) Ltd ("SRK") was appointed to undertake the Environmental Impact Assessment (EIA) for the project. The EIA process is relatively advanced, with a Draft EIA Report released for public comment in March 2015. In response to the potential air quality impacts (considered to be relatively limited beyond the site boundaries) and noise impacts (which are quite significant), residents of potentially affected communities surrounding the airport raised concerns about the potential human health impacts associated with atmospheric emissions and noise. In response SRK appointed EOH Health to conduct a Health Assessment.

1.2 Terms of reference

The following terms of reference apply to this study:

1.2.1 Review findings of the Noise Impact Assessment, including outcomes of the noise model;

1.2.2 Review findings of the Air Quality Impact Assessment, including outcomes of the air quality model;

1.2.3 Conduct a literature review on health impacts of environmental exposure of communities to aircraft noise and air emissions from airport operations;

1.2.4 Provide an opinion on the significance of community health impacts related to increased airport capacity as determined by the noise and air quality impact assessments (i.e. a comparison of two scenarios modeled by the noise and air quality specialists);

1.3 Information sources

The Health Assessment was undertaken as a desktop evaluation of health risks associated with the modeled air pollution and noise exposures to surrounding communities in two scenarios: Scenario 2, the No Go alternative, in which the existing runway reaches maximum capacity; and Scenario 4, which assumes that the runway has been re-aligned and lengthened, and reaches maximum capacity.

EOH Health had access to the specialist Noise and Air Quality Assessments performed by DDA (2014), and to the draft EIA report released to the public for comment in March 2015.

1.4 Assumptions and limitations

This literature review was undertaken with the following assumptions:

- That the information provided to EOH Health was as complete as possible.
- That the methodology used by the specialists in air quality and noise impact assessment was sound.

It is subject to the following limitations:

- As the EIA process is already advanced, timeframes to conduct the study were short.
- There is a vast body of literature (numbering thousands of articles) on the subjects of air and noise pollution and human health. Resources, both in terms of time and allocated staff, were insufficient to perform a full-scale systematic review of all the literature, and this was not the brief from the client. Therefore, in order to maximize information obtained from fewer articles, previous systematic reviews and more recent literature were preferentially reviewed. The

resultant literature review should be seen as a brief surface review of a very complex topic, and not a complete analysis.

- Much of the literature is from the developed world. This should not lead to any known health effects being missed, but it may mean that quantitative analysis of health risks in the affected community is harder to perform as calculated increased risks may not be relevant to the Cape Town population.
- Much of the interest in health effects of noise and air pollution has been in the recent past. For some exposures, exact risk of health effects is still unclear, and studies are ongoing. This review is based on the most up-to-date literature available at the time of the study.
- The estimates of exposure to noise and air pollution in the communities surrounding the airport are based on models and may not accurately reflect true exposures.

2. Methodology

The Noise and Air Quality Assessments undertaken for the project by Demos Dracoulides and Associates (DDA) were reviewed and summarised. Population numbers quoted below are based on the findings of this study. It should be noted that they do not take into account the implementation of mitigation measures for Scenario 4 as these were not available at the time of this study.

The literature review was conducted as a desktop exercise in September, October and November 2015. The databases PubMed, ScienceDirect and Academic Search Premier were searched using the phrases: “air pollution”, “air quality”, “noise”, “airports”, “environmental noise”, “health effects” “respiratory disease” “cardiovascular disease” “cerebrovascular disease” “stroke” “pregnancy outcomes” “cancer” and “systematic review and meta-analysis”. The searches yielded more than two thousand articles. The scope of this project was not to perform a complete systematic review. Therefore, EOH identified the most relevant and useful articles by beginning with meta-analyses and systematic reviews. Relevance of other articles was determined by a reading of abstracts. Additional useful references were found in a ‘snowball’ manner by perusing reference lists of included articles.

3. Impact Identification and assessment

3.1 Summary of findings of Noise Impact Assessment

Noise is defined as unwanted sound, and noise pollution is increasingly recognized as hazardous to human health. There are many different metrics used to assess noise exposure. These include averages of noise exposure over various timeframes ($L_{R,dn}$ – an average of noise exposure for day and night, with increased weighting for night time noise; $L_{Req,d}$ the average exposure for the 16 hours between 06:00 and 22:00 or 07:00 and 23:00; and $L_{Req,n,}$ the average exposure for the night between 22:00 and 06:00 or 23:00 and 07:00) as well as estimates of number of noise events of a certain decibel level (e.g. the N70 describes number of events of 70 dB(A) that will occur in a specified timeframe).

Noise at night is assumed to be more disturbing than noise during the day, as that is when most people are trying to rest, and are more sensitive to increased noise levels. In South Africa, guideline levels for environmental noise are categorized by area (e.g. industrial, urban). Table 1 shows the relevant recommended South African noise levels (SANS, 2008), and compares them with guideline levels published by the World Health Organisation (WHO, 1999 & WHO, 2009). Within a community, there are activities and organizations that may be adversely affected by noise even within the recommended limits. For instance, the WHO (1999) recommended that hospital wards should be quieter than 30 dB(A) to minimize sleep disturbances in patients, and the indoor noise level in school classrooms should be less than 35 dB(A) to optimize speech intelligibility and communication. The WHO Nighttime Noise Guidelines (2009) are set at 40 dB(A) for nighttime exposure as that is the level below which there are no apparent adverse health effects, according to current information.

Table 1. Comparison of guideline environmental noise exposure levels

		SANS 10103 (dB(A))	**WHO Community Noise Guideline levels (1999) (dB(A))**	**WHO Nighttime Noise Guidelines for Europe (2009) (dB(A))**
Urban residential area	Full day (L_{Rdn})	55	55	-
	Night ($L_{Req,n}$) (outdoor)	45	45	40
Urban residential area with main roads	Full day ($L_{R,dn}$)	60	-	-
	Night ($L_{Req,n}$)	50	-	-

Although there will be some noise associated with construction of a new runway and additional terminal buildings and facilities, this will be temporary, and the noise levels within communities around the airport are not expected to exceed guideline levels due to the distance of construction from the surrounding residential areas and the introduction of risk mitigation. Therefore, effects related to construction noise are likely to be short-term and relatively minor, such as annoyance and short-term sleep disturbance, and have not been considered further.

The models produced in the Noise Impact Assessment have only provided results for noise levels above 55 dB(A), which is the current recommended South African day-night limit. Therefore, there is no information available about numbers of people exposed to levels of noise between 45 dB(A) and 55 dB(A), which are levels that may result in annoyance and sleep disturbance but are unlikely to contribute significantly to chronic disease.

Noise levels in the communities around the airport have been modeled for current operation, as well as the No Go scenario (Scenario 2) and Scenario 4. Historically inappropriate land use planning, coupled with significant demand for housing and the growth of the airport has resulted in a situation where approximately 226 180 people are currently exposed to noise above the recommended 55 dB(A) limit. When the **current** runway reaches full capacity, there will be an estimated 367 450 people exposed to noise above 55 dB(A). Once the new runway is operational, the noise zones around the runway will shift so that some new communities are affected by excess noise (Edgemead, Goodwood, Delft South, Khayelitsha and Harare), and some communities that are currently in the flight path, will no longer be exposed to as much noise (Phillippi East, Mitchells Plain, Woodlands and Tafelsig).In total, 400 560 are expected to be exposed to noise when the new, realigned runway reaches full capacity, a jump of 33 110 people or 9.01%. The numbers of exposed people are presented in Table 2 (taken from DDA, 2014b).

Table 2. Number of people exposed to Day-Night noise ratings above 55 dB(A)

	Number of people exposed within LRdn noise contour (dB(A)						
	55-60	**60-65**	**65-70**	**70-75**	**75-80**	**>80**	**All > 55 dB**
Scenario 1 (current)	177 580	46 280	2 320	0	0	0	226 180
Scenario 2 (existing runway at full capacity)	259 210	95 430	12 670	140	0	0	367 450
Scenario 4 (re-aligned runway at full capacity)	281 530	87 460	29 930	1 640	0	0	400 560

Source: DDA, 2014a

In each scenario, there are noise-sensitive receptors that will be exposed to noise. These include schools, places of worship, old-age homes, hospitals, and libraries. In Scenario 1, 126 noise-sensitive receptors are exposed to noise between 55 and 65 dB(A). In Scenario 2, this increases to 188, and in Scenario 4, there are 370 noise-sensitive places exposed to noise levels above 55 dB(A).

Apart from average daily noise exposure, the models evaluated exposure to separate noise events during the day. They have considered numbers of events of 70 dB(A) and of 60 dB(A). Table 3 compares numbers of people exposed to numbers of events in each scenario.

Table 3. Number of people exposed to N70 and N60 events in the current situation, the No Go alternative, and a realigned runway operating at maximum capacity.

	No of events	Scenario1 (current)	Scenario 2 (existing runway at full capacity)	Scenario 4 (re-aligned runway at full capacity)
Events N70 (day night)	>200	0	0	78 780
	100-200	17 440	123 240	61 050
	50-100	130 750	110 790	83 020
	20-50	140 170	126 690	96 810
	10-20	89 650	91 220	86 760
Events N70 (night)	>200	0	0	0
	100-200	0	0	0
	50-100	0	0	0
	20-50	0	29 920	75 180
	10-20	48420	159 280	67 680
Events N60 (night)	>200	0	0	0
	100-200	0	0	0
	50-100	0	0	0
	20-50	1 370	246 500	265 090
	10-20	364 930	386 580	340 000

Source: DDA, 2014a

Because of the increase in numbers of flights per hour, and the change in flight paths with a realigned runway, in Scenario 4, more people are exposed to higher numbers of N70 events than in Scenario 2 (78 780 people will experience more than 200 N70 events in a 24 hour period in Scenario 4 compared to none in Scenario 2). However, in total fewer people will be exposed to N60 and N70 events in Scenario 4 (406 420 people will experience at least 10 N70 events in a 24-hour period in Scenario 4 compared to 451 940 in Scenario 2.

3.2 Summary of findings of Air Quality Impact Assessment

Air pollutants that are considered harmful to human health include Sulphur Dioxide (SO_2), Nitrogen Oxides (NOx), particularly Nitrogen Dioxide (NO_2), Ozone (O_3), Carbon Monoxide (CO) and particulate matter (PM). For particulate matter, $PM_{2.5}$ (particles smaller than 2.5 microns) and PM_{10} (particles smaller than 10 microns) levels are usually measured. Other harmful pollutants include volatile organic compounds (VOC), heavy metals and dioxins, but those are not considered in the models.

Current South African air quality standards under the National Environment Management: Air Quality Act (No. 39 of 2004) are listed in Table 4. These are compared to World Health Organisation guidelines for air quality, which are generally much lower (WHO, 2006 & WHO, 2014a).

Table 4. South African air quality standards (2004 and 2012) and WHO air quality guidelines (2006)

	Averaging period	South African standards (concentration in µg/m^{3})	WHO guidelines (concentration in µg/m^{3})
Sulphur Dioxide (SO_2)	1 hour*	350	-
	24 hours	125	20
	1 year	50	-
Nitrogen Dioxide (NO_2)	1 hour*	200	200
	1 year	40	40
Benzene (C_6H_6)	1 year	5	
Ozone (O_3)	8 hours^{+}	120	100
Carbon Monoxide (CO)	1 hour*	30 000	-
	8 hours^{+}	10 000	-
PM_{10}	24 hours$^{\&}$	75	50
	1 year	40	20
$PM_{2.5}$	24 hours$^{\&}$	60 (40/25)	25
	1 year	25 (20/15)	10

Note: $PM_{2.5}$ guideline concentrations are decreasing to 40 µg/m^{3} and 20µg/m^{3} for 24 hour and annual exposure respectively from 1 January 2016 and 25 µg/m^{3} and 15µg/m^{3} from 1 January 2030.

*Allowed 88 exceedances in one year.

$^{+}$Allowed 11 exceedances in one year.
$^{\&}$Allowed 4 exceedances in one year.

The air quality monitoring station at Cape Town International Airport has measured SO_2, NO_2, O_3, CO and PM_{10} concentrations 950m northwest of the existing runway since 2008.

In that time, SO_2 levels have increased marginally but have never exceeded guideline levels (South African Air Quality Standards, SAAQS) for hourly, daily and yearly exposure. NO_2 levels have generally been well below guideline levels, but there was one peak above recommended hourly maximum concentrations in April 2009. Ozone levels are below the guideline level most of the time, but showed a few exceedances in 2009 and 2011. Ambient CO and PM_{10} levels have always been below SAAQS levels. Since the guidelines suggest that there can be a maximum of 88 exceedances of hourly levels in a year, and there have been far fewer than that, all of the readings for air pollutants taken in the vicinity of the airport have fallen within recommended South African guideline limits for air quality (DDA, 2014b).

In either of Scenario 2 (the No Go alternative) or Scenario 4 (a new re-aligned runway operating at maximum capacity), we can expect to see an increase in air pollution in future due to an increase in aircraft, other traffic, generators and auxiliary power units, and a general increase in traffic on Cape Town's roads. In Table 5 the total emission inventory for the two scenarios as modeled by DDA is compared.

Table 5. Comparison of emissions in Scenario 2 and Scenario 4

	Emissions (ton/yr)							
	CO_2	**CO**	**THC**	**VOC**	**NOx**	**SOx**	**PM_{10}**	**$PM_{2.5}$**
Scenario 2	89 974	1726	34.1	88.0	679.9	173.1	21.1	15.9
Scenario 4	191 454	2695	83.6	177.6	1305.6	366.2	38.9	30.6
Extra emissions Scenario 4	101 480	969	49.5	89.6	625.1	193.1	17.8	14.7

Source: DDA, 2014b

The models using dispersion simulations predict that CO, PM_{10} and $PM_{2.5}$ should be well within the relevant South African air quality guidelines during both scenarios. Therefore, no further risk modeling was done. NO_2 and SO_2 levels are likely to exceed guideline levels beyond the airport boundary, and were discussed further.

In both Scenario 2 and Scenario 4, 1-hr maximum concentrations of NO_2 are expected to exceed the 200 $\mu g/m^3$ limit on occasion. This is expected to be less than twice a year for Scenario 2 and less than 10 occurrences a year in Scenario 4. The areas affected in Scenario 4 are a small portion in each of Bishop Lavis, Elsies River and Delft South. Although the number of exceedances falls within guideline limits of 88 occurrences per year, it is to be expected that there will be some short-term health effects from the peak NO_2 levels on days when levels are high (predominantly acute respiratory effects). No chronic health effects are anticipated.

Similarly for SO_2, 1-hr concentrations may exceed guideline levels, but this is generally within the airport boundary and extremely unlikely to reach the maximum of 88 allowed exceedances in a year. In Scenario 2, areas outside the airport are likely to see maximum 1-hr concentrations of between 100 and 200 $\mu g/m^3$, and in Scenario 4, this increases to 150 to 200 $\mu g/m^3$. The areas that may experience these hourly levels are parts of Bishop Lavis, Elsies River, Delft, Delft South and Crossroads, but it is estimated to occur less than once per year. Again, although these levels of exposure are well within South African legal limits, inhabitants of the affected areas may experience short-term health effects, such as an acute asthma exacerbation at the time of the exceedance. Daily and annual concentrations are expected to be well within South African guidelines for both scenarios (less than 30 $\mu g/m^3$ for 24-hour exposure and less than 4 $\mu g/m^3$ for annual exposure). Therefore, there are not expected to be significant long-term or chronic health effects in the population from this level of exposure.

The air quality expert calculated anticipated increases in short-term and long-term health effects of airport operations using recommended coefficients from the Committee on the Medical Effects of Air Pollutants (COMEAP). These equations take into account likely health effects from all pollutants together, and provide an estimated increase in risk of health outcomes. Table 6 is a comparison of the relative risk of short term and long term health effects related to differences in air quality in three scenarios – Scenario 1, the current situation; Scenario 2, the current runway operating at maximum capacity; and Scenario 4, a re-aligned, longer runway operating at maximum capacity. The majority of the effects are within the airport boundaries, with only the lower side of the estimates applying to small areas of Bishop Lavis, Elsies River and Delft South.

Table 6. Comparison of additional risk of health conditions in exposed people across three scenarios

		Scenario 1 (Current)	**Scenario 2 (No Go alternative)**	**Scenario 4 (Re-aligned runway at maximum capacity)**
Short term health effects	**All-cause mortality**	0.5%	1-2%	2-5%
	Respiratory hospital admissions	2-6%	2-6%	4-10%
Long term health effects	**All-cause mortality***	0.1-1.0%	0.1-1.0%	0.1-1.0%

*In Scenarios 1 & 2, the area with increased all cause mortality is restricted to the airport and major roads. In Scenario 4, the area is larger and includes parts of Bishop Lavis, Elsies River and Delft South.

The main changes in health outcomes for communities around the airport because of future airport operations compared to current operations are expected to be as follows:

In Scenario 2,

- A small section of Crossroads falls within the +2% boundary for short-term all-cause deaths i.e. there could be a 2% increase in relative risk of all-cause death due to air pollution in the people who live in that section of Crossroads.
- The +2% increased risk of respiratory hospital admissions extends to cover small sections of Bishop Lavis and Crossroads.
- The long-term health effect calculated as an increase in risk of all-cause deaths is expected to be below 0.1% in all communities surrounding the airport.

In Scenario 4,

- The +2% boundary for all-cause deaths in the short term shifts east to a small section of Delft South, but Crossroads is spared.
- The +4% risk contour for respiratory hospital admissions extends to small portions of Bishop Lavis, Elsies River and Delft South.
- The long–term health effect is expected to be 0.3% increased risk of all-cause deaths in the affected areas.

Although there will be an increase in air pollution with both the No Go option and Scenario 4, CO, PM_{10} and $PM_{2.5}$ are all expected to remain within South African air quality guidelines. In Scenario 4, CO 1-hr levels are not expected to exceed 14 000 μg/m^3, which is less than half of the guideline limit. Increases in concentrations of both PM_{10} and $PM_{2.5}$ are expected to be small (less than 5 μg/m^3 in the worst case scenario), so the likely effect on both acute and chronic illnesses will be small. Cape Town's annual levels of PM_{10} and $PM_{2.5}$ are currently estimated at 30 and 16μg/m^3 respectively (WHO, 2014b), so a small increase will still mean that the levels fall within current South African guidelines. There is very little difference in particulate matter concentration between Scenario 2 and Scenario 4, so it is unlikely that Scenario 4 will have significantly higher impacts on long-term community health than Scenario 2.

Although SO_2 and NO_2 levels will on occasion exceed recommended hourly limits, on the whole, the annual exposures will be within guidelines. Therefore, as the calculations have suggested, the majority of the health effects are expected to be acute (increased mortality and respiratory hospital admissions) during times of exceedances, which will occur very infrequently outside the airport boundaries, and the overall increased risk to long-term health is extremely low (0.3% additional risk of all-cause mortality).

Table 7 summarises the worst-case scenario (upper end of the estimate of exposure) for residential areas adjacent to the airport for the various pollutants in Scenario 1, 2 and 4. For SO_2 and NO_2, the 1-hr maxima are only expected to reach this highest level less than 10 times a year. These modeled exposures represent a change in air pollution due to airport operations, rather than absolute air pollution, as they do not take into account existing air pollution from other sources such as nearby industry or use of biomass fuels in the local communities.

Table 7. Worst-case scenarios for exposure to air pollutants for residential areas adjacent to the airport

		Scenario 1 (current)	**Scenario 2 (current runway at full capacity)**	**Scenario 4 (re-aligned runway at full capacity)**
SO_2 (μg/m^3)	**1-hr maximum**	200	200	200
	24-hr average	10	20	30

	Annual average	1	2	2
NO_2 (µg/m^3)	**1-hr maximum**	400	500	1000
	Annual average	-	5	5
PM_{10} (µg/m^3)	**24-hr average**	2	2	5
	Annual average	0.2	0.2	0.5
$PM_{2.5}$ (µg/m^3)	**24-hr average**	1	1	3
	Annual average	0.1	0.1	0.5

3.3. Literature Review

3.3.1 Typical health effects related to environmental noise

3.3.1.1 Annoyance

Unwanted noise exposure has long been associated with annoyance, defined as a feeling of displeasure or dissatisfaction (Babisch et al, 2009). Annoyance can be caused by noise interfering with usual activities and feelings, as well as sleep or rest times (Basner et al, 2014). People who experience noise annoyance may become aggressive, angry and show stress symptoms (Basner et al, 2014; King and Davis, 2003).

The level of annoyance an individual experiences is determined not only by how loud the noise is, but by many other factors including, but not limited to, whether the noise is considered unnecessary; how much control the individual has over the noise; the nature of the sound; and if it affects property values. (King and Davis, 2003). In Quehl and Basner's model of noise annoyance (2006), there were significant increases in annoyance with female gender, increasing age and those believing that air travel was unnecessary. Another possible modifying factor is levels of background noise. A Korean study found that people in communities with high levels of background noise reported lower levels of annoyance to the same level of aircraft noise when compared to communities with low background noise (Lim et al, 2008).

Various curves are reported for annoyance related to transport noise. The studies used to create these curves were from Europe and the United States of America. Aircraft noise appears to cause higher levels of annoyance than road and rail noise for the same decibel level. Miedema and Vos (1998) calculated that at an Ldn of 55 dB due to aircraft, 12% of the exposed population is highly annoyed and at 70 dB, 37% of the population is highly annoyed. A Korean study (Hong et al, 2009) found similarly that about 16% of the exposed population reported high levels of annoyance when exposed to 55 dB, but 60% were highly annoyed when exposed to 70 dB average noise over 24 hours.

In the HYENA (HYpertension and Exposure to Noise near Airports) study (Babisch et al, 2009) at an L_{den} of 55 dB(A), between 20 and 70% of respondents reported being highly annoyed by aircraft noise. This proportion was lower at night (approximately 15-40%). Annoyance has also increased over time across all the European countries involved in the study, suggesting that people are becoming less tolerant of aircraft noise. (Babisch et al, 2009). Similarly, the recently conducted Noise-Related Annoyance, Cognition and Health (NORAH) study found that reported levels of annoyance related to transport noise are higher than in the past (NORAH, 2015b).

Annoyance has been linked with noise sensitivity, a personal characteristic that makes an individual more susceptible to noise exposure. People who are noise sensitive may be less able to cope with noise, and therefore experience increased levels of annoyance and stress. Conversely, people who already have underlying anxiety or mental health issues, as well as other health issues, may have increased noise sensitivity (Black et al, 2007).

Annoyance has been shown to modify the risk of hypertension from noise exposure i.e. those people with higher levels of annoyance had a slightly stronger effect on their blood pressure from noise exposure than those who were not annoyed (Babisch et al, 2013).

3.3.1.2 Sleep disturbance

Sleep disturbance is a very commonly reported effect of noise exposure. The percentage of the population reporting sleep disturbance increases with increasing L_{night}. About 12% of the exposed population complains of sleep disturbance at an L_{night} of 55-60 dB and this rises to 17% between 60 and 65 dB (WHO, 2009).

Noise affects quantity of sleep by causing a delay in onset of sleep and earlier waking, as well as nighttime awakenings (Muzet, 2007). Intermittent noises as low as 45dB(A) can delay time to sleep and

55 dB(A) peaks are associated with increased numbers of awakenings (Muzet, 2007; Basner et al, 2014). People exposed to an L_{night} of more than 55 dB can expect about 40 additional night-time awakenings annually. This is compared to the average 600 awakenings that occur spontaneously during an individual's sleep annually (WHO, 2009). In addition, noise exposure at night can affect quality of sleep by changing sleep cycles, resulting in shorter periods of deep sleep (King and Davis, 2003; Muzet, 2007; Perron et al, 2012).

Whether noise disrupts sleep depends not only on the level and type of noise, but on individual noise susceptibility and sleep stage. Certain groups of people are at higher risk of having sleep interrupted by noise. They include shift workers, who already have disrupted sleep cycles due to interference with normal circadian rhythm; pregnant women or women with small babies; the elderly; children; and people with a pre-existing sleep disorder such as insomnia (Basner et al, 2014; Muzet, 2007; Zaharna and Guilleminault, 2010).

In the short term, poor sleep quality and quantity is linked with subjective feelings of fatigue, daytime sleepiness and subjectively and objectively decreased cognitive performance with impaired work performance (Muzet, 2007; Basner et al, 2014). Poor sleep caused by road traffic noise has been linked to poor mental health (Sygna et al, 2014).

It is also probable that lower amounts of sleep, and nighttime awakenings increase stress hormone (cortisol, adrenaline and noradrenaline) production (Basner et al, 2014; Zaharna and Guilleminault, 2010). Various studies have had conflicting results, but the HYENA study showed an increase in salivary cortisol in women exposed to nocturnal aircraft noise above 60 dB(A) compared to women exposed below 50 dB(A) (Selander et al, 2009). Increased levels of stress hormones may partly explain the observed relationship between noise exposure and cardiovascular events (Selander et al, 2009).

3.3.1.3 Cognitive dysfunction and mental health

There are many studies showing a relationship between noise exposure and poor learning outcomes and cognitive function in children (Basner et al, 2014). The RANCH (Road traffic noise and Aircraft Noise exposure and children's Cognition and Health) study in Europe showed a linear relationship between aircraft noise exposure and decreasing reading comprehension and recognition memory (Stansfeld et al, 2005). There was no threshold level for effects, suggesting that any decrease in noise exposure at school would improve a child's performance. For every L_{Aeq} 5 dB increase in noise exposure, children in England had a two-month delay in reading age. The NORAH study in Germany similarly found a delay in children's reading abilities with increasing noise exposure (NORAH, 2014).

The same RANCH study showed no overall increase in mental ill-health in children; however, aircraft noise exposure was associated with increased hyperactivity scores on the Strengths and Difficulties Questionnaire (Stansfeld et al, 2009). This association with hyperactivity was not maintained in secondary school children, but there was a large loss to follow-up in the study so there is a chance that results are not accurate (Clark, 2013). The secondary school children still showed a probable association with increasing noise exposure and poorer reading comprehension, but this was not statistically significant, likely due to small numbers of participants (Clark, 2013).

Although there have been very few studies on noise and cognitive impairments in the developing world, two recently published South African studies (Seabi et al, 2012 and 2015) have reviewed reading comprehension in learners in Durban who were previously exposed to chronic noise before the Durban airport was relocated. The initial study in 2009 found a significantly lower level of reading comprehension in learners in a high noise exposure group compared to a low noise exposure group (Seabi et al, 2012). In the follow-up study after the airport relocation, learners previously exposed to high noise still appeared to have worse reading comprehension than their peers. Very few of the learners participated in the follow-up study, so the results should be interpreted with caution as they may be biased (for example, those people with ongoing problems may have been more likely to participate in the study).

A surprising finding of the recently published NORAH study was the association between exposure to environmental noise and depression (NORAH, 2015b); however, insufficient research has been undertaken in this regard to draw any significant conclusions.

3.3.1.4 Cardiovascular disease

The effects of noise exposure on blood pressure have been relatively well studied. The threshold below which there appears to be no risk of either hypertension or heart attack is a night time exposure level of 50 dB(A). In a review in 2009, Babisch and van Kamp (2009) concluded that there was sufficient evidence to link hypertension to aircraft noise exposure, and calculated that study participants were 13% more likely to have hypertension for every 10 dB(A) increase in noise. Between 2008 and 2012, the results of the HYENA study were published. These show an increase in blood pressure related to increasing nighttime noise exposure in particular. They similarly estimated a 14% increase in likelihood of hypertension with increasing noise exposure (Jarup et al, 2008).

There have recently been reports in the press (Does aeroplane noise cause high blood pressure?, 2015) that a study in Frankfurt conducted over the past 5 years has found no relationship between airport noise exposure and hypertension. Although the findings of this study (NORAH) have not yet been published in peer-reviewed medical journals, the authors have published limited results on their website. The data appears to show that there was no difference in measured blood pressure over a three-week period, and again a year later, in people exposed to varying levels of airport noise (NORAH, 2015a). In addition, the study did not confirm a link between aviation noise exposure and heart attacks although there was an association with cardiac failure (NORAH, 2015b).

Noise sensitivity may modify a person’s response to noise exposure, and result in a greater likelihood of chronic illness. A study conducted by Black et al (2007) showed that amongst residents of Sydney suburbs exposed to aircraft noise, those who had chronic noise stress were twice as likely to have raised blood pressure. Similarly, cardiovascular mortality was significantly increased in noise sensitive women in Finland who were nearly twice as likely to die from a cardiovascular event compared to women who were not noise sensitive (Hazard Ratio 1.80 95% CI 1.07-3.04) (Heinonen-Guzejev et al, 2007).

Conversely, a Japanese study found no effect of exposure to aircraft noise on blood pressure of women who lived near a city airport (Goto and Taneko, 2002), and Eriksson et al (2010) noted that there was no increased risk of hypertension in a Swedish population exposed to an L_{den} >50 dB(A). However, men in that same cohort did have a statistically significant increase in blood pressure (20% increased risk of hypertension compared to those not exposed to noise) for every 5 dB(A) increase in aircraft noise exposure when the analysis was restricted to non-smokers. Interestingly, both men and women who reported noise annoyance had an increased risk of hypertension, suggesting that annoyance may be an additional risk factor for cardiovascular disease over and above noise levels.

A Swiss study (Huss et al, 2010) reported a 30% increased risk of heart attack in people over 30 exposed to noise > 60 dB(A) compared to people exposed to < 45 dB(A). A study focusing on people over 65 in America, found that people exposed to 10dB higher airport noise had a 3.5% higher hospital admission rate for cardiovascular disease than those not exposed to noise. Total numbers of affected people were low (6 288 per 100 0000 population, or 6%, of the population of people over 65 who were admitted to hospital with a cardiovascular disease over the course of a year) (Correia et al, 2013).

A recently published French study (Evrard et al, 2015) found an increased risk of mortality from cardiovascular disease with increasing airport noise exposure. They estimated an 18% increase in mortality from cardiovascular disease per 10 dB(A) increase in day-night noise levels. Basner et al (2014) report that meta-analyses considering noise and cardiovascular disease (hypertension and ischaemic heart disease) have generally found an increased risk of between 7% and 17% per 10 dB increase in noise level.

3.3.1.5 Cancer

Public commentary on the first draft of the Environmental Impact Assessment for the re-alignment of the airport runway yielded concerns about the relationship between noise exposure and development of cancer. Whilst there have been a few recent studies reporting a relationship between noise and certain sub-types of post-menopausal breast cancer (Sørensen et al, 2014) and non-Hodgkin lymphoma (Sørensen et al, 2015), another study on prostate cancer found no association with noise exposure (Roswall et al, 2015). This field of study is still in its infancy, and there is insufficient evidence to support a causal relationship between environmental noise exposure and cancer at this time.

3.3.2 Typical health effects related to air quality

Air pollution is one of the four main drivers of respiratory disease globally (the others are tobacco, indoor air pollution and occupational exposures) (Schluger and Koppata, 2014). In urban areas, traffic-related pollution is one of the main contributors to total particulate matter. Worldwide, traffic is estimated to account for approximately a quarter of $PM_{2.5}$ levels. Other significant contributors are industry and domestic fossil fuel use, which is particularly relevant in Africa (Karaguhan et al, 2015).

Air pollution has been classified as a carcinogen by the International Agency for Research on Cancer (IARC, 2013) and outdoor air pollution is thought to be responsible for approximately 6% of deaths across the world (WHO, 2014a). Norman et al (2007) estimated that 3.7% of cardiopulmonary deaths in people over 30 and 0.9% of all deaths in South Africa in 2000 were attributable to air pollution.

The main constituents of air pollution that have been well-studied in terms of effects on human health are SO_2, NO_2 (as a proxy for all nitrogen oxides), O_3, CO and particulate matter. Particulate matter is generally described as ultrafine (< 1micron or 100 nanometers in diameter), $PM_{2.5}$ (particles smaller than 2.5 microns in diameter) and PM_{10} (particles smaller than 10 microns in diameter). The majority of the research to date has focused on $PM_{2.5}$ and PM_{10} particles, but the focus is shifting to ultrafine particles. Other constituents of air pollution, such as volatile organic compounds, dioxins and heavy metals are not considered in this review as they have not been included in the air quality impact assessment models, and are therefore, not thought to be relevant to the scenarios evaluated.

The short-term effects of exposure to air pollution are many and varied. Acute (short-term) exposures to high levels can cause respiratory irritation and nausea, as well as increased hospital admissions and mortality (Kampa and Castanas, 2008, WHO 2014a). Chronic exposure health effects are divided into cancerous and non-cancerous effects. The non-cancerous effects are predominantly related to the respiratory and cardiovascular systems, but fertility concerns and abnormal pregnancy outcomes may also occur (Kampa and Castanas, 2008). Measureable health outcomes such as mortality and hospital admissions probably account for a small percentage of ill-health effects caused by air pollution as they are the most severe outcomes. However, it is harder to study other outcomes and therefore, most research has focused on the severe outcomes.

Not all people are equally affected by exposure to air pollution. People with pre-existing respiratory and heart disease, as well as diabetes mellitus, are known to be at increased risk from exposure to air pollutants (WHO, 2014a). In addition, children and the elderly are more at risk, and people of lower socio-economic status appear to bear more of the burden of disease related to air pollution (Sacks et al, 2011).

The mechanism of action of most air pollutants is thought to relate to the production of free radicals that cause oxidative stress and an inflammatory response (WHO, 2014a). Chronic inflammation has been implicated in many chronic diseases including atherosclerosis, heart disease, strokes and cancer.

3.3.2.1 Respiratory disease

The effects of air pollution on the respiratory system can be acute or chronic. Acute high exposures (as in the case of high hourly levels of Ozone, SO_2 or NO_2) cause respiratory tract inflammation and bronchospasm ("tight chest") in both healthy individuals and people with pre-existing conditions, particularly asthma (Kim et al, 2013). Concentrations of NO_2 above 0.6 parts per million (ppm) can induce inflammation in people with asthma and COPD. Concentrations of SO_2 above 3-5 ppm cause physiological lung function changes even in healthy people (Kim et al, 2013).

Exposure to air pollutants, particularly NO_2 and PM_{10}, has been associated with increased susceptibility to respiratory infection in children (Kulkarni and Grigg, 2008).

The European Pollution Effects on Asthmatic Children in Europe (PEACE) study aimed to quantify the associations between exposure to air pollution and symptoms in asthmatic children. Although individual countries within the study almost all reported no significant association, a later meta-analysis which included 14 PEACE related studies and 22 other studies, found an association between PM_{10} and asthma symptoms (OR 1.028, 95% CI 1.006-1.051), and NO_2 and asthma symptoms (OR 1.031, 95% CI 1.001-1.062). This suggests approximately a 3% increase in incidence of asthma symptoms per $10\mu g/m^3$ increase in PM_{10} or NO_2. The association for PM_{10} appeared to be stronger in summer and in places with higher NO_2 concentrations. (Weinmayr et al, 2010). In an earlier review, Weiland and Forastiere (WHO, 2005) had concluded that there is sufficient evidence to link air pollution to an increased incidence of cough, asthma exacerbations and decreases in lung function in children.

Determining whether exposure to air pollutants can cause asthma as opposed to merely triggering symptoms in someone who is already asthmatic has been harder to do. As allergic disease and asthma has increased worldwide over the past few decades, there has been a great amount of interest about whether early exposure to air pollutants influences development of both inhalant and food allergy as well as asthma. The (European Study of Cohorts for Air Pollution Effects (ESCAPE) had data from more than 6500 children who were followed up from birth for approximately 10 years. They could find no evidence of an association between air pollution and development of allergic sensitization (Gruzieva et al, 2014). However, some studies (but not all) have suggested that there is a link between development of asthma in children and exposure to air pollutants (Jacquemin et al, 2015).

Adult-onset asthma has also been studied as this has different characteristics to asthma that starts in childhood. The ESCAPE study found associations between adult onset of asthma and exposure to NO_2 (approximately 10% increased risk of developing asthma per 10 $\mu g/m^3$ increase in NO2 levels). Although there was a suggestion of increased risk of asthma with exposure to PM_{10} and $PM_{2.5}$ (4% increased risk), the results were not statistically significant (Jacquemin et al, 2015). This may have been due to misclassification of exposure. In the total study cohort, approximately 1 257 of 23 704 participants developed asthma over a 10-year period. The rates varied across countries in Europe from 2.9 cases of asthma per 1 000 people per year to 8.3 cases per 1 000 people per year.

3.3.2.2 Mortality and Cardiovascular disease

Cardiovascular disease and mortality related to air pollution have been studied since the mid 1900s. There have been several large studies evaluating mortality related to acute exposures to particulate matter in particular. The National Mortality and Morbidity Air Pollution Study (NMMAPS) in the United States evaluated mortality with same day exposures to pollutants, and found an absolute increase in total and cardiopulmonary mortality of 0.21% and 0.31% respectively for each $10\mu g/m^3$ increase in PM_{10}. A similar study in Europe, the Air Pollution and Health: A European Approach (APHEA-2) found a 0.6% absolute increase in daily mortality for 10µg/m3 increase in PM_{10}. (Brook et al, 2004)

The American Heart Association issued a statement in 2010 (Brook et al) that a $10\mu g/m^3$ increase in $PM_{2.5}$ increases relative risk of daily cardiovascular mortality by 0.4-1%. As susceptibility to particulates varies according to underlying medical conditions, at current air pollution levels, particulates are probably contributing to mortality in susceptible populations only. The group attempted to calculate an absolute risk of acute cardiovascular mortality in addition to the relative risk calculated. They concluded that on average a $10\mu g/m^3$ increase in $PM_{2.5}$ in the previous 24 hours results in the premature death of 1 susceptible person in a population of 5 million people, and that while the dangers to the individual are small, the potential burden of disease from a public health point of view is large.

For long term exposures to air pollution, the NMMAPS in the United States estimated a 6% increased risk of cardiopulmonary mortality for every $10\mu g/m^3$ increase in $PM_{2.5}$ particles. The California Teachers study found a relationship between ischaemic heart disease mortality and $PM_{2.5}$ exposure (19% increase per $10\mu g/m^3$ increase in concentration) (Ostro et al, 2015). In total, approximately 6% of the study sample died over the 6 years of follow-up (6 285 all-cause deaths of 101 884 participants).The ESCAPE project in Europe recently evaluated exposures to different subtypes of $PM_{2.5}$ particles and found a statistically significant increased risk of natural cause mortality with increasing exposure to $PM_{2.5\ sulfur}$. (Beelen et al, 2015).

Pope (2000) estimated in the Six Cities Study that, on average, people living in the most polluted cities in America lost between 1.8 and 3.1 years of life compared to people living in the least polluted cities.

Increasing rates of hospitalizations have been reported for all cardiovascular diseases, including ischaemic heart disease, arrhythmias and cardiac failure. There is an estimated increase in risk of heart failure and heart attack (myocardial infarction) of approximately 0.8% and 0.7% respectively with each 10 $\mu g/m^3$ increase in PM_{10} (Brook et al, 2000). The ESCAPE study has attempted to quantify atherosclerosis (fatty plaques on the walls of arteries) related to air pollution. Although the results were not statistically significant, there was a suggestion of an association between increasing exposure to $PM_{2.5}$ and atherosclerosis (Perez et al, 2015).

3.3.2.3 Cerebrovascular disease

Many studies have investigated the relationship between short-term and long-term exposure to air pollution and the risk of hospitalization or death from stroke. Anderson et al (2012) report that although associations between NO_2, CO, $PM_{2.5}$ and PM_{10} and hospitalization for stroke have been reported (a 0.8% increase in risk per 10 $\mu g/m^3$ increase in $PM_{2.5}$ in one study), they are not consistent. This may be because different types of strokes have different causes, and this has not been accounted for in the studies.

Three recent review articles (Ljungman & Mittleman, 2014; Shah et al, 2015; Wang et al, 2014) reiterate this increased risk. Based on their meta-analysis, Wang et al (2014) report a 1.4% increased risk of stroke-related death for every $10\mu g/m^3$ increase in $PM_{2.5}$ concentrations and a 0.5% increase for PM_{10}

concentration. Shah et al (2015) noted increased risk of hospital admission for stroke as well as stroke-related deaths with increasing concentrations of CO, NO_2, SO_2 and particulate matter. These effects were strongest on the day of exposure, but $PM_{2.5}$ seemed to have a longer-lasting effect.

3.3.2.4 Cancer

In 2013, the International Agency for Research on Cancer, designated air pollution a Group 1 carcinogen (confirmed human carcinogen based on human and animal studies) for lung cancer. A meta-analysis in 2014 (Hamra et al) included 17 studies and estimated an increased risk of lung cancer of approximately 8% per 10µg/m^3 increase in $PM_{2.5}$ and 9% per 10µg/m^3 in PM_{10}. The risk was much greater in former smokers. Schluger and Koppata (2014) report that globally an estimated 9% of lung cancer deaths can be attributed to fine particulate matter.

Other types of cancer have not been studied as extensively as lung cancer, and information needs to be considered a work in progress. One potential cancer of concern is leukaemia because benzene is recognized as an occupational carcinogen. As benzene is found in fuel, studies have considered whether there is an association between exposure to traffic-related pollution and development of leukaemia. A recent review and meta-analysis (Filippini et al, 2015) found an increased risk of childhood leukaemia with exposure to increasing traffic density. They also noticed an association with benzene exposure, particularly for Acute Myeloid Leukaemia (AML, one of the sub-types of leukaemia). Similarly, Boothe et al (2014) also reported an association of childhood leukaemia with residential traffic exposure. Raaschon-Nielsen et al (2015) considered leukaemia in adults and noted an association between proximity to major roads and development of AML. Further research is needed to confirm these associations.

3.3.2.5 Pregnancy outcomes

Exposure to air pollution has been associated with adverse pregnancy outcomes, but the evidence has not all been conclusive. Stieb et al (2012) performed a meta-analysis of 62 studies, and found increased odds of low birth weight in relation to exposure to CO, NO_2, PM_{10} and $PM_{2.5}$. In their meta-analysis, the association between low birth weight and SO_2 and ozone were less consistent. However, Shah et al (2011) reported associations between exposure to SO_2 and preterm birth, as well as low-birth weight and preterm birth associated with $PM_{2.5}$ exposure. In Shah's systematic review (2011), the evidence for abnormal pregnancy outcomes for exposure to NO_2, CO and ozone was not conclusive. Given the conflicting outcomes of studies, it appears that the correlation between exposure to air pollutants and adverse birth outcomes is not robust, and is probably influenced by other factors that may not have been considered in the studies, such as socio-economic status and geographic region (Backes et al, 2013).

Intra-uterine growth restriction has been associated with exposure to PM during pregnancy (Backes et al, 2013; Shah et al, 2011). Although the exact mechanism is unclear, the pro-inflammatory state engendered by particle exposure may be responsible for changes in placental function, leading to abnormal fetal growth (Backes et al, 2013). Additionally, there is some evidence that congenital cardiac anomalies may have an association with maternal exposure to NO_2, SO_2 and PM_{10} (Vrijheid et al, 2011).

3.4 Probable significance of public health impacts related to increased airport capacity: comparison of two scenarios

Although it is clear that both air pollution and noise can have significant effects on human health, quantifying that effect is more difficult for a given population. Globally, air pollution is believed to be responsible for 6% of all deaths because of it's impact on cardiovascular and respiratory diseases, which are leading causes of mortality (WHO, 2014a). In South Africa, a study attributed just under 1% of all deaths to exposure to air pollution (Norman et al, 2007). This apparently low number may be due to the methods of calculation, or may be because South Africa has other competing causes of mortality such as interpersonal violence, injuries and infectious diseases (HIV/AIDS and tuberculosis), that account for a large proportion of deaths every year (Groenewald et al, 2014).

The diseases that have been associated with both noise and air pollution are relatively common diseases in the general population, and have multiple known other risk factors. The risk factors usually associated with cardiovascular and respiratory diseases (obesity, physical inactivity, smoking, poor diet) are responsible for the majority of disease. For instance, it is thought that around 75% of hypertension is related to obesity (Krauss et al, 1998), and it has been found that decreasing salt intake and increasing potassium intake can have a significant effect on blood pressure (He et al, 2013 & Mente et al, 2014). In

South Africa, approximately 27% of the population was obese in 2012 (Sartorius et al, 2015), and in the Western Cape, 32.9% of the population are tobacco smokers (Reddy et al, 2015). This high prevalence of risk factors results in a high burden of cardiovascular and respiratory disease in the absence of any environmental exposures.

With the information available at a population level, it is not possible to evaluate an individual's risk for a disease due to changes in environmental air quality or noise levels. This study can only work out what effect these environmental exposures are likely to have on the population as a whole rather than for an individual.

3.4.1. Noise exposure and probable health effects

Exposure to noise in the communities around the airport could cause (and/or may already be causing) a bigger public health problem than air quality because more people will be exposed, and levels of noise are above guideline limits. With current airport operations, there are already 226 180 people exposed to noise levels above the recommended 55 dB(A) day night levels. This number increases substantially in Scenario 2 (367 450) and slightly more in Scenario 4 (400 560). In developed countries, the percentage of people who are highly annoyed by noise increases with increasing noise. This data is not available for South Africa, but at present, there is reportedly very little evidence of complaints from the populations currently exposed to high noise levels around CTIA airport (personal communication, ACSA). Therefore, it is possible that estimates of annoyance from existing literature will over-estimate levels of annoyance in the local populations. However, taking estimates of percentages of populations that report annoyance at different levels of aircraft noise from Miedema and Vos, (1998) Table 8 provides estimates of numbers of people that could report annoyance in Scenario 2 and 4.

Table 8. Possible numbers of people reporting high levels of annoyance due to airport noise in Scenario 2 and Scenario 4.

Noise level (Ldn in dB(A)	**Percentage population highly annoyed (from Miedema and Vos, 1998)**	**Scenario 2**		**Scenario 4**	
		Total exposed population	Number of highly annoyed people	Total exposed population	Number of highly annoyed people
55-60	12	259 210	31 105	281 530	33 784
60-65	19	95 430	18 132	87 460	16 617
65-70	28	12 670	3 548	29 930	8 380
70-75	37	140	52	1 640	459
All	-	367 450	52 837	400 560	59 240

Similarly, on average 12% of people report sleep disturbances at 55-60 dB overnight and 17% at 60-65 dB (WHO, 2009). The models for the different scenarios at the Cape Town airport do not give a nighttime noise exposure average, only numbers of disturbing events. However, an assumption has been made that the areas with a day-night average above 65 dB will have a nighttime noise level above 55 dB. Therefore, it could be expected that around 1 544 people will report sleep disturbances in Scenario 2 and around 3 871 in Scenario 4. These sleep disturbances will be more likely in vulnerable people such as the elderly, children, mothers with small children and shift-workers.

One area of concern is the impact that daytime noise exposure will have on sensitive nodes such as schools, hospitals, places of worship and old age homes. Several studies, including one in South Africa (Seabi et al, 2012 and 2015), have shown that children who attend school in noisy areas perform less well on reading tests, suggesting an impact on learning ability. There is also the suggestion that the children do not catch up if they are no longer exposed to noise. In Scenario 2, 188 noise sensitive receptors will be exposed to high noise levels and in Scenario 4 this becomes 370.

Hypertension and cardiovascular disease are also linked to noise exposure, and there is believed to be sufficient evidence for a causal association particularly for hypertension (WHO, 2009). Quantifying the effects of noise exposure related to airport populations in the communities surrounding the airport is difficult as there are no equations for health effects in current use as there are for air quality. The WHO (2009) suggests a 10% increased risk of hypertension for people exposed to 55-60 dB, and a 20% increased risk for those exposed to 60-65 dB in a 24-hour period, and most studies report an increased risk somewhere between 10 and 20% per 10 dB noise exposure for both hypertension and cardiovascular disease. These studies are predominantly from the developed world, however, so whether this level of increased risk is applicable in the South African context is unclear. Although on the whole, most studies have reported an association between noise and cardiovascular disease, a recent 5-year prospective study in Germany did not confirm an association with aircraft noise exposure and blood pressure changes or heart attacks (NORAH, 2015a &b),

South Africa has a very high prevalence of hypertension, both diagnosed and undiagnosed. In total, it is estimated at 42% by the WHO (Ogah and Rayner, 2013), although in the Western Cape the prevalence is believed to be between 25 and 30% (Ardington & Case, 2009 and Shisana et al, 2014). There are other risk factors, such as diet and salt intake, sedentary lifestyle, obesity and family history, that have a far greater impact on the overall prevalence of hypertension and heart disease than noise exposure does. Similarly for cardiovascular disease, other causes such as uncontrolled hypertension, diabetes mellitus, smoking and obesity are likely to be contributing to burden of disease far more than noise exposure does.

Making the assumption that the estimated prevalence of hypertension of 30% in the Western Cape is without any noise exposure and that the relative increase of 10-20% proposed by the WHO (2009) holds true in this context, then in the communities exposed to noise it is possible that prevalence of hypertension could reach as high as 36%. This is almost certainly an overestimate since at least some of the current reported prevalence of hypertension in South Africa could already be attributed to either environmental or occupational noise exposure. Therefore, in EOH Health's opinion, there is unlikely to be a sudden dramatic increase in cases of hypertension in communities exposed to airport noise, but total numbers of cases could conceivably rise by 3-6% in areas without prior noise exposure or with low current noise levels.

It is not possible to estimate the effect of noise on cardiovascular disease and cancer rates, as there are no equations in current use. Based on studies in other parts of the world, however, there is a theoretical small increase in relative risk (10-20%) of ischaemic heart disease in those exposed to high noise levels.

3.4.2 Air pollution and probable health effects

Air pollution is known to have significant health effects, including an impact on daily mortality rates as well as an association with lung cancer deaths specifically, and cardiopulmonary deaths more generally. Poor air quality may pose significant risks for vulnerable populations (children, the elderly, people with pre-existing conditions) even when the levels are within those stipulated in the SAAQS. However, the changes in air quality related to a change in airport operations are not dramatic, and there is not much difference between Scenario 2 and Scenario 4, particularly in terms of particulate matter, which is generally thought to be the major cardiovascular disease-causing culprit. Therefore, the change in cardiopulmonary disease and related mortality associated with a change in airport operations is not expected to be significant.

Exceedances of hourly levels of gases (NOx, SO_2, CO, O_3) are well within legal guidelines and are likely to be very infrequent, occurring less than 10 times per year. Therefore, they are not likely to contribute significantly to mortality or hospital admissions in the exposed population. Although the air quality models have estimated a relative increase in risk of hospital admissions between 2 and 4% in very small areas adjacent to the airport, it is not possible to contextualise this against an absolute risk as figures are not available for daily respiratory hospital admissions in Cape Town. However, it is safe to assume that absolute numbers of daily respiratory hospital admissions in each exposed community are relatively low and that increase in individual risk will be almost negligible, particularly for people with no pre-existing conditions.

For short-term all-cause mortality due to $PM_{2.5,}$ exposure, the American Heart Association estimated at most a 1% increase in relative risk of daily cardiovascular mortality for a 10μg/m^3 increase in concentration (Brook et al, 2010). On average, approximately 73 people die every day in Cape Town (using 2011 mortality data from Groenewald et al, 2014), and about 10% of deaths are due to ischaemic heart disease. This equates to a daily all-cause mortality rate of 1.9 per 100 000 people and cardiovascular mortality of 1.9 per million people. A 1% increase in this rate – which is higher than expected given that the anticipated increase in $PM_{2.5}$ is only 3 μg/m^3 - is marginal and will have no effective impact on local mortality rates.

Whilst annual exposure to particulate matter exposure will increase, the relative increase in annual all-cause mortality due to air quality is expected to be only 0.1% in Scenario 2 and 0.3% in Scenario 4. The Western Cape annual mortality rate for 2013 was reported as 7.7 per 1 000 people (Statistics South Africa, 2014). Therefore the 0.1% increase in relative risk of all-cause mortality estimated in the model for Scenario 2 suggests that mortality rate in affected areas could go up to 7.77 per 1 000 people. For Scenario 4, the relative risk of all cause mortality is expected to increase by 0.3%, which would suggest an absolute mortality rate of 7.93 per 1 000 people. This increase is unremarkable, both in terms of absolute numbers and in terms of the difference between the two scenarios. The mortality rate in affected areas would still be well below the 2013 national South African average of 8.6 per 1 000 people (Statistics South Africa, 2014).

Although relative risk of lung cancer related to air pollution was not reported in the models, additional calculations have been performed using equations from the literature (Norman et al, 2007). (See Appendix A). These suggest that the increase in mortality from lung cancer in Cape Town due to increased exposure to $PM_{2.5}$ from airport operations would be extremely small in both Scenario 2 and Scenario 4, amounting to less than one additional lung cancer death per year.

4. Conclusion and Recommendations

Exposure to environmental noise has been associated with sleep disturbance, decreased cognitive function and cardiovascular diseases such as hypertension and myocardial infarctions (heart attacks), although a recently published prospective 5-year study was not able to confirm these associations. Air pollution exposure has been associated with increased risk of respiratory disease, cardiovascular disease and strokes, as well as lung cancer.

Quantifying the effects of exposure is difficult. However, because air quality changes from the current baseline are expected to be minimal based on the models, the likely overall effects on health and mortality in particular will be extremely small. There may be infrequent exceedances of guideline levels of SO_2 and NO_2 that result in exacerbations of respiratory conditions in susceptible people, but the number of exceedances and the extent of spread of the pollutants are relatively small in the context of the whole city.

Particulate matter is a significant contributor to respiratory disease such as chronic obstructive pulmonary disease and lung cancer worldwide. In the models presented, the annual increase in particulate matter concentration due to airport operations is anticipated to be very low. Therefore, ultimately the increased burden of disease in the communities surrounding the airport will be negligible in both Scenario 2 and Scenario 4 with very little difference between the two.

Exposure to noise around the airport could have greater implications for public health. Inappropriate land use planning, a high demand for housing due to population growth and the growth of the airport have all contributed to a large number of people already being exposed to noise levels in excess of guidelines published by South Africa and the World Health Organisation. The number of people exposed can be expected to rise with maximum airport operations using the current runway (Scenario 2), and would only be increased by around 9% above that for the re-aligned runway (Scenario 4). The noise levels to which people will be exposed are expected to cause annoyance and sleep disturbance in a significant proportion of the population, and impact on learning in schools as well as quality of life for people in hospitals and residential homes.

The impact on prevalence of hypertension and heart disease in the local populations is harder to quantify, but the additional burden of disease in Cape Town from Scenario 4 compared to Scenario 2 will likely be small as only an additional 33 110 people will be exposed to high noise levels. This represents only a 9% increase in numbers of people exposed in Scenario 4 when compared to Scenario 2, and less than 1% of the total population of Cape Town. Therefore, any changes in absolute numbers of people with hypertension and cardiovascular disease will be small.

In conclusion, the Cape Town International Airport Runway re-alignment project may have some health impacts on the surrounding communities because of changes in air quality and noise exposure. However, changes in air pollution are expected to be minimal and the numbers of people exposed to noise above guideline limits are only marginally higher when comparing the current runway at full operation to a re-aligned runway. Therefore, EOH Health is of the opinion that any changes in burden of disease in the communities surrounding the CTIA will be relatively insignificant.

4.1 Recommendations

Noise and air pollution related to airport operations can affect the health of individuals in the surrounding communities. Current airport operations may already have an impact on health, and the changes expected with full operation (Scenario 2) or with a re-aligned runway (Scenario 4) would increase the numbers of people exposed to pollutants, although with minimal differences between the two scenarios.

The City of Cape Town and ACSA should aim to reduce exposures of the surrounding communities to air pollution and noise as far as reasonably practicable. Managing air pollution from the airport would need to form part of a comprehensive plan to reduce air pollution from all sectors including road traffic, industry and the use of fossil fuels for cooking in informal settlements. The environmental engineer who conducted the impact assessments for both noise and air quality has provided comprehensive recommendations to reduce emissions and noise during airport operations (DDA, 2014a and b). These include:

1. Managing the way that airplanes idle, queue, take off and land to decrease emissions and limit noise exposure outside the airport. This includes an assessment of alternative flight paths.
2. Ensuring adequate maintenance of all equipment to ensure that it functions optimally, thereby decreasing emissions and noise.
3. Encouraging public transport use for both staff and people travelling through the airport to reduce car traffic and hence emissions.
4. Consideration of passive measures, such as noise insulation on existing residential dwellings and noise sensitive buildings. In communities that already have low literacy and poor education, the additional burden of noise at school will need to be avoided and steps should be taken to decrease noise in the classrooms.
5. Manage future city planning so that residential areas are further away from the airport, and commercial or industrial processes that are not affected to the same degree are closer to the airport.

Should the re-alignment project go ahead, air pollution and noise should be monitored to ensure that predicted exposures from the models reflect actual exposures. Further risk assessments should be undertaken if exposures appear to be higher than predicted.

Aside from exposure to noise and particulate matter, the local communities may have many other risk factors for the illnesses of concern that are causing a greater proportion of the burden of disease. These include low socioeconomic status (in some communities), high prevalence of obesity and smoking, and poor diet and exercise habits. Education should be provided to encourage people to be aware of those risk factors, and hence work to modify their overall risk of chronic conditions. Other adaptations in the community that would enable people to live more healthily in general (e.g. green spaces, access to healthy food, access to healthcare) are outside of the scope of this report.

28.02.2016

Signed: Dr Amy Burdzik Date

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Appendix A: Calculations to determine health effects of air pollution in communities surrounding the Cape Town International Airport

In order to work out the population attributable fraction (PAF, the percentage of a disease that would not exist if the risk factor was removed i.e. the proportion of a certain disease related to a particular risk factor), we need to know several parameters:

- the incidence of a disease in exposed people compared to unexposed people (or the relative risk)
- the prevalence of exposure

If we want to convert the fraction to numbers of people (e.g. numbers of deaths), we need even more information:

- numbers of people exposed to the risk factor
- baseline incidence of the condition
- change in concentration of the pollutant
- the percentage change in the condition for a given concentration of the pollutant

Norman et al (2007) used the following equation to calculate risk ratio for death (risk of death in exposed vs. unexposed) in a burden of disease study from exposure to air pollution for South Africa:

$RR = \exp[ß\ x\Delta C]$

Where

ß is the slope of the concentration-response gradient determined in other studies
ΔC is the change in concentration of the pollutant in $\mu g/m^3$

Because of all these factors, there will necessarily be a large margin of error in any calculation. Some reasons for this are:

- The slope of the concentration-response in the first equation is taken from pre-existing epidemiological data. Studies that generated this data are most likely from the developed world and may not be generalisable to the South African population. In addition, we can only calculate the risk ratio for exposures and health effects where the concentration-response slope is known. On the whole, this means we can attempt to calculate mortality data rather than morbidity data. We can also not be sure that the slope remains accurate at very low and very high concentrations of exposures that are outside the concentrations presented in the original studies.
- Incidence of deaths are available at a larger population level e.g. Cape Town as a whole rather than for Delft South in particular, and therefore, may not reflect the local situation.
- Similarly, background prevalence of disease would be available for a larger population group rather than the particular communities that are exposed to air pollution and noise.
- The equation does not take into account individual susceptibility.
- Particularly in the air pollution models, exposures appear likely to affect only small portions of suburbs adjacent to the airport. Therefore, estimating numbers of people exposed is difficult and likely to lead to inaccuracies.
- We have to assume that the associations found in the literature have a causal relationship with the outcome, which may not be true.

Nevertheless, attempts have been made to calculate the same mortality data that Norman et al (2007) calculated, using the same equation they did. There is no calculation for mortality data for childhood respiratory infection, as no figures were available for the Cape Town population for childhood respiratory deaths. Estimates are compared across Scenario 2 and Scenario 4. In this situation, exposures to PM act as a proxy for exposure to air pollution in general.

1. Health effects related to air pollution

1.1 Predicted changes in mortality from cardiopulmonary disease due to an increase in annual PM2.5 exposure due to airport operations

For Scenario 2:

$RR(\text{cardiopulmonary death}) = \exp[ß\ x\ \Delta\text{concentration}]$

ß = 0.00575 (taken from Norman et al, 2007)

$\Delta\text{concentration} = 0.1\ \mu g/m^3$ (assuming the worst annual exposure estimate in Scenario 2)

Exposed population = 5% Cape Town's population (using the precautionary principle and assuming largest possible number exposed)

Therefore, RR(cardiopulmonary death)=1.0005, or a 0.05% increased risk compared to risk in people not exposed to airport emissions.

PAF = Prevalence of exposure(RR-1)/Prevalence of exposure(RR-1)+1
= 0.05(0.0005)/[0.05(0.0005)+1]
= 0.002%

In other words, 0.002% of cardiopulmonary deaths in a year in Cape Town would be attributable to increased exposure to airport emissions. To obtain absolute numbers, we need mortality data for cardiopulmonary deaths in Cape Town. The MRC released data for 2011 deaths (Groenewald et al, 2014), and included some breakdown of causes of death. Summing up numbers of deaths from ischaemic heart disease, respiratory infection, COPD, tuberculosis and cancer of the trachea/bronchi/lung is the closest estimate we have. Of a total of 26 681 deaths in Cape Town in 2011, 7515 were due to cardiopulmonary causes.

Therefore, 0.002% of 7515 deaths is 0.18 additional deaths per year due to cardiopulmonary disease caused be exposure to chronic particulate matter air pollution from airport operations.

For Scenario 4:

Assuming the same slope and underlying mortality data, but using a change in concentration of 0.5 $\mu g/m^3$:

RR(cardiopulmonary death)= exp(0.00575 x 0.5)=1.003 or a 0.3% increased risk
PAF = (0.05(0.003)/[0.05(0.003) +1]
= 0.014%

In absolute numbers, this translates to 1 additional cardiopulmonary death per year due to particulate matter air pollution.

1.2. Predicted change in mortality from lung cancer due to an increase in annual $PM_{2.5}$ exposure due to airport operations

This calculation is done assuming the same baseline population data as before, but using a concentration response slope of 0.00789 (from Norman et al, 2007) and a total number of lung cancer deaths of 1145.

For Scenario 2:

RR =exp(0.00789x0.1)=1.0008=0.08% increased risk.
PAF =0.05(0.0008)/[(0.05x0.0008)+1]
=0.004%

For total numbers of deaths, this exposure would contribute an additional 0.05 lung cancer deaths.

For Scenario 4:

RR =1.004 or a 0.4% increased risk
PAF =0.02%
This translates to an additional 0.2 lung cancer deaths.